Glazed Tiles from Lodhi and Mughal Northern India: A Technological Appraisal

Maninder Singh Gill

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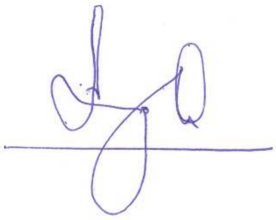
Declaration

I, Maninder Singh Gill confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.



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Abstract

Glazed tiles were used by the Lodhis and Mughals to embellish their buildings in northern India from the late fifteenth to seventeenth century. Tile-work from this region and period is understudied, particularly on matters related to its origin and technology.

This thesis presents findings of a research undertaken on a series of tiled buildings located at Delhi, Agra, and Punjab in northern India, from the period of Lodhi and Mughal rule. Tile samples from the buildings have been scientifically analysed - mainly using scanning electron microscopy with energy dispersive spectrometry, and electron microprobe microanalysis with wavelength dispersive spectrometry - for their characterisation. Ethno-archaeological studies on related traditional craft industries have been used to build a more accurate rendition of the technologies employed in their manufacture. A field survey of *in situ* tile-work has been used to correlate stylistic and physical attributes with data determined through analyses.

Results from the study show that different methods were utilized for the production of tiles at Delhi/Agra and Punjab. Those of the Delhi type have indigenous features in their technology, while the Punjab specimens are shown to be technologically closer to those from the core Islamic lands. The industry at Delhi is further shown to have evolved locally, developing gradually from the Lodhi to Mughal period, while the Punjab tile industry at the time of the Mughals is demonstrated to be an import, its establishment clearly influenced externally, with the sudden appearance of a new technological style. The tile-work at both places is however determined to be of the same basic character as Islamic tile-work of the stonepaste variety.

This study, besides presenting a comprehensive picture on Lodhi and Mughal tiling traditions, provides important new information in the discipline of Islamic ceramic studies, particularly on the development of stonepaste technology and its transfer.

Acknowledgments

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Contents

Appendices

List of figures

List of tables

CHRONOLOGY

(Islamic dynasties in northern India from 1206-1707 CE)

Mamluk or Slave Dynasty		1206-1290 CE
Khalji Dynasty		1290-1320 CE
Tughluq Dynasty		1320-1413 CE
Sayyid Dynasty		1414-1451 CE
Lodhi Dynasty	Bahlul Lodhi	1451-1489 CE
	Sikandar Lodhi	1489-1517 CE
	Ibrahim Lodhi	1517-1526 CE
Mughal Dynasty	Babur	1526-1530 CE
	Humayun	1530-1540 CE
Sur Dynasty		1540-1555 CE
Mughal Dynasty	Humayun	1555-1556 CE
	Akbar	1556-1605 CE
	Jahangir	1605-1627 CE
	Shah Jahan	1628-1658 CE
	Aurangzeb	1658-1707 CE

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Map of India and its adjoining regions showing towns/cities where significant specimens of tile-work from the Islamic period are known to exist.

1. INTRODUCTION

1.1 Research framework

The existence of an artificial disconnect between architectural glazed tiles from northern India and those in the central Islamic lands may be gauged from the many publications on the history and technology of Islamic ceramics and tile-work, where scarcely a mention of such Indian tiles is found, and where done no linkages between the two are assertively claimed. While the *a priori* assumption of such connections may in itself be a fallacy, it is no secret that the use of glazed tiles as a means of building embellishment in northern India follows the advent and establishment of a Muslim state in the region, ruled for the most part by dynasties of foreign origin. Indeed it was under the Afghan Lodhi Sultans (r. 1451-1526 CE) that glazed tiles began to be first consistently employed in the region, many a Lodhi building at Delhi showcasing blue coloured tiles as evidence of their use. It was again with the arrival of the Mughals (r. 1526-1857 CE), who were of Central Asian descent, and who maintained close cultural contacts with the lands of their origin, that the potential of the craft was further realised and taken to new heights. It is on the Mughal buildings of the sixteenth and seventeenth century, and particularly those in their capital cities of Delhi, Agra, and Lahore in the north, that lavish tiling was resorted to, in styles and schemes evocative of traditions followed further west.

Notwithstanding the overt suggestions of their likely origin, a foreign connection cannot be outright assumed, particularly as the first blossoming of tile-work in the region is retarded by more than a century when compared to developments in the core Islamic lands. Mughal tiling of the mid-sixteenth century, usually considered as representative of the coming of the craft in northern India, in fact follows the heyday of Timurid tiling in Central Asia by almost one hundred and fifty years. Other factors are meritorious of attention in this regard too, the existence of centres of tiling elsewhere in India for instance, that notably predate the arrival of the craft in the north of the country. The role that local influences and indigenous practices may have had to play in the transmission and technologies of the craft cannot be likewise underestimated, or eliminated, without being subject to sufficient debate.

Surprisingly, such discussions on issues of their origin and character are uncommon if not rare, Lodhi and Mughal tiles being relatively less well-studied as a subject, and largely overlooked in architectural appreciations of the buildings they embellish (Brown 1964, Koch 1991, Asher 1992). Even less is the interest displayed in their technology. Most contemporary descriptions tend to be ambiguous and generic in details, either repeating observations of pioneering works undertaken about a century ago (Smith 1901, Vogel 1920), or carrying unsubstantiated speculations on foreign influences (Nath 1989, Porter 1995, Degeorge and Porter 2002, Akhund and Askari 2011). Existing technical information on the production and composition of these tiles is similarly wanting, with no reported archaeological evidence on their manufacture, and little available on their material character other than four known published studies limited to a few monuments (Marshall 1926, 114-115, Lal 1953, Singh *et al.* 2004, Gulzar *et al.* 2013). Attempts at conservation to address their ongoing natural decay have been likewise hampered by scarce technical information on possible causes of deterioration.

In comparison, much more has been written about the ceramic traditions of central Islamic lands, co-relating developments in the industry to influences and cultural diffusions. Authoritative works undertaken on architecture here give due credence to forms of decoration such as tile-work, devoting special effort to detailing their characteristics (O'Kane 1987, Golombek and Wilber 1988, Soustiel and Porter 2003). Scientific research has also significantly contributed to an understanding of technologies associated with the growth and development of ceramic crafts in these lands (Tite and Bimson 1986, Henderson and Raby 1989, Mason and Tite 1994, Tite *et al.* 1998). Particularly noteworthy has been the employment and efficacy of analytical studies in the characterisation of ancient ceramic materials, including tiles, bringing forth meaningful information on associated technological processes and the organization of contemporary industry. Cognisance of such scientific studies has been constantly taken note of by leading authorities writing on the subject, allowing a deeper and more holistic understanding of the craft and its technology.

Against this backdrop, an in-depth technical study of glazed tiles from fairly well-dated Lodhi and Mughal monuments in northern India was deemed necessary to contribute towards a better understanding of Islamic tile-work and ceramics in general, and to tiles from this region and period in particular. A scientific approach for the work would be most appropriate, given the articulated ability of scientific investigations to inform a range of questions on technological developments and related social aspects. A further rationale for choosing this approach is the ready availability of published technical information on tiles and ceramics from culturally connected Islamic lands, allowing comparative evaluations and reasoned interpretations. A technical appreciation of related local craft technologies is warranted at the same time, for the interpretations to be impartial and consider local influences. For an overall understanding, it is also imperative that the study also takes into consideration typological characteristics of the tile-work in drawing inferences, especially as the majority of the sites are fairly well-contextualized standing monuments bearing remnants of tiles.

1.2 Aims and objectives

The broad aim of this project is then to undertake a systematic study of Lodhi and Mughal period glazed tiles in northern India, to fill existing gaps in knowledge, gain a comprehensive picture on their tradition and technology, and to highlight correlations with historical and art historical phenomena. The study is aimed at providing an inclusive understanding of tile-work traditions of this period, spanning the disciplines of archaeology and science, while laying the foundations for future research in the area.

In fulfilment of the aims and objectives, a combination of laboratory and field methods of investigation was made use of. Select samples, representative of tile-work on fairly well-dated monuments were subject to scientific analyses for their material characterisation, and to shed light on their production technology. Compositional similarities and relationships with Islamic ceramics from other regions were utilized to identify raw materials employed in their manufacture, and to substantiate cross-cultural interactions where evident. Related traditional crafts in practice in the region were subject to study, to examine the role and influences of local technologies in their manufacture. Colour schemes and typologies of *in situ* tile-work, surveyed through field work, were interpreted against scientific data to characterise regional styles and identify possible production centres. In addition, information derived on the technology of the tiles was tentatively interpreted against observations on their deteriorated physical state, widening the impact of the research to attempt assist in the preservation of extant remnants.

In more specific terms, the aims and objectives to be fulfilled through this study include:

- To characterise the material composition of architectural glazed tiles from Lodhi and Mughal northern India.
- To identify tile-work typologies existent in the region.
- To reconstruct the technology of their production and the organization of industry in contemporary times.
- To discuss matters related to their origin.
- To examine technological relationships between these tiles and those from the wider Islamic world.
- To assess local influences in their technology.
- To draw possible correlations between material composition and observed deterioration phenomena.

Twenty four monuments with extant tile-work ascribed to the Lodhi and Mughal periods in northern India were accordingly taken up for study. Findings of the investigations undertaken for the realisation of the above-defined aims and objectives are presented in the succeeding chapters of this document. Apart from contributing to the body of knowledge on Lodhi and Mughal tiles, the thesis also aims at presenting the mutual beneficence of technical and historical, or art historical, studies in each other's domains.

1.3 Structure of the thesis

Following Chapter 1 that introduces the thesis, are Chapters 2 and 3, which provide the background and context of the study in more detail. Chapter 2, concerned with Islamic tile-work as broadly understood, first concisely describes technological developments in the Islamic ceramic industry commensurate with the rise and spread of Islam. The later part of this chapter deals with the evolution and employment of glazed tiles on architecture in Islamic lands, concentrating on countries or empires culturally affiliated with India in the past.

Chapter 3 is focused on tiles and the tile-work industry in Islamic India. An overview of centres of tiling that came up in various parts of the country and their activities are first discussed. This is followed by a detailed note on the status of the industry, as known, in northern India during Lodhi and Mughal times, with deliberations on shortcomings in the current state of knowledge on the subject.

Chapter 4, on research methods, outlines the overarching theoretical framework governing the study, and justifies the methods found suitable and adopted for the research. An explanation of the wider definition of technology is discussed, as is the notion of the *chaîne opératoire* as a means of enabling a fuller and more meaningful interpretation of Lodhi and Mughal tiling traditions. Discussions on the field and laboratory methods and techniques utilized for the study are further provided.

Chapter 5 describes ethno-archaeological studies carried out on two related traditional crafts in practice in the region, that of raw glass production, and of a glazed ware bearing similar characteristics to the material under study. Findings of a field cum archival study on the two crafts are detailed, the recorded data assisting in the illumination of technologies potentially involved in tile manufacture in Lodhi and Mughal times.

Chapters 6 and 7 present the findings of field and laboratory investigations undertaken on tile-work embellishing Lodhi and Mughal buildings respectively. Each of these chapters comprises three sections, the first reporting findings of a broad-based survey carried out on all known standing tiled buildings of the period in the region. In the next, the tiles on buildings specific to the study are assessed, with details provided on their physical characteristics and their application on architecture. The last section in each gives the results of scientific analyses undertaken on tile samples sourced from the buildings under study, providing data on their microstructural characteristics and chemical composition.

Chapter 8 elucidates in detail the technologies of Lodhi and Mughal glazed tiles as determined through the research. Discussions are given on each of the parameters spelt out in the aims and objectives, and Lodhi and Mughal tiling traditions interpreted within the context of Islamic tile-work as a whole.

Chapter 9, in conclusion, presents a brief summary of the research, and outlines future works that would potentially further enhance an understanding of the subject of study.

2. ISLAMIC GLAZED TILE-WORK

The technology of Islamic glazed tiles is inseparable from that of the pottery industry, to which it owes its origin and early development before charting an independent course later as a specialized craft associated with building architecture. An appraisal of technological progresses in Islamic ceramics is thus essential in understanding reasons for material preferences and processes associated with the production of tile-work in the wider Islamic world, and as a consequence in the region of this study as well. On the same lines, a study of tile-work in northern India would be lacking without first taking into account its growth and employment in culturally connected lands. This chapter, divided over two sections, starts with a comprehensive synopsis on the technologies and technological factors that shaped the making of ceramic tiles, followed by a more detailed note on the evolution and employment of architectural glazed tile-work in the central Islamic lands, as an entity distinct from glazed pottery.

2.1 Technological developments

The early years

Clay-based pottery in the early centuries of Islam was of little interest in the courts, being mostly relegated to unglazed vessels of basic domestic use, though an alkali-glazed ware derived from an earlier tradition was also being made in some parts of the Near and Middle East, as well as a rarer lead-glazed relief-ware (Lane 1958, 9, Fehérvári 2000, 23, 35). In the ninth century, the import of large quantities of highly sophisticated Chinese porcelain and stoneware from the Tang period (618-906 CE), created a demand for fine pottery leading to resurgence of the local industry. Potters in Baghdad, the seat of the Abbasid Empire (750-1258 CE), and possibly Samarra further north, now began to manufacture imitations of the Chinese ware by experimenting with a range of material to produce an astonishing variety of ceramics. Lead or lead-alkali glazes on clay bodies coated with white slips became the norm displacing alkali glazes on ceramics, with glazes ranging from being clear, to coloured, to opacified (Lane 1958, 11-16, Tite *et al.* 1998). Amongst the achievements of the potters in the early Abbasid era, two technological innovations merit attention, the first being the addition of tin oxide in the opacification of glazes making them deceptively similar to the Chinese cream-coloured porcelain that they chose to replicate (Mason and Tite 1997, Tite *et al.* 2015). The second was the application of lustre-painting on lead-glazed earthenware pottery, a technique already in practice in the glass industry wherein an iridescent metallic overglaze was achieved through the application of metallic colorants on an already glazed or glass surface, followed by a second firing in reducing conditions at a lower temperature (Lane 1958, 14, Watson 1985, 31-36, Caiger-Smith 1991, 21-30, Mason 2004, 2).

The arrival of stonepaste

In the twelfth century, a revolutionary change occurred in the character of high-quality ceramics, the clay body being altogether discarded in favour of a white quartz-rich ‘stonepaste’ covered with an alkali or lead-alkali glaze in yet further attempts to emulate Chinese ceramics, this time the ivory-white and white wares from the Song period (960-1279 CE). Although the quartz-enriched stonepaste body or ‘fritware’, as it is often but not very accurately referred to, bore an uncanny resemblance to some pre-Islamic ceramics and early Egyptian faience, it was in fact a sort of re-discovery of technology rather than a continuation. Technical studies have established that while the widespread use of stonepaste is first noticed in twelfth century Iran, its discovery is more likely attributable to developments in Fatimid Egypt a century or so earlier, the technology then being transported by potters migrating to Iran, possibly via Syria (Mason and Tite 1994, Watson 2004, 54). Notwithstanding the uncertainty of its precise origin, stonepaste was soon to become the prevalent technology utilized in the manufacture of glazed ware, including tiles, its soon to be dominant position propelled by the properties offered through use of the new material.

An accurate description on the production of stonepaste ceramics is available through a manuscript dated 1301 CE, attributable to Abu’l Qasim, an Il-Khanid court historian who himself hailed from an illustrious family of potters in the town of Kashan, Iran, a city noted for its ceramic products at that time (Allan *et al.* 1973).

Abu'l Qasim, in his writings, describes at length the materials and methods employed in the manufacture and decoration of glazed stonepaste ceramics, his detailed commentary providing an understanding of their technology (Allan 1973, Watson 2004, 25-32), and oft-used as a basis for drawing analogies while investigating similar archaeological material. The bodies, he writes, comprised ten parts crushed quartz and one part each of clay and glass frit, the quartz being obtained from white pebbles which were ground to a fine powder and sieved for use. He then goes further to describe the preparation of the glass frit, by introducing roughly equal parts of powdered quartz with plant-ash soda (105 parts: 100 parts) in a kiln to form a molten glaze, which when poured into water instantaneously cooled 'with great noise' to a glass frit that could be powdered and utilized when required. That a similar if not unaltered technology existed in the region to near recent times is apparent from the account of Ali Muhammad Isfahani, a potter of repute in nineteenth century Tehran (Scarce 1976). His narrative on the craft of contemporary tile-making, dated 1888 CE, prepared and recorded on the request of a high official, indicates that little had changed over the centuries. In the document[1], Ali Muhammad states that the bodies of contemporary *kashi* tiles were being fabricated using eight parts of crushed quartz, derived from a kind of quarried flint pounded to a fine powder with an iron hammer, to which was being added one part each of clay and powdered glass, remarkably similar to Abu'l Qasim's recipe. Interestingly, while the description given by Ali Muhammad on the production of glass used in the body and glaze is also close enough to Abu'l Qasim's account, in that equal proportions of finely-divided quartz and plant-ash soda were being mixed together and fired in a kiln to form a mass of raw glass, the process of fritting by pouring the molten glass into water finds no mention. The molten glass in this instance is made to flow into a basin to cool and harden, and then pounded to a fine powder for use. More recently, Wulff (1966), in his comprehensive ethnographic study of traditional crafts in modern day Iran, not only broadly corroborates the technologies described by Abu'l Qasim and Ali Muhammad Isfahani, but also highlights a distinction between artisans engaged in this craft vis-à-vis others engaged in the making of earthenware. Such exclusivity is likely to have been in existence in the heyday of stonepaste

[1] Reproduced in Furnival 1904, 215-223.

production earlier as well, the nature of the material and the technologies involved in its manufacture dictating the necessity of specialization for this craft practice.

With its arrival, stonepaste signalled the onset of a new era of technological progress in the world of Islamic ceramics. The white body together with the now prevalent use of alkali glazes allowed the freer use of underglaze-painting, a technique that was to take root and flourish across Egypt, Syria and Iran. This involved the painting of designs on a stonepaste body or white slip that was then covered with an overlying transparent glaze, the tiles at times being bisque-fired before painting, but fired anyway to incorporate the glaze (Figure 2.1). Through the thirteenth and early fourteenth centuries it was stonepaste that took on the lead in the development of ceramics. A popular high-quality product of note was lustre-painted glazed tiles, often modelled in relief, that were used as ornamental wall-revetments. This period was to also oversee the development of overglaze-decorative techniques, with luxury *minai* (enamelled) and *lajvardina* ceramics being created by the fusing of colours and leaf-gilding on a glazed surface through a short second firing (Mason *et al.* 2001, Freestone 2002).

Figure 2.1 An underglaze-painted stonepaste tile from fifteenth century Mamluk Syria in the collection of the Metropolitan Museum of Art (from http://www.metmuseum.org/toah/works-of-art/x.228.1.).

The re-emergence of earthenware

The benefits of the technological advancements in the ceramic industry were fully exploited by the Timurids in Central Asia over the fourteenth and fifteenth century, stonepaste tiles covered with alkali or lead-alkali glazes being decorated and applied in a bewildering variety of ways on their buildings. Besides stonepaste tiles that were *de rigeur*, Timurid Central Asia in the fourteenth century was also to witness the emergence and flowering of an innovative polychrome overglaze painting technique on an earthenware body called *haft rang* or ‘seven colours’ (Figure 2.2). Specific to tile-work, this technique first involved the painting of colours, separated by a waxy resist, onto clay tiles already glazed in opaque monochrome colours. The tiles were then fired again to incorporate a second overlaid glaze, both glazes usually being the lead-alkali type, but sometimes also of the high-lead type (Fabbri *et al*. 2002, Tite and Salter 2011, Holakooei *et al*. 2014). Thin lines of the resist, generally manganese oxide, but also at times iron oxide and possibly chromite, remained insoluble in the glaze and prevented the colours from flowing into each other.

Figure 2.2 A star-shaped stonepaste *haft rang* tile from fifteenth century Timurid Central Asia in the collection of the British Museum (© Trustees of the British Museum).

A parallel technique, called *cuerda seca* (literally 'dry cord'), apparently developed in the western extremities of the Islamic world at this time as well, earthenware polychrome tiles with glaze colours delineated through a black line being produced in substantial numbers in Islamic Spain. While both the *haft rang* and *cuerda seca* techniques may appear to be outwardly similar, studies have revealed that they are more likely to be independent developments with different stylistic antecedents in their respective regions. Technological dissimilarities are also evident. A tin-opacified white substrate glaze is found only in *haft rang* tiles, being notably absent in the *cuerda seca* variety (Holakooei *et al*. 2014). The chemical composition of the glaze layers of the two typologies also differs, *cuerda seca* tiles are reported to have only lead glazes, whereas those associated with *haft rang* tiles are usually of the lead-alkali type (Pérez-Arantegui *et al*. 1999, Chapoulie *et al*. 2005, Tite and Salter 2011, Holakooei *et al*. 2014).

Variances in technology apparently existed within the *haft rang* typology of tiles as well, those produced in the Ottoman royal workshop at Istanbul in the first half of the sixteenth century ostensibly not similar in material composition to the Timurid specimens that antedate them. Archival records of expenses incurred by the royal ceramic workshop over 1527-1528 CE (Necipoğlu 1990, 159-165) indicate the use of raw materials that find no mention in the treatise of Abu'l Qasim. Large quantities of cullet are mentioned for instance in the court registers, as is crude potash, in addition to the more familiar material that Abu'l Qasim speaks of. The precise use of each ingredient mentioned in these registers however remains unclear, as are the typology of the tiles that they were used to fabricate. One can only surmise that the lesser-known ingredients mentioned were used in the manufacture of glaze frit for all kinds of tiles being produced by the royal ceramic workshop; *haft rang* as well as underglaze-painted specimens.

The culmination of innovation

Perhaps the last of the major technological developments that was to occur in the world of Islamic ceramics is related to the Iznik industry that appeared in Ottoman Turkey in the late fifteenth century. Technically perfect almost since inception, Iznik ware was to remain remarkably sophisticated through its period of use till the mid-seventeenth century. It’s almost sudden appearance without any apparent phase of evolution has led to postulations that the industry was created and promoted by the state. The backing of the imperial court and systematic experimentation are said to have allowed the creation of a highly refined product before its introduction in the market for use (Necipoğlu 1990, 139-140, Watson 2004, 64-65). Based on stonepaste bodies, Iznik wares, besides their distinctive stylistic features, are noted for their long-term durability, extant specimens being on the whole well-preserved since made (Watson 2004, 64). In material character, while the lead or lead-alkali glazes used were a continuation from an earlier tradition, the glass frit used in their stonepaste bodies is found to have undergone a transformation, from an earlier alkali-lime or non-existent presence to now being consistently lead-alkali just as the glazes (Henderson and Raby 1989, Tite 1989, Paynter *et al.* 2004). Interestingly, a historical account on Iznik potters dating to the second half of the seventeenth century cites the use of white sand as a raw material, suggesting that sources other than river pebbles or quarries were also being exploited for obtaining quartz at this time and place (Atasoy and Raby 1989, 50-51, Mason 1995, 311).

The Iznik industry is also credited with the introduction of a vibrant red colour, the ability of Armenian bole to impart a brilliant red colour on firing, leading to its application as a thickly applied slip by artisans looking for ways to expand their colour palette. Thereafter, from the late seventeenth century onwards, although ceramic traditions and tiling were to continue across the Islamic lands, no new technological advancements of merit were conceived save the introduction of additional colours. Notable among these is the pink colour that was widely used on tiles in the Zand and Qajar periods in Iran (Porter 1995, 81). Regional industries were otherwise mostly content with the employment or revival of established methods, leading to the development of technical styles confined within political boundaries. A demand for Islamic ceramics in nineteenth century Europe may have resurrected the industry, but only to the extent of leading to the manufacture of mass-produced imitations of earlier designs and styles. The era of innovation had already come to an end.

The kilns

In spite of the variability witnessed in the techniques of production of glazed ceramics and tiles, the firing kilns are remarkably similar in their basic form. Abu'l Qasim, in his writings, describes such a kiln to be '…like a high tower and inside has row upon row of earthenware pegs, each an *arsh*[2] and a half long, fitted into holes in the wall'. Indeed excavations and findings throughout the Islamic world indicate that the kilns used in the firing of wares were primarily cylindrical-shaped updraft kilns, comprising an upper firing chamber in which the vessels were placed, separated by a perforated grate from a lower firebox in which the fuel, usually wood, was burnt (Figure 2.3). Vessels would be placed on earthenware pegs fitted to the walls of the firing chamber, such pegs having been discovered in excavations, with saggars used for protecting luxury items from direct heat and contaminants.

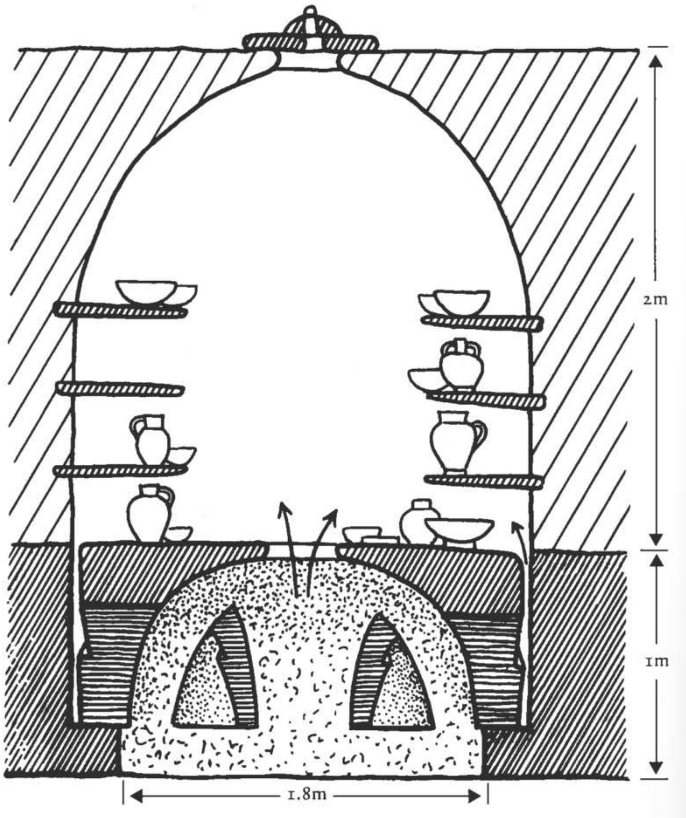


Figure 2.3 Schematic representation of a typical updraft kiln used in the medieval Islamic world (from Porter 1995, Fig. 2, p. 12).

[2] Allan (1973) considers this to be a *dhira'*, a unit of measure equivalent to an elbow length.

Not all kilns however conform to the typology described; few rectangular-shaped kilns have reportedly been unearthed in addition to circular ones at Iznik in Turkey, at Raqqa in Syria, and possibly at Merv in Turkmenistan (Henderson 2013, 185). Their comparatively smaller size however indicates that they may have been used for other purposes, a speculation being for the specific production of glass frit, such special kilns finding mention in the manuscript of Abu'l Qasim. In the loading of kilns too, departures from the conventional method of positioning wares on pegs seem to have been followed, particularly in the case of tiles. While luxury lustre or *minai* tiles would have been placed on pegs or saggars to avoid blemishes, commonplace monochrome tiles for use on architecture are more likely to have been stacked closer together. These would have been placed vertically along the walls of the firing chamber, on the lines described by Ali Muhammad who states '…set them around the kiln, as you would set looking-glasses, and apply the fire'.

Irrespective of the exact design of these kilns, and technique of placement of vessels or tiles within, the fact that they were all of the updraft variety implies that the maximum temperature that could be attained in their firing would typically range between 900 to 1050 ^{o}C (Rye and Evans 1976, 143-147, Rice 1987, 160, Tite *et al.* 1998). Such furnace conditions would have been inadequate for the manufacture of celadons or porcelain, the Chinese products that the Islamic potters were attempting to reproduce, which required a higher temperature firing, achievable only in kilns of a special design that were virtually absent in the Islamic lands. Islamic potters were therefore not only constrained by the lack of raw material, such as kaolinite rich-clays that went into the making of Chinese ceramics, but equally so on technological grounds, on account of the nature of the kilns employed.

2.2 Evolution and employment

A tradition of glazing is known to have long-existed in ancient Egypt and Mesopotamia from pre-Islamic times, specimens of early coloured revetments recovered from the Step Pyramid in Saqqara known to date to as far back as the third millennium BCE (van Lemmen 2013, 13). Maturity in faience developments in Egypt were realised by the time of the New Kingdom (sixteenth to eleventh century

BCE), wherein elaborate glazed plaques and tiles were produced for the palaces and temples of the pharaoh's Ramesses II and Ramesses III (Hayes 1937, Wilber 1939, 20). From the twelfth to sixth century BCE, the Assyrians in northern Mesopotamia used glazed bricks in a variety of ways to decorate their buildings at Assur, Khorsabad, and Babylon, the highpoint of this period perhaps being the magnificent panoramic friezes executed for the Throne-room, 'Processional Way' and Ishtar Gate at Babylon during the reign of Nebuchadnezzar II (c. 605-562 BCE). Architectural glazed bricks continued to be employed in much the same way by the Achaemenids at Persepolis and Susa in the fifth and fourth century BCE, but their use thereinafter in the region gradually declined so that by the beginning of the Islamic period in the seventh century CE, although glazed vessels were still made, glazed bricks were no longer an architectural feature (Wilber 1939, 21, Porter 1995, 22).

The early Islamic period under the Umayyads (661-750 CE) was witness to a tradition of architectural decoration that carried on from the late classical world, murals and mosaics, indistinguishable from their precursors, being the preferred form of embellishment of buildings. Actual glazed tiles began to make their appearance only under their successors, the Abbasids (750-1258 CE), who ruled over a vast empire from their capital at Baghdad in Mesopotamia, presiding over a period of great cultural, scientific, and literary achievement. Findings of a few square lustre tiles amongst copious quantities of glazed pottery in excavations at the ninth century Abbasid palace at Samarra (Sarre 1925, 50-54), and the discovery of similar tiles existing *in situ* in the Great Mosque of Kairouan (836 CE) in Tunisia (Marcais 1928, 15-33), indicate that not only were glazed tiles being now produced, but experimentation on their use on buildings was also being attempted. Being similar in decoration to the lustre-glazed vessels of their period but scant in numbers, it is clear that the early Abbasid era tiles were products of pottery workshops that were churning out lustre-pottery in substantial numbers, in attempts to replicate the imported Tang Chinese ceramics as remarked upon in the previous section. Though the ceramic industry in the Muslim world was now to set to grow, evidence of the use of glazed tiles over the tenth and eleventh centuries is scanty, an uncommon find being the small group of tiles recovered from the site of Qal'at Bani Hammad in Algeria (Golvin 1965). The limited numbers of tiles from this period, and their continued limited employment on architecture, seems to confirm that they were still a secondary product of the pottery industry, yet to be an inclusive part of an architectural ensemble.

Yet buildings were seemingly not devoid of tile-work in this period. Wilber (1939, 23), citing historical literary sources, provides brief accounts of what appear to be buildings decorated with glazed tiles. He quotes Mas'udi, writing in the tenth century, mentioning a green-dome built by al-Hajjaj at Wasit in Iraq. Another source speaks of a green-domed structure that survived till 941 CE being the focal element of al-Mansur's caliphal palace at Baghdad, while yet another, Ibn Rusta, describes the congregational mosque of Baghdad in 903 CE, as being 'covered with a teak roof studded with lapis lazuli'. While there is no reason to outright doubt the veracity of these writings, the fact is that none of these buildings have survived down to the modern period. In the absence of any material evidence the existence of tiled structures in this period can only be speculated upon. That the colouring described was attained by other means such as the painting of surfaces, and not by glazed tiles, cannot also be ruled out.

The sole standing building with vestiges of tiles that may be ascribed to the eleventh century with confidence is the Seljuk minaret of the Masjid-i Jami at Damghan, in Iran, dating to c. 1058 CE (Wilber 1939, 30-31, Pickett 1997, 23). The tiles however in this instance are only slabs or plaques, disconnected in a way with the structural form, and it is only on a series of later Seljuk buildings commencing from the early twelfth century, that glazed terracotta tiles and plugs designed to be an intrinsic part of architectural ornamentation start being seen (Wilber 1939, 31-38, Pickett 1997, 23-25). The practise of such ornamentation was carried forth by the Karakhanids and later Khwarazm Shahs in Central Asia, over the twelfth and thirteenth century, the frequent use of turquoise coloured glazed bricks and terracotta on their buildings marking the entrenchment of a new decorative tradition in the region (Figure 2.4). A similar style is also observed in the buildings of Ghurid Khurasan, notably on the minaret of Jam and on the portal of the Masjid-i-Jami at Herat (Pickett 1997, 28), but such instances are few, and occur only towards the end of the twelfth century. It is therefore in Iran and Central Asia, that the beginnings of tile-revetments associated with an inception stage of building design are found, a systematic progression then noticeable in their development over a century of use. The culmination of these developments is the achievement of the tile-mosaic technique, comprising polychromatic compositions attained by cutting, shaping and assembling monochrome tiles of different colours. While the tile-mosaic is first noticed in the early thirteenth century monuments of Anatolian Konya, it is believed to have been conceived by migrant artisans from Iran, where its logical arrival in the sequence of development had been arrested by the Mongol invasions of 1220-1221 CE (Wilber 1939, 38-40, Hillenbrand 1976, 545).

Figure 2.4 Turquoise coloured glazed tiles and plaques employed for embellishment on the mausoleum of Khwarazm Shah Tekesh (c. 1200 CE) in Turkmenistan, Central Asia (from Soustiel and Porter 2003, p. 36).

The Mongol subjugation of central and western Asia followed by the installation of the Il-Khanid dynasty (1256-1335 CE) in Iran may have initially halted architectural productivity, but once settled the Il-Khans proved to be great patrons of the arts and culture, adopting the customs and traditions of the lands they had conquered. Building architecture underwent a revival, new styles were encouraged, and imposing monuments erected in their capital cities at Tabriz and Soltanieh. Tile-work especially was to receive a great fillip under their patronage. Expensive decorative techniques, whose utilization in the ceramic industry was hitherto confined to fine pottery, now began to be used on tiles as well. While glazed bricks and plugs, and monochrome tiles continued to enliven the exteriors, a penchant for the use of luxury high-quality tiles in the interiors of buildings came to be introduced. Kashan, in Iran, where a well-established stonepaste pottery industry was already functional, now took on the lead in the manufacture of lustre, underglaze-painted, and *lajvardina* tiles for use on dados, friezes and in the creation of mihrabs in buildings. That luxury tiles and pottery were once again intertwined may be determined from the signature of eminent potters on both high-quality tiles and vessels, an indication also of the organization of the workshops at Kashan at this time (Porter 1995, 39-42). By the mid-fourteenth century, with the diminishing authority of the Il-Khans, the production of lustre tiles and its industry in general began to decline. Tiles however continued to be used by their successors on their buildings, the tile-mosaic finding increased use now, to cover larger surfaces of exteriors in elaborate geometric and stylized floral patterns (Blair and Bloom 1995, 16).

A tumultuous set of events was to occur in the last quarter of the fourteenth century, resulting in the emergence of a new power in Central Asia that was to quickly assume a pivotal role in shaping the art and architecture of much of the Islamic world. Timur, chieftain of a semi-nomadic Turco-Mongolian tribe in the region east of the Caspian Sea, set about the task of restoring the glory of the Mongol empire of Chingiz Khan, from whom he claimed descent. Assuming control of the tribesmen of his region and subjugating his foes, he turned his attention to expanding the frontiers of his empire, intent on global domination. In a series of decisive and brutal campaigns between 1386 CE up to his death in 1405 CE, Timur, with his armies, was able to add to his control large swathes of territory establishing an empire that besides his Central Asian homeland included Iran, Afghanistan and parts of Iraq and China. Iran was completely overrun by 1387 CE, the Golden Horde in the north vanquished by 1395 CE, Delhi sacked in 1398 CE, Aleppo and Damascus taken in 1400-1401 CE, and the Ottoman Sultan defeated at Ankara in 1402 CE. Undefeatable in battle, Timur was an enigmatic personality, his military prowess and so-ascribed cruel temperament in the theatre of war, matched by and yet contrasting with a deep passion for the arts and culture. While cities were systematically destroyed and urban populations terrorized, men of learning, artisans, and craftsmen were spared, many carted away to his capital Samarkand where a new building style in his name, designed to impress in its sheer scale, would germinate and proliferate.

If the monumental buildings commissioned by Timur reflect his aspirations of global authority, their lavish tile-work decoration illustrate his partiality for this craft form and the seemingly unlimited resources that he had access to. Under his generous patronage, tiled buildings of gargantuan proportions were erected at Shahr-i Sabz, Turkestan city and then at Samarkand, his capital, where significant specimens illustrating his favoured style of decoration still abound Figure (2.5). The employment of glazed tiles was now prolific to the extent of enveloping entire facades, 'cloaking them' as Hillenbrand (1976) says '…in a veil of tile-work increasingly unconnected with the structural forms beneath'. Irrespective of the dominance of decoration at the cost of building form, this was truly the golden era and apogee of architectural tile-work, now completely diverged and distinct from the pottery industry as an entity by itself.

Figure 2.5 Gur-e Amir (c. 1400 CE), the tile-decorated mausoleum of Timur at Samarkand, in Uzbekistan, Central Asia (from http://eurasia.travel/uzbekistan/cities/samarkand/gur-e-amir_mausoleum/).

Figure 2.6 Techniques and typologies of tile-work employed by the Timurids on their buildings. (Top left) Glazed bricks laid in the *banna'i* technique on the northern facade of the mausoleum of Tuman Aqa (1404-1405 CE) in the Shah-i Zindah complex in Samarkand (from Soustiel and Porter 2003, p 139). (Top right) A *haft rang* polychrome glazed tile panel in the mausoleum of Amir Burunduq (c. 1390-1420 CE), also located in the same complex (from Soustiel and Porter 2003, p 130). (Bottom) Glazed tiles laid in the tile-mosaic technique, above and around the door of the prayer room in the complex of Tuman Aqa (1404-1405 CE) (from Soustiel and Porter 2003, p 136).

A range of techniques were now being used; the tile mosaic being ubiquitous and most preferred, but also polychrome tiles of the *haft rang* variety, and glazed bricks laid in *banna'i*[3] technique all of which can be found on the Aq Saray at Shahr-i Sabz and at the Shah-i Zindah complex in Samarkand (Figure 2.6). The tile-mosaic that was hitherto confined to the use of turquoise, dark-blue, and white colours, now took on shades of black, green, brown, and yellow as well (Golombek and Wilber 1988, 125). Clearly, the assortment of techniques used could only have been the work of skilled artisans adept at handling the material, no doubt many of them coming from neighbouring lands where architectural tiling had an earlier history of use. That artisans from abroad imported wilfully or otherwise were used in the creation of Timur's buildings can be gauged from the contemporary chronicler Yazdi's account, who mentions that masons from India and Iran were brought for the construction of one of his most ambitious projects, the mosque of Bibi Khanum at Samarkand (Golombek and Wilber 1988, 256). The execution of projects of such large proportions would doubtless also have resulted in the creation of a fairly large pool of talented artisans and craftsmen locally.

Timur's architectural legacy was carried forth by his successors over the fifteenth century, his kingdom on his death being principally divided and governed by his son and heir Shah Rukh, and grandsons Ulugh Beg and Ibrahim Sultan. Ulugh Beg, who assumed control of Transoxania at Samarkand, indulged himself in building activities in emulation of his grandfather, his significant contributions being the erection of a *madrasa* at Registan in Samarkand and an astronomical observatory on the outskirts of the city. Although monumental in size and decorated similarly with glazed tiles, his buildings, unlike Timur's, have a sense of purpose, and were successful in functioning as great centres of learning of that age. In 1411 CE, in a curious turn of events, Ulugh Beg, under the authority of Shah Rukh, issued an edict freeing the artisans and intellectuals who had been forcibly brought by Timur to Samarkand, allowing them to return to their homes (Woods 1990, 115, Golombek *et al*. 1996, 129). This seems to have triggered a reverse migration of sorts, at least on a small-scale, some of those released choosing to return to their native lands for

[3] An application technique in which glazed bricks or tiles are alternated with unglazed bricks on masonry to create geometric patterns, and at times spell out pious names or phrases.

employment, others departing for better opportunities in other courts within the Timurid realm and elsewhere. Some corroboration of this is apparent in the case of tile-work artisans. In Turkey, extensive tile-work decoration with a Timurid flavour appears for the first time soon after in Bursa between 1419 CE and 1424 CE. This tile-work, executed by tile artisans from Iran, is reported to have been designed and supervised by Ali *al-naqqash* (the painter), a native of Bursa, who by Ottoman accounts had been taken by Timur to Transoxiana where he received his training (Necipoğlu 1990, 136). At Damascus in Syria likewise, the use of blue-and-white ceramic tiles over 1420 CE and 1436 CE that follow a Timurid model, are believed to be the work of artisans previously employed by Timur in Samarkand (Golombek 1993, Golombek *et al*. 1996, 129).

Some artisans are also likely to have migrated to the region of Khurasan where Timurid ceramic traditions were to continue for long thereafter. Shah Rukh (r. 1405-1447 CE), who ruled from Herat, was an avid builder and connoisseur of the arts. He was, in his reign, able to successfully transform the city and the region in broader sense into a centre of artistic excellence and culture. On his buildings, and those attributed to his formidable wife Gawhar Shad, the tile-mosaic and *haft rang* tiles continued to be used, the former possibly surpassing all known precedents in technique and style. This can be evidenced in the remnants of tile-work visible on the Gawhar Shad complex at Herat, and from the tiled decoration on the shrine of Imam Riza at Mashhad. The pre-eminence of Khurasan was to continue with the later Timurids, Abu Sa'id (r. 1451-1469 CE) and Husayn Bayqara (r. 1470-1506 CE), in the second half of the fifteenth century, but less emphasis was now paid to architecture. Excellent tiled buildings in the style of their predecessors, such as the Husayn Bayqara Madrasa at Herat, were however still being erected. Timurid building traditions in this manner, even later, on the passing of the Timurids with the demise of Husayn Bayqara, would continue to influence and inspire architectural form and decoration in neighbouring lands.

The political reshaping of the Islamic world in the early sixteenth century and new beginnings made through the emergence of powerful dynasties across the region, was as much as an era of stability and territorial consolidation as the flowering of art and culture. Ottoman rule in Turkey now extended to encompass all parts of central and eastern Anatolia, where the westward transmission of the 'international' Timurid style had already made its presence felt. Hitherto, tile-work in Turkey had been confined to works in the fifteenth century that were attributed to itinerant tile-makers from Timurid Iran and Khurasan. The group of tile-makers who were supervised by Ali *al-naqqash* at Bursa, as mentioned earlier, signed their works as the 'Masters of Tabriz', and apparently proceeded to Edirne to decorate other buildings there as well in the 1430's (Riefstahl 1937, Necipoğlu 1990, 136-137). Their repertory of underglaze-painted blue-and-white tiles, *haft rang* tiles, and the tile-mosaic is reminiscent of the tile-work found on buildings of contemporary Timurid Khurasan (Necipoğlu 1990, 137). The Çinili Kösk at the Topkapi palace (1472 CE) is similarly attributed to a second group of itinerant tile-makers, referred to as 'tilecutters of Khurasan' from contemporary documents, who seemed unsuccessful in getting further commissions in the Ottoman court and probably returned home. In the first half of the sixteenth century, however, from court documents, it becomes apparent that a new centralized order of court ceramists functioning under the auspices of a larger ensemble of royal workshops had come into existence. Itinerant tile-makers were no longer being accommodated, immigrant artisans being instead attached to such workshops, which catered to the demands of royalty and nobility. Tile revetments on imperial buildings of this period, on the Sünnet Odasi (Circumcision Room) and the Arz Odasi (Chamber of Petitions) in the Topkapi Palace for instance, are ascribed to this 'community of court ceramists' who worked on a range of tile-work techniques, similar to those utilized by the Tabrizi masters in the preceding century (Necipoğlu 1990, 140-141).

The control exercised by the courts was seemingly responsible for the high degree of standardisation attained by the local ceramic industry at Iznik in Anatolia as well, which was to become the dominant player in Ottoman Turkey in the second half of the sixteenth century. The almost sudden appearance of a high-quality underglaze-painted stonepaste ware at Iznik in the last quarter of the fifteenth century, without any developmental phase, is now acknowledged to be resultant of imperial patronage, the energies of the court directed towards the engineering of an exceptional ceramic product. The output of the Iznik kilns in the early years was primarily concentrated on the production of pottery vessels, initially painted blue-and-white in locally influenced designs. The industry progressed thereon with the addition of more colours to establish a unique character of its own, identifiable by underglaze-painted delicate floral and vegetal forms in a palette that included a new bright red from the slip. From around 1550 CE onwards, an increasing emphasis was laid on the production of tiles, commensurate with a noticeable decline in the role of the court ceramists for the same. The second half of the sixteenth century was also the golden age of Ottoman architecture, in which an extraordinary number of buildings were erected, several designed by the highly talented architect of the age, Sinan. Many of these buildings were embellished with tiles from Iznik, a preference for their employment in the interiors now apparent, being added only occasionally in significant numbers on the outside. The genius of the Iznik artisans, witnessed in the tile-work cladding in the Selmiye Mosque (1569-1579 CE) for instance (Figure 2.7), was however not destined to last for very long. A decline in use and standards had set in by the early seventeenth century, and although tiles continued to be manufactured for local consumption and export, the days of the industry were numbered, shutting down practically in entirety before the end of the same century.

Figure 2.7 A spandrel in the Selmiye Mosque (1569-1579 CE) at Edirne decorated with Iznik underglaze-painted tiles (from Degeorge and Porter 2002, p. 208).

Parallel to events in Ottoman Turkey, post-Timurid Central Asia of the sixteenth and seventeenth century was an era of neo-Chingizid revival, where the descendants of Chingiz Khan and tribal groups remain engaged in political manoeuvrings, staking claims to kingship based on lineage and seniority. In Transoxiana, legitimacy to rule in the early sixteenth century was appropriated by the Shibanid family, who claimed descent from a grandson of Chingiz Khan by the name of Jochi, and then later in the seventeenth and early eighteenth century by the Janids (Astarkhanids), another branch of the family of Jochi. The period of rule of the two families in the history of the region falls under what is referred to as the Uzbek period, the principality governed by them being the Khanate of Bukhara. Under the Shibanid and Janids, the city of Bukhara replaced Samarkand as the political centre of Transoxiana, and became the focus of renewed construction activities. Contemporary sources mention the erection of no less than three hundred and fifty public buildings in this period (Blair and Bloom 1995, 199), major projects being reserved for the capital Bukhara, and to a lesser extent, to other large centres of note such as Samarkand.

In architectural style and decoration, the Uzbek buildings of the Bukhara khanate follow the Timurid model, a significant role accorded to embellishment with tile-work. Evidence of contemporary tastes can be found in the ceramic decoration of the sixteenth century buildings of the Pa-yi Kalan ensemble in Bukhara. On the Mir-i Arab Madrasa in Pa-yi Kalan, the high-quality tile mosaic decoration that is limited to the main facade only, reflects the tiling technique favoured during the period as well as the comparative restraint followed in its application vis-à-vis Timurid times. The employment of the tile-mosaic continued into the seventeenth century on buildings at Bukhara, at the Lab-i Hauz complex, and at Samarkand as well, where the Shir-dar Madrasa was erected at Registan, its facade constructed in a manner to mirror the older *madrasa* of Ulugh Beg that lay opposite. Completed in 1635-1636 CE, Shir-dar (literally ‘Lion-bearing’) takes its name from the figural composition of lions pursuing deer executed on the spandrels of the main portal of the building. The increased use of yellow colour in the tile-mosaic as opposed to the earlier usual blue is quite noticeable for tiling in this period (Figure 2.8). Other methods of glazed decoration, particularly the *banna’i* technique, were also still being used, the emphasis generally being more on symmetry and the repetition of patterns than on the design of individual units. An overall decline in authority however had by now begun to set in, and by the mid-seventeenth century civil war and Mughal interference led to the division of the khanate. Perhaps the last of the tiled buildings of significance to be erected at Bukhara was the Madrasa of Abd al-Aziz, erected in 1651-1652 CE. A brief reunification towards the end of the seventeenth century could not halt the slide, the khanate steadily losing lands and disintegrating into smaller divisions at the hands of resurgent nomads and tribal forces.

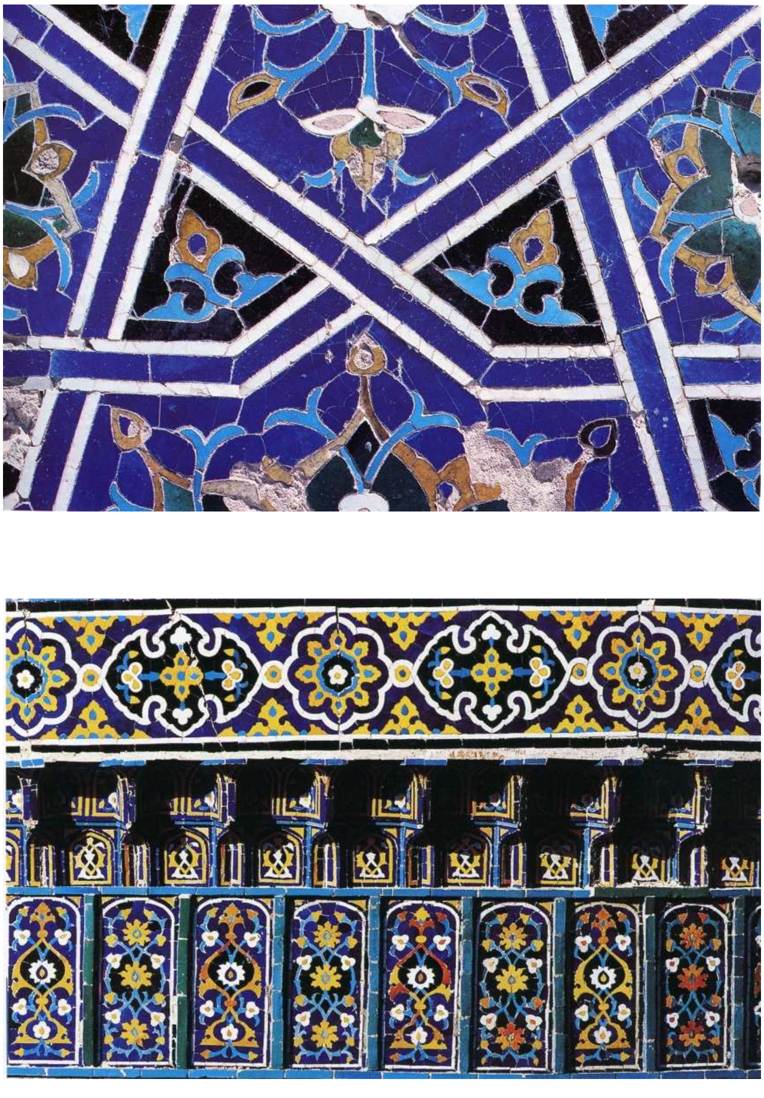


Figure 2.8 The changing face of the tile-mosaic from Timurid to Uzbek times. (Top) A mosaic composition in the Timurid Tuman Aqa funerary complex at Samarkand (1404-1405 CE), the domination of shades of blue most apparent (from Degeorge and Porter 2002, p 117). (Bottom) Tile-mosaic employed on the Mir-i Arab Madrasa, Bukhara, Uzbekistan (1535-1536 CE), the use of appreciable numbers of yellow coloured tiles reflecting prevailing tastes (from Degeorge and Porter 2002, p. 123).

In contrast to the extensive use of tiles in sixteenth century Transoxiana, very little evidence of architectural tiling is available from contemporary sixteenth century Iran under the Safavids (1501-1722 CE), as is architecture from this period in the history of region. Timurid traditions of tiling that continued under the Turkmen confederations in Iran in the preceding century, are conspicuously absent in the first century of Safavid rule. The lack of architecture in this period is ascribed to long-drawn hostilities with neighbouring empires entailing even the changing of the capital on more than one occasion. It is with Shah Abbas I (1588-1629 CE), and on the transfer of the capital for the third time, to Isfahan in 1598 CE, that the glory of Safavid architecture and the grandeur of the tile-work decorative traditions set by them was realised.

The most famous of Shah Abbas's projects is undoubtedly the Naqsh-i Jahan or 'Royal Square', the new centre of the city, conceived to be utilized as a multi-purpose space for political ceremonies and sporting activities. On the Mosque of Shah Lutfallah (1602 CE) and the Shah Mosque (begun c. 1611 CE) that lie astride the royal square, can be found the most splendid specimens of polychrome tile-work and tiling techniques utilized in this period (Figure 2.9), shades of blue initially dominating the colour scheme, but then later being increasingly contrasted with a bright yellow (Porter 1995, 76). In vastness and numbers, as evidenced on the tiled buildings at Naqsh-i Jahan, Safavid tile-work probably exceeds its Timurid precursors, imitating Uzbek tile-work in a way in their display of endless repetitive principally floral patterns. The tile-mosaic, although still used, was surpassed in usage by polychrome *haft rang* tiles (Figure 2.9). The latter was preferentially employed on the later tiling of Shah Abbas's period, most likely on account of its relative inexpensiveness and ease of application (Vogel 1920, 14, Porter 1995, 76).

A notable stylistic development in seventeenth century Safavid Iran was the creation of large pictorial tiled compositions on buildings, individual polychrome tiles being painted with a part of the figurative depictions of an overall larger scheme. Such tiles are however largely limited to the palaces of Isfahan, the Hasht Behesht pavilion in the city being one such example. Fine tiles continued to be produced till the very end of Safavid rule in the first quarter of the eighteenth century, as found on the Madrasa of Madar-i Shah (1706-1714 CE), but the scale of activity was much lesser now, commensurate with fewer building commissions in the wake of declining prosperity.

Figure 2.9 A panel and border of polychrome *haft rang* tiles on the Shah Mosque (c. 1611-1627 CE) at Isfahan, Iran. Such tiles were typically preferred over the tile-mosaic in Safavid tiling of the early seventeenth century, the shades of colour employed on these tiles also typical of this time (from Degeorge and Porter 2002, p. 148).

As the tile-mosaic diminished and disappeared from use, *haft rang* tiles and the hitherto less frequently employed underglaze-painted polychrome tiles became a favoured means of embellishment in Iran and Central Asia in the eighteenth and nineteenth century. Pictorial depictions and foliated patterns with a dense congregation of flowers prevailed in this new decorative style, particularly at Shiraz and Kashan in Zand (1750-1794 CE) and Qajar (1794-1925 CE) Iran, a notable addition being the introduction of the colour pink in the palette employed.

Underglaze-painted tiles as a means of building decoration were also popular in the Khanate of Khiva in Central Asia in the nineteenth and early twentieth century, perhaps the last bastion of architectural tiling in the entire region that bore some semblance to its Timurid progenitors. The European-influenced tiles that were also being manufactured in this period, in Iran and Turkey, are clearly disenfranchised from what may be considered an 'International Timurid' or Timurid-influenced style. Inspirations and demand in these countries were now being fuelled by lands that lay to the west.

2.3 Summary

Although the development of architectural tiling in the Islamic world commenced in the earlier centuries of Islam as an off-shoot of the pottery industry, the craft truly flourished on its establishment as an independent entity in parallel with large-scale building construction over the fourteenth to seventeenth century. Tiles from the ninth to twelfth century are limited in numbers, and follow the high-end glazed vessels of this period, in being lead or lead-alkali earthenware specimens having tin-opacified and lustre-painted glaze layers. Glazed decoration on architecture took root as a distinctive tradition in the twelfth century, with the use of glazed bricks and glazed terracotta on buildings in Iran and Central Asia.

A sea change occurred with the widespread introduction of stonepaste technology in the same century, leading to the development of an assortment of new decorative techniques, and the employment of tiles in greater numbers on buildings thereafter. Under the Il-Khanids in Iran in the thirteenth century, stonepaste tiles with alkali and lead-alkali glazes were used in notable quantities for the embellishment of both exterior and interior building surfaces. The successors of the Il-Khanids in Iran and Central Asia carried on with the tradition of tiling buildings in the fourteenth century, the tile-mosaic gradually becoming a favoured means of glazed decoration.

The apogee of tiling took place in the reign of Timur and his dynastic successors from the late fourteenth to the first half of the fifteenth century, impacting in style and technique the tiling traditions of the eastern Islamic world for the next few centuries to come. Under the Timurids, stonepaste tiles, in the form of the tile-mosaic, and earthenware polychrome *haft rang* tiles were lavishly used on the exteriors of immensely-proportioned buildings. An increase in the colour scheme of the tile mosaic took place in the Timurid era, the range of colours earlier being mainly turquoise, dark-blue, and white, but now encompassing black, green, brown, and yellow as well. Shades of blue however remained the dominant colour through Timurid times. Relatively fewer tiling commissions were undertaken by the later Timurids in the second half of the fifteenth century till the end of their rule.

The tile-mosaic and *haft rang* tiles continued as the preferred typologies of tile-work in post-Timurid Central Asia under the Uzbeks in the sixteenth and the seventeenth century, the tile-mosaic continuing in use till the end of their rule. In post-Timurid Iran, little tiling took place for the most part of the sixteenth century in the early Safavid era. Resurgence in tiling was witnessed in the late sixteenth and first half of the seventeenth century in Safavid Iran, centred on Isfahan, where the more economical *haft rang* tiles were preferred in use over the tile-mosaic in commissions. A noticeable shift in the colour palette of the tiles employed occurred in both Central Asia and Iran in the seventeenth century, the colour yellow being increasingly used in monochrome and polychrome tiles to counter the dominance of shades of blue in tile-work compositions.

Underglaze-painted tiles that were comparatively less popular in Central Asia and Iran were the mainstay of the court-supported Iznik industry that flourished in Ottoman Turkey in the second half of the sixteenth century. Commissions involving the use of the tile-mosaic in Turkey are limited to the fifteenth century, those carried out attributed to migrant artisans or locals trained in Timurid Central Asia and Khurasan. The migration of artisans to Turkey is related to declining opportunities for work in their native lands.

Polychrome *haft rang* and underglaze-painted tiles in a new decorative style were employed in the eighteenth and nineteenth century in parts of Iran and Central Asia, as Timurid influences declined. Underglaze-painted tiles used on buildings at Khiva in the nineteenth and early twentieth century are the last vestiges of a Timurid-influenced tile industry.

3. GLAZED TILES IN ISLAMIC INDIA

Tiles in the Indian subcontinent are not just limited to northern India, many centres of architectural tiling having evolved and flourished during the period of Islamic rule in the region. Considering that prevailing practices and knowledge-systems are known to often transcend boundaries, understanding tile-work from northern India necessarily entails looking into the development of the craft in the neighbourhood as well. The first section of this chapter accordingly provides an overview of tiling and the various centres of tile-work that came into existence in medieval and post-medieval Islamic India while discussing the socio-political conditions and influences of the time. The second section is more focused on northern India, deliberating on Lodhi and Mughal tile-work in this region, the specific context of this research, and evaluating the shortcomings in the current state of knowledge on the subject of study. The third section summarizes the chapter, providing a concise background against which Lodhi and Mughal tiles may be assessed and interpreted.

3.1 History and development in India

The art of glazing was not entirely unknown in the Indian subcontinent in the centuries preceding Muslim rule, the recovery of glazed bricks from excavations at the Kushan period (first to third century CE) site of Shahji-ki Dheri, near Peshawar in modern day Pakistan, indicating that the technique was probably in practice much earlier (Spooner 1912, 55, Nath 1989, 11, Degeorge and Porter 2002, 224). Vestiges of glazed ware and tiles are found in other pre-Islamic sites as well, such as Brahmanabad, in Sind, and at Gaur and Pandua, in Bengal (Furnival 1904, 116-119, Nath 1989, 15-16), but such instances are rare and sporadic at the best. It is only later with the advent of Islam, and its influences, that tiling as means of architectural decoration gained popularity and widespread use.

The Arab conquest of Sind and parts of western Punjab in 711 CE by the young Umayyad general Mohammed bin Qasim, and the subsequent founding of minor sultanates in the area, marks the earliest presence of Islamic rule in the subcontinent. Expansion however remained curtailed for the next few centuries, the new faith influencing little beyond the appropriated provinces. Little remains also of the building activities that were undertaken by the Arabs in this time. Although cities such as Mansura and Multan, in the provinces of modern day Sind and Punjab in Pakistan, are recorded as having been built or rebuilt by them, ruins that may be accurately ascribed to this period are rare. Moreover, none of those purported to be so have yielded glazed tiles or bricks of any kind. A series of devastating raids in the early eleventh century by Mahmud of Ghazni to regions further east was the next serious incursion of Islam, this time purely for reasons of loot and plunder, the marauding armies of Central Asian Turks focusing more on pillaging than on installing themselves in the region. It is only a century later, with the firm establishment of an Islamic state, that the effects and influences of the religion in the domain of building architecture began to be realised.

3.1.1 Early sultanates of Delhi

Permanent establishment of an Islamic dominion in the Indian subcontinent is attributed to the Ghurid dynasty from Afghanistan, Muhammad Ghor's defeat of the combined Rajput forces at the battle of Tarain in 1192 CE, and his occupation of Delhi, paving the way for prolonged Muslim rule in the region. The Delhi Sultanate (1206-1526 CE) was formally instituted by Qutb al-Din Aibak, a slave general installed by Muhammad Ghor at Delhi, who declared himself independent on the death of his master in 1206 CE, founding the Slave or Mamluk Dynasty (1206-1290 CE). From the time of his installation as administrator soon after the Muslim conquest, Aibak, and then his successors, not only laid the foundations of an Islamic empire centred on Delhi in northern India, but also set the stage for the development of a new 'Indo-Islamic' architectural style in the region. Imported influences and the introduction of a new creed began to transform building form and ornamentation. Buildings that were foreign in plan and function started being constructed, decorated in a manner and spirit to suit the tastes of Islam (Brown 1968, 1-5, Blair and Bloom 1995, 149-151).

Yet the new building style was not deprived of local influences. In choice of building material the Muslims took recourse to stone, not only on account of its greater permanence vis-à-vis the brick and rubble construction that they were more accustomed to, but for its employment in the land for centuries beforehand, and for the great pool of local workmen, skilled in its manipulation, available for use. While spolia from the destruction of Hindu temples and buildings was extensively used in early architectural commissions and locally available quarried stone soon thereafter, the knowledge and skills of local artisans in the art of working stone also began to be advantageously exploited by the new incumbents. A merging of traditions gradually took effect. Buildings that were modelled on Ghaznavid and Ghurid architectural styles further west began to be constructed making use of indigenous materials and practices. In the Qutb complex at Delhi, the Qutb Minar, erected in 1199 CE, imitates in building and style the Ghurid minaret of Jam (c. 1190 CE) in Afghanistan, but while the Jam Minaret is constructed with baked bricks and exhibits stucco and glazed tile decoration (Figure 3.1), the Qutb Minar is of dressed stone only, and ornamented entirely by the meticulous carving in relief of the stone surface (Figure 3.2), no doubt by local artisans of sufficient expertise.

While tiling was then not apparently employed on the early Muslim buildings of Delhi, evidence of introduction of the art in the early years of the Mamluk period can be made out elsewhere in northern India. At Badaun, an early Muslim centre of learning located south-east of Delhi, a row of glazed bricks is found used on the Mamluk period Shamsi Idgah, erected in 1209 CE (Rahman 1988, 268). Fragmentary remains of blue tiles on the now ruined tomb of the later Mamluk sultan Ghiyath al-Din Balban at Delhi, dating to the last quarter of the thirteenth century, are a further testimony to the use of glazed bricks or tiles in the region during this period. Some tiling can also be evidenced in the era of the Afghan Khalji Turks (1290-1320 CE), successors of the Mamluks, who brought with them fresh influences in the architectural treatment of building art. The *idgah*[4] at Rapri, near Agra, has a row of glazed tiles that run over an inscription ascribing the building to the period of Ala al-Din Khalji (r. 1296-1316 CE) (Rahman 1988). A series of embossed earthenware tiles unearthed at Delhi, now in the collection of the Victoria and Albert Museum at London, are also believed to date to the period of Khalji rule (Hasan 1995, 86-88). For the most part however, the early dynasties remained

[4] An open-air place of worship used on specific festive occasions.

engaged in military campaigns and in the annexation of provinces to their empire. Less time was available at their disposition in pursuing projects of aggrandisement, and in the incorporation of decorative traditions of their native lands.

Figure 3.1 (Top and Bottom) The Jam Minaret in Afghanistan with details of its ornamentation (from Wikimedia Commons).

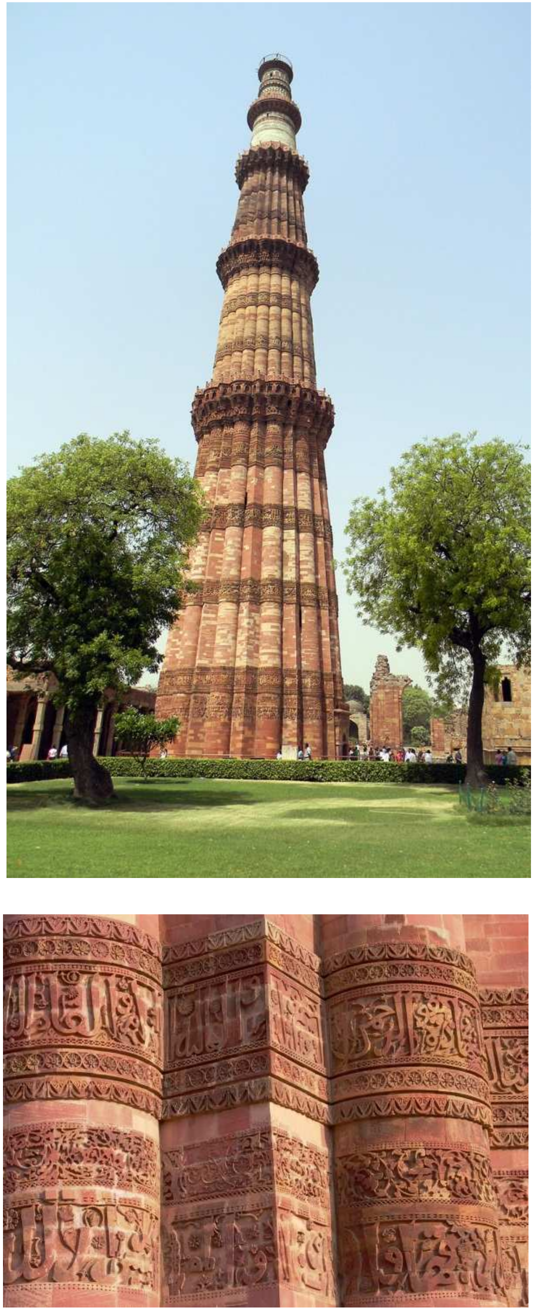


Figure 3.2 (Top and Bottom) The Qutb Minar at Delhi with details of its ornamentation (from Wikimedia Commons).

In 1320 CE, the Khaljis were replaced by yet another regime of Turkic origin, the Tughluqs, who occupied the throne of Delhi for the next century or so. With the Tughluqs, Muslim authority spread further, adding to the gains made by their predecessors in the expansion of the state and imposition of Islam. This was the richest and most productive period of the Delhi Sultanate, marked by great progress in architecture and learning. Building construction was now systematized and standardized, identifiable for the first time as an indigenous dynastic style with its typical features (Welch and Crane 1983). The earliest specimen of Tughluq architecture, the Tomb of Rukn-i Alam (c. 1320 CE), is however not in Delhi but at Multan in Pakistan (Figure 3.3), on the western fringes of the empire. In its construction and decoration, the tomb embodies a synthesis of the distinctive features of Tughluq architecture combined with techniques of embellishment borrowed from Turco-Iranian lands (Hillenbrand 1992). While the battered walls and turrets of the tomb can be seen replicated in Tughluq buildings at Delhi, its exemplary blue-and-white glazed brick and tile decoration is resonant of practices followed in lands further west.

Figure 3.3 Glazed brick and tile decoration on the Tomb of Rukn-i Alam (c. 1320 CE) in Multan, Pakistan (from Akhund and Askari 2002, Fig. 224, p. 142).

The employment of such blue-and-white tiles on buildings would hereinafter continue uninterrupted in the Sind-Multan region under the many dynasties that followed over the centuries, taking root as a local tradition that has endured to the present day. In striking contrast to developments in Multan, very little tile-work was used by the Tughluqs on their buildings at Delhi. The Begumpur Masjid, with isolated turquoise coloured tiles embedded at places on its exterior facade, is as yet the only confirmed example of this period here.

Timur's sack of Delhi in 1398 CE ended the period of Turkic consolidation, facilitating the dismemberment of the Delhi Sultanate into a series of independent provincial sultanates. In the north, the impact of Timur's assault extended well into the era of the Sayyid dynasty (1414-1451 CE) that followed the Tughluqs, their rule overseeing a much diminished empire, broken in spirit and resource. In the provinces that emerged on the other hand, much building activity took place in the fifteenth century, leading to the development of new styles of building and decoration that were less dependent on Delhi for inspiration. In the Sultanate of Bengal in the east, earthenware glazed tiles of a local character began to be used on brick mosques and tombs at Gaur and Pandua (Furnival 1904, 116-119, Nath 1989, 15-16). In the Deccan in south India, and in the Malwa region in central India, tile-work with stronger influences of central Islamic lands started being employed on architecture.

3.1.2 Provincial sultanates of the Deccan and Malwa

In the Deccan, the Bahmani kingdom (1347-1527 CE) that had already gained independence for some time now, developed into a great centre of culture and learning, attracting Persians, Turks, and Arab emigrants among others to its court. Ambassadors were regularly exchanged by the Bahmani Sultans with the Ottomans. Reflections of the influx of foreigners and the overseas interactions can be found in their art and architecture that was doubtless subject to foreign influences as well. The tomb of Sultan Ala al-Din Bahman Shah (r. 1436-1458 CE) at his capital at Bidar for instance, is decorated with polychrome tiles and the tile mosaic in colour schemes and styles that are evocative of Persian or Central Asian workmanship (Yazdani 1947, 130-132). The *madrasa* of the powerful Persian vizier, Mahmud Gawan, at

Bidar (1472 CE), is a building of Timurid proportions and form (Figure 3.4), more at home in Central Asia than in the Deccan (Brown 1964, 70). The tile-work that it bears comprises the entire repertory of Timurid tiling techniques, small glazed bricks applied in the *bannai* technique, and polychrome *haft rang* tiles in addition to the omnipresent tile-mosaic (Degeorge and Porter 2002, 237). It is interesting to note that this building was constructed around the same time as the Çinili Kösk (1472 CE) in Turkey, described in Chapter 2 earlier, the tile-work of which is attributed to migrant tile artisans from Khurasan.

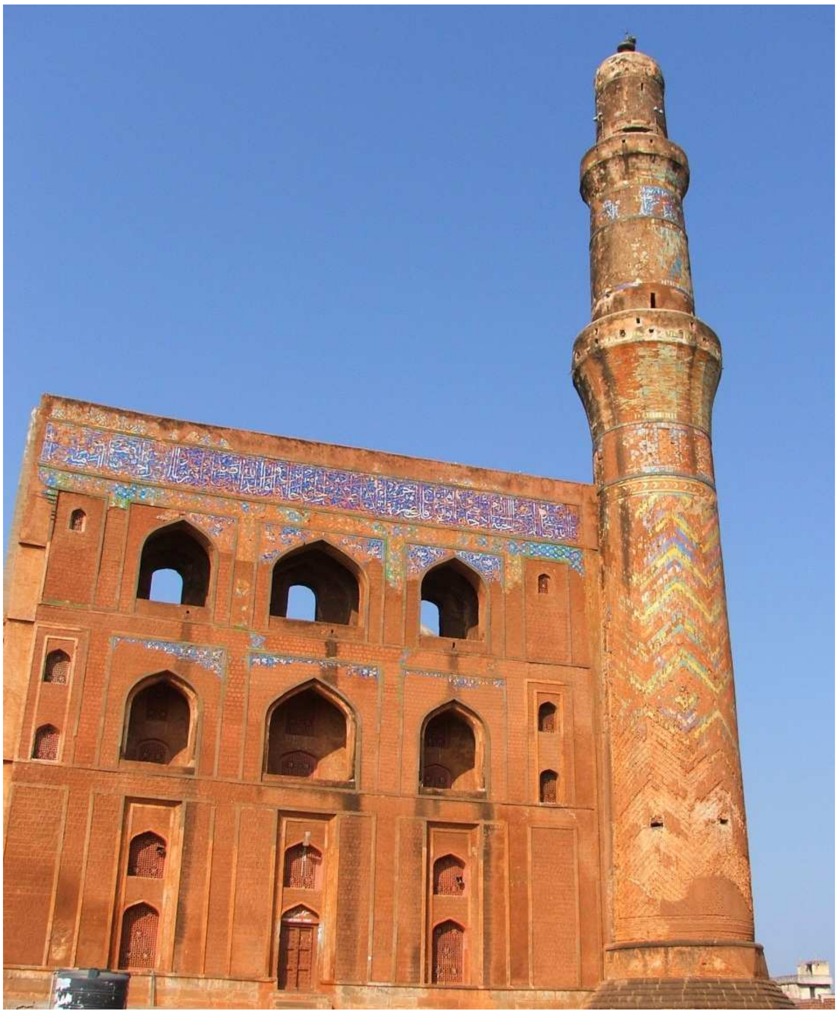


Figure 3.4 A facade of the Madrasa of Mahmud Gawan at Bidar (1472 CE), exhibiting its Timurid characteristics in building form and glazed tile decoration (from Wikimedia Commons).

Elsewhere in Bidar, mosaic tiles employed on the tomb of Hadrat Shah Abul Faid (1474 CE) display for the first time a so-called 'Deccani' colour scheme, comprising 'mustard-yellow' and green colours in addition to the dark-blue, turquoise, and white colours noted used on the earlier monuments (Michell and Zebrowski 1999, 136). The passion for use of glazed tiles on buildings in Bidar continued well into the sixteenth century under the Barid Shah's who succeeded the Bahmanids. The mausoleum of Ali Barid Shah (r. 1542-1580 CE) and the Rangin Mahal or Painted Palace built by him, have exemplary specimens of tile-work décor, not only on the exteriors but in the interiors as well.

At Golconda, also in the Deccan, the Shiite Qutb Shahi's (1518-1687 CE), who were of Persian descent, were avid builders as well as keen patrons of cultural traditions associated with their homeland. It is then no surprise that several of their buildings are embellished with glazed tiles, the craft finding significant use in their native land. That the founder of the dynasty, Sultan Quli Qutb Shah (r. 1518-1543 CE), was in the service of the Bahmanids as a governor at Golconda before declaring himself independent may be noted, the interrelation between Bidar and Golconda dictating to an extent the styles of architecture and decoration that developed in the latter. The tombs of Ibrahim Shah (r. 1550-1580 CE) and Abdullah Shah (r. 1626-1672 CE) bear remnants of a multi-coloured tile-mosaic on their exteriors (Figure 3.5), the palette notably including tiles of a yet unreported 'mellow-terracotta' hue (Michell and Zebrowski 1999, 138). On Muhammad Shah's tomb (r. 1612-1626 CE), tiles, probably of a monochrome green colour only, were apparently utilized to cover the entire dome (Sardar 2007, 175-176), an indicator of the importance placed on this means of decoration.

In the Malwa region of central India, sandwiched between Delhi and the Deccan, Dilawar Khan Ghuri (r. 1401-1406 CE), the governor appointed at the behest of the Delhi Sultan, assumed independence in the wake of Timur's invasion. Under the Ghurid dynasty (1401-1436 CE) founded by him and the Khalji dynasty (1436-1531 CE) that followed, a series of remarkable buildings were erected in a new capital city located in an impregnable fortress, Mandu. Not only were authoritative tombs and mosques constructed at Mandu in emulation of their contemporaries elsewhere, but also the finest pleasure pavilions and palaces for occasions of gaiety and festivity (Yazdani 1929, 5-40). While the impact of the architectural style of Delhi lingered on in the construction of buildings, new ways of embellishment were experimented with, including the use of tiles. Ali ibn Mahmud Kirmani, the court chronicler of Mahmud Khalji (r. 1436-1469 CE), tells us that in 1442 CE, Persian craftsmen were engaged in the execution of inscriptions and decoration using glazed tiles on the ceilings and walls of the Bam-e Behesht Madrasa, no trace of which unfortunately survives today (Porter 1997, 125).

Figure 3.5 Tile-mosaic decoration on the Tomb of Ibrahim Shah (c. 1580 CE) at Golconda in the Deccan. The palette employed is notably found to include the use of a new mellow-terracotta (orange) colour.

Of the tiled buildings that have been passed down to us, most are adorned with tiles of the monochrome variety only, either dark-blue or turquoise, employed with restraint as individual specimens or at the most in narrow bands, as evidenced on the Jami Masjid (1454 CE) and on the tomb of Hoshang Shah (d. 1432 CE). Other forms of tiling are also found to exist at Mandu. The Jahaz Mahal, dating to the second half of the fifteenth century, has tiles employed in the mosaic fashion on its exteriors, possibly applied by artisans from Khurasan (Porter 1997, 129-130). The sixteenth century structure that goes by the name of Dai-ki Chhoti Bahen-ka Mahal has remains of blue-and-white underglaze-painted tiles on the drum of the dome, the dome itself bearing evidence of having been once completely encased with square-shaped monochrome tiles (Degeorge and Porter 2002, 241-242).

The tiling traditions of Mandu are quite likely to have influenced the transmission of glazed tiles onto Hindu architecture in fifteenth century central India as well. The Man Singh Mahal in Gwalior Fort, erected by the Hindu ruler Raja Man Singh Tomar (r. 1486-1516 CE) of Gwalior, is elaborately decorated with tile-work laid in geometric and figural compositions on its exteriors (Figure 3.6), some patterns and motifs of which are found earlier used in the Jami Masjid at Mandu (Porter 1997, 128, Tillotson 1999, 63-64). Although the practice of tiling seemingly discontinued in Gwalior following the appropriation of the fort by the Lodhis in 1518 CE, the employment of blue coloured tiles on buildings apparently continued unabated under the Hindu rajas of neighbouring Bundelkhand, who used them on their buildings at Orchha over the sixteenth and seventeenth century.

Figure 3.6 Glazed tile decoration on the exteriors of Man Singh Mahal (1489-1516 CE) in Gwalior Fort. The fort and building, a rare specimen of Hindu tiling for the period, was taken over by the Lodhis in 1518 CE.

3.1.3 Lodhi Sultanate of Delhi and the Mughals

Bahlul Khan Lodhi's (r. 1451-1489 CE) nomination to the throne of Delhi in 1451 CE heralded the advent of Afghan Lodhi rule (1451-1526 CE) in northern India, a period of reassertion of power and restoration of stability in the aftermath of Timur's invasion. Through his son and grandson, Sikandar (r. 1489-1517 CE) and Ibrahim Lodhi (1517-1526 CE), imperial authority was once again established, new territories conquered, novel administrative reforms introduced, and effective governance once again enforced.

Building undertakings also resumed, but not on a large scale with no cities being founded, no large public buildings constructed, or palaces and fortresses created (Brown 1964, 26). Construction activity was mainly centred on mosques and tombs, the erection of mausoleums being most widely patronised. Delhi, on account of its imperial associations, was deemed a most appropriate site for their exhibition, and was gradually converted into a vast necropolis of tombs characterised by uniformity in form and design. Decoration matched architectural sombreness and included the innovative introduction of glazed tiles, applied in a manner of complementary restraint (Figure 3.7).

Figure 3.7 A band of blue coloured tiles on the tomb called Chhote Khan-ka Gumbad (early sixteenth century) at Delhi, illustrates the restraint exhibited in tiling during Lodhi times.

In 1526 CE, following a decisive battle against Ibrahim Lodhi at Panipat and a crucial victory over the Rajputs at Khanua the next year, northern India was firmly annexed by Babur, the young dislodged heir of the tiny kingdom of Ferghana in Central Asia. This marked the commencement of a new period of Mughal rule (1526-1857 CE) that was to endure for the next three centuries but for a brief hiatus that saw the Afghan Sur dynasty (1540-1555 CE) led by Sher Shah Suri temporarily wrest control. Babur, who claimed descent from both Timur and Chingiz Khan, and particularly his next five successors, Humayun, Akbar, Jahangir, Shah Jahan, and Aurangzeb, proceeded to unite the subcontinent into a single political state, instituting wide ranging social and administrative reforms over a period that witnessed expansion, stability and prosperity.

In the great building activities that followed the ascent of the early Mughals, many towns emerged and grew astride the Badshahi Sadak (literally 'Imperial Road'), the principal thoroughfare running through northern India. Remarkable monuments were then erected in the cities and settlements along this route, particularly at Agra, Delhi, and Lahore (Pakistan), which functioned as the residence of the imperial courts at various times. Building art now climaxed, with the construction and ornamentation of grand and magnificent palaces, forts, tombs, mosques and gardens. Cultural interchanges with Afghanistan, Iran and Central Asia, besides influencing the building form, manifested in the decorative arts. Tile-work, used alongside stucco, carved stone, inlay-work and paintings, became more prolific, appearing with greater regularity and in a variety of colours and forms. The art of tiling flourished over the sixteenth and seventeenth century, particularly at Delhi and in the Punjab in the north of the country, a great many tiled buildings appearing at each.

On the demise of Aurangzeb in 1707 CE, the Mughal Empire weakened by the repercussions of orthodoxy and inept rule, entered a phase of unending decline. Under continued onslaught from the Marathas in the south, the Sikhs in Punjab and the expanding East India Company, the empire continued to shrink with the last Mughal, Bahadur Shah Zafar, only exercising nominal control over Delhi and its environs. His ousting in 1857 CE brought to an end an epoch of more than six centuries of uninterrupted Islamic rule in the region.

3.2 Glazed tiles in Lodhi and Mughal northern India

3.2.1 Lodhi tile-work

Lodhi tile-work may be said to be markedly unpretentious in both employment and variety, particularly when viewed vis-à-vis the commissions of the Mughal period. Most tiling at this time was limited to the sparing application of monochrome tiles on the exterior facades of buildings, to break the monotony of the building surfaces, and at times to highlight decorative architectural elements. In colour scheme, turquoise-glazed tiles were predominantly utilized, although other shades of blue, and greens and yellows, are also found in more elaborate but rarer circumstances. The Nili Masjid (1505-1506 CE) and the *mihrab*-wall of the Madhi Masjid in south Delhi for instance, have a single band of turquoise coloured tiles running below the parapet across the length of their front elevations (Sharma 1974, 67, 84) (Figure 3.8). The Moth-ki Masjid (1505 CE), also in south Delhi, has turquoise coloured glazed tiles decorating *chhatris* (pillared-canopies) placed at the corners of its entrance courtyard (Sharma 1974, 78-79). More elaborately decorated buildings include the Sheesh Gumbad (c. 1500 CE) in the Lodhi Gardens that is adorned with bands of monochrome turquoise and dark-blue coloured tiles (Figure 3.9), a few tiles in 'three colours' noted as well (Fanshawe 1902, 244, Vogel 1920, 56, Sharma 1974, 93-94, Degeorges and Porter 2002, 232). The nearby Tomb of Sikandar Lodhi (d. 1517 CE), besides exhibiting remnants of turquoise coloured tiles on *chhatris* near its entrance gate, has considerable tile-work in its interiors as well. The palette here encompasses the use of green and yellow colours in addition to the usual blues (Fanshawe 1902, 244, Vogel 1920, 56).

In spite of the obvious presence of tiles on many a Lodhi building as described above, very little has come to light on their background and character. It is only through surveys and listings of architecture carried out from time to time that an estimate of their presence can be gauged, but in these too they are usually dealt with in a passing remark and at times omitted entirely. While the paucity of details in earlier significant architectural listings such as Khan's (1901) or Fanshawe's (1902) is understandable, omissions in more recent notable works is inexplicable. No mention of tiles is made for instance in Sharma's description of Sikandar Lodhi's tomb, his book on the monuments of Delhi being published by an agency no less than the Archaeological Survey of India (Sharma 1974, 94-95). Even the most recent comprehensive listing of buildings in Delhi by Nanda and Gupta (1999) is short of expectations in reporting matters related to tile-work, for both Lodhi and the later Mughal buildings.

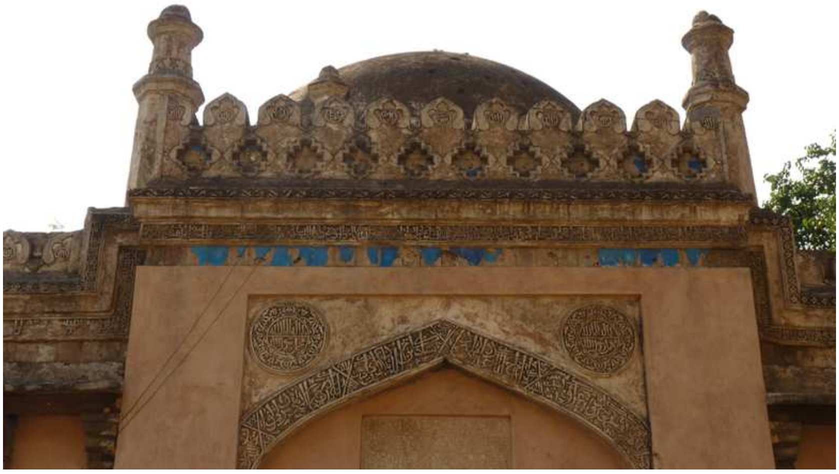


Figure 3.8 A band of turquoise coloured glazed tiles above the main portal of Nili Masjid (1505-1506 CE) in Delhi exemplifies the most common form of tiling employed by the Lodhis. The band of tiles in this case, and in many others, runs across the entire length of the front elevation of the building.

Figure 3.9 Two bands of glazed tiles are noticeable on the facade of the relatively more elaborately decorated Sheesh Gumbad (c. 1500 CE), the upper one comprising alternating turquoise and dark-blue coloured specimens.

More authoritative works on the subject of tile-work from the subcontinent are more inclined to describing the more noticeable Mughal tiles, paying less attention to Lodhi specimens that are relatively much fewer in numbers. Furnival (1904, 123) for instance only talks of the latter kind briefly, mentioning the presence of numerous 'Pathan' tombs at Delhi many of which he says are ornamented with tiles of 'great beauty' in colour and design. He goes on to rather inaccurately state that the main colours used were copper-blue, cobalt, and mustard-yellow colours, the last two actually being rare in Lodhi buildings. Vogel (1920, 6-7) provides some information in his introductory notes, given as a background to his seminal work on the tile-work of the Lahore Fort. He remarks on the presence of tiles on some specific Lodhi period buildings, and then provides brief details of five such buildings in a list of tiled monuments at Delhi and Lahore, the majority of the buildings in the list being from the Mughal period (Vogel 1920, 56-59).

Among the more recent publications, Nath (1989, 19-20), while dealing with evidence of pre-Mughal tiling, only remarks on the presence of 'blue tiles' on some Lodhi buildings, all of which have been mentioned earlier by Vogel. His own added suggestion that a large number of domes on palaces, mosques, and tombs of this period are also likely to have been tiled is however doubtful and seems far-fetched. Hasan's (1995, 88) report on Sultanate period tile-work is clearly focused on the Sind-Multan region, commenting in only few words that the Sheesh Gumbad and Fazlullah Khan's tomb (Tomb of Jamali-Kamali), provide evidence of Sultanate tiling at Delhi. She does interestingly mention that the tiles of Sheesh Gumbad have a stonepaste body, but gives no reasons for stating so. Porter (Degeorges and Porter 2002, 232), who has collated a great deal of information on glazed tiles from all over the subcontinent, provides little new data on Lodhi tiles. He too quotes Vogel to describe the colours of the tiles employed on Sheesh Gumbad, and mentions (again) the presence of turquoise-blue tiles on the Tomb of Sikander Lodhi. The Jahaz Mahal, a late Lodhi or early Mughal building, is remarked by him to be similarly tiled.

Not all recent works are lacking in substance. Credit must be given to Parihar (2006, 99-108) for highlighting the existence of some tile-decorated Lodhi tomb-buildings at Sirhind, in the province of Punjab. While his descriptions on the tiles do not go beyond remarking on their turquoise colour and their locations on the architecture, the significance of their presence is noteworthy enough, little being known of tiled Lodhi buildings away from Delhi. That Sirhind was of special interest to the Lodhis is emphasized upon by him, Bahlul Lodhi being the governor of the province in the first half of the fifteenth century before being installed as the sultan at Delhi. Discussions on the shape and form of the Sirhind buildings have also been initiated by him, advancing opinions in favour of a style originating from the Lodhi buildings of Delhi (Parihar 2006, 99).

Interestingly, in all that has been said, no opinions or conjectures are offered on the issue of origin of Lodhi tiles, such remarks only reserved for Mughal tile-work that followed. On the technology of Lodhi tiles too there is a deafening silence, no publication having come to notice of any laboratory analysis or technical study carried out on Lodhi era tile specimens so far. No accurate study on their physical characteristics, other than random observations on glaze colours, is similarly known to exist.

The paucity of information on Lodhi tiles goes beyond the lack of detail on their origin, and on their material and physical character. Very little is known on the development and application of the craft during this period, which in a way is interwoven with the history of the structures that they adorn. That tiling in northern India commenced in the Lodhi era, and that the vast majority of buildings erected in this period were tombs and mosques has already been pointed out earlier. The numerous funerary structures in spite of there being just three Lodhi sultans, are reasoned by Ara (1982) as symbolising a unique concept of kingship and power arrangement that prevailed between the sultan and the powerful Afghan noble class of that time. The excessive numbers of tomb-buildings, and their equitable sizes (Figure 3.10), are viewed by her as an expression of a power relationship that placed the sultan and all nobles at par, absolute authority being vested with the sultan notwithstanding. She proposes that a similar reasoning should be applicable to mosque-structures of this period as well.

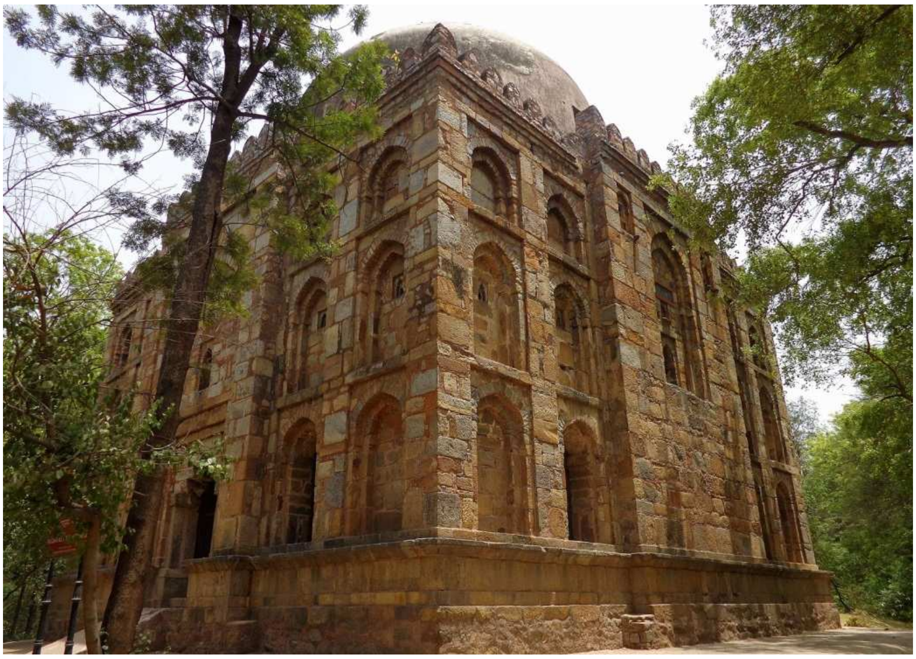


Figure 3.10 Similarities in building size and form can be evidenced between the tomb-structures called Bade Khan-ka Gumbad (top) and the Bagh-e Alam-ka Gumbad (bottom). Their equitable sizes are said to reflect the equal status enjoyed by high nobles in the Lodhi courts (from Wikimedia Commons).

While the argument is sound enough, corroboration is complicated by the near absence of inscriptional evidence on the Lodhi tombs and mosques, their chronological appearance and attribution as much in debate as the identity of the persons interred within. The tombs of the two Lodhi sultans buried in Delhi, Bahlul and Sikandar Lodhi, are themselves not conclusively identified. The building that goes by the name Tomb of Sikandar Lodhi in the Lodhi Gardens, noted for its extravagant tile-work decoration for the period, is accepted to be that of the sultan based mainly on its identification by Sayyid Ahmad Khan in 1847 CE (Khan 1901, 42), who does not provide any source for the statement (Digby 1975, 550). Sultan Bahlul Lodhi's tomb is the subject of even more debate. Digby (1975) considers the tile-decorated Sheesh Gumbad in the Lodhi Gardens to be the tomb of the sultan based on his interpretation of some historical references. The Archaeological Survey of India meanwhile continues to maintain an altogether different and simpler tomb-structure at Delhi in his name.

It is worthwhile noting that in both cases little attempt has yet been made to investigate what contribution the stylistic and technological characteristics of Lodhi tiles can make in this regard. While general distinctions between Lodhi buildings have been attempted through a study of architectural features, identifying royal tombs based on the shape of a structure for instance, the role that a study of tiled ornamentation can play in this context has not been exploited. The possibility of discriminating between earlier and later Lodhi period buildings, on the basis of the colour scheme or material character of the tile-work that they exhibit for example, has potential that has not yet been fully explored. Available details of Lodhi tiled ornamentation thus not only fall short on the issue of their characterisation, but also in their better contextualisation with the architecture that they embellish.

3.2.2 Mughal tile-work

In comparison to the scarcity of information related to Lodhi tile-work, a great deal more is known of the craft during the period of the Mughals, the greatest and richest of the Muslim dynasties to have ruled the subcontinent. The reign of the first six Mughal emperors (1526-1707 CE), including the Sur interregnum (1540-1555 CE), was particularly marked by frenetic building activity, many grand projects being commissioned as means of self-representation and assertion of authority. With increased influences from Iran and Central Asia, a new and distinctive architectural style evolved, a merging of Timurid and existing traditions appearing in the buildings. One persuasive reason for the transformation of architecture to incorporate Timurid characteristics was the everlasting desire of the Mughals to connect with the land of their forebears. Foltz (1996) notes that the Mughals of India considered Central Asia to be their true home, to the extent of harbouring designs to take possession of their ancestral domain by force, even attempting to do so on two occasions. Grants for the maintenance of Timur's mausoleum at Samarkand were also apparently provided by Jahangir (r. 1605-1627 CE) and Aurangzeb (r. 1658-1707 CE) from India (Foltz 1996, 49). This sort of strong psychological desire of the Mughals to associate with their Timurid predecessors has been convincingly argued by Golombek (1981) to be manifest in the physical form in their art and architectural tastes. The augmented interest in architectural tiling shown by the Mughals perhaps occurred for similar reasons, the desire to emulate the tiling traditions of their Timurid ancestors being the driving force behind the increased use of tiles in their reign.

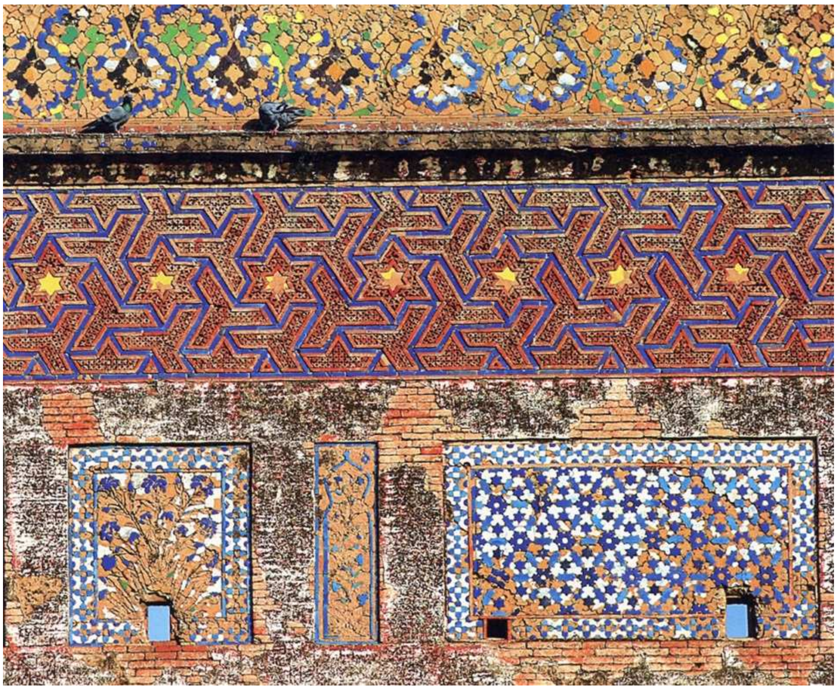
The contribution of the Mughals to the growth and development of the tile-work industry was largely confined to the northern part of their empire, particularly at the cities of Delhi, Agra, and Lahore (Pakistan), which functioned as their capital at different times. Little evidence remains of buildings and any tiling that may have been carried out by the first two Mughals, Babur (r. 1526-1530 CE) and Humayun (r. 1530-1540 CE, 1555-1556 CE), at these cities. It is through Akbar's (r. 1556-1605 CE) buildings at Delhi that Mughal tiling comes to the fore. The Khairul Manzil Masjid (1561-1562 CE), the undated Sabz Burj, and Atgah Khan's tomb (1566-1567

CE), all at Delhi, are oft-cited as specimens that exemplify the tile-work of this time (Vogel 1920, 7-8, Nath 1989, 24). The repertory of glaze colours exhibited includes the two blues, yellow, green, and white, with individual tiles being laid in mosaic compositions, the preferred style of this period (Figure 3.11). Tiles are also known to have been employed by Akbar on his buildings in and around Agra, on Amar Singh Gate at Agra Fort for instance, where they maintain the harmonious correlation with architecture as followed at Delhi (Nath 1989, 24-26). Some tiling in the region continued under Akbar's successor, Jahangir (r. 1605-1627 CE), the Tomb of Akbar and the Kaanch Mahal near Agra being two such examples (Smith 1901, 2, 21-26, Nath 1989, 26), but overall less use of this craft is noted at this time both at Agra and Delhi. Evidence of greater use is instead found in Punjab, where several tiled buildings such as the Tomb of Ustad at Nakodar (1612 CE) are attributed to the period of Jahangir's rule (Parihar 1985, 34). A peculiar technique of application used on these buildings, of tiles inlaid in compositions of raised bricks, is notably different from others seen before (Figure 3.12).

Figure 3.11. Detail of the tile-work employed on the wall-mosque at the Tomb of Atgah Khan (1566-1567 CE). The range of five colours and mosaic form of application seen here is typical of tile-work employed in Delhi in the sixteenth century during Akbar's rule.

Figure 3.12 Tiled panels on the facade of the Tomb of Ustad (1612 CE) at Nakodar. The technique of application seen here, of tiles inset in geometric compositions of raised bricks, is a peculiarity of early seventeenth century tiling in the region, in the period of Jahangir.

In contrast to the controlled application of tiles at Delhi and Agra, extensive use of a multi-coloured tile-mosaic in the region of Punjab is noticed for commissions during Shah Jahan's reign (r. 1628-1658 CE). Elaborate tile-mosaic compositions, featuring monochrome tiles of seven colours, purple and orange being added to the existing known shades at Delhi, are found on buildings from this period. While most such buildings are concentrated in Lahore, Wazir Khan's mosque (1634 CE) and the 'Picture Wall' of Lahore Fort being the best known examples (Figure 3.13), several structures bearing similar tile-work are also found at other places along the old imperial highway connecting Lahore with Delhi and Agra. The Tomb of Shagird at Nakodar (1657 CE) in Indian Punjab is one such well-preserved specimen (Parihar 1985, 36-37).



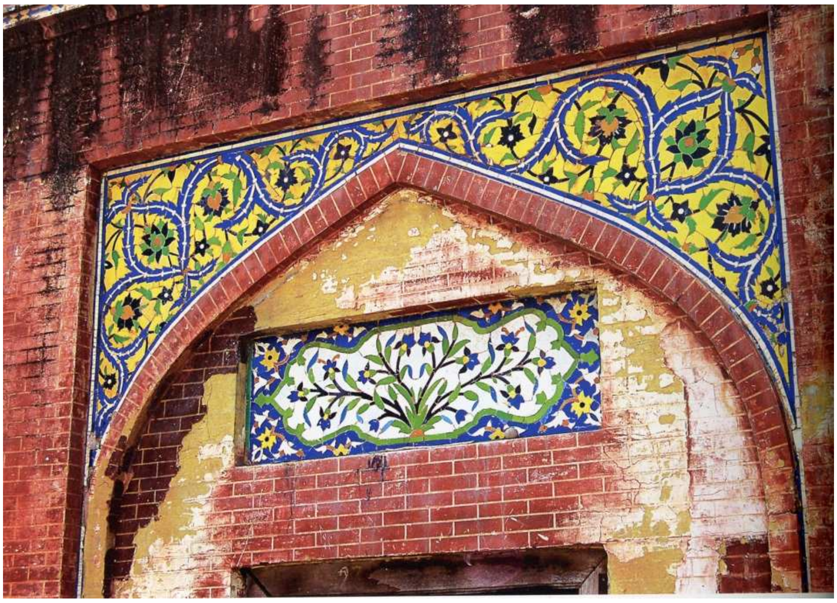


Figure 3.13 A comparatively lavish use of the tile-mosaic, as evidenced on the 'Picture Wall' of the Lahore Fort (top), is the hallmark of Mughal tiling undertaken at Lahore and in the Punjab in general in the seventeenth century. The palette, comprising seven distinct colours, can be observed on the detail of a tiled facade (bottom) on the Mosque of Wazir Khan (1634 CE) (from Akhund and Askari 2011, Figs. 384, 400, p. 235, 248).

Besides the tile-mosaic, polychrome *haft rang* tiles are also known to have been employed on buildings during Shah Jahan's rule, the mausoleum of Asaf Khan at Lahore displaying remnants of such tiles thereon (Vogel 1920, 10, Akhund and Askari 2011, 250-251)[5]. But overall little use of this technique is known in the region, only a few random examples of this kind known to exist. With the demise of Shah Jahan, the tile-mosaic of seven colours continued to be employed for a while under his successor Aurangzeb (r. 1658-1707 CE), but not for very long thereafter. The mosaics on Dai Anga's Tomb (1671 CE) at Lahore and the Abdul Wahab's Mosque (1669 CE) at Sadhaura are among the last of their kind (Vogel 1920, 9, 59), the chapter of Mughal tiling virtually coming to a close during the first half of his rule.

While publications of note on Mughal architecture and its decoration largely just about contain the generic overview presented above, some additional information can be determined from few of them that dwell on tile-work in more detail. Among these is Smith's (1901) survey conducted for the Archaeological Survey of India on modes of colour decoration employed on Mughal buildings at Agra and nearby Sikandra. His report, including photographs and excellent colour plates, fairly comprehensively covers the tile-work employed on three notable buildings, the Chini-ka Rauza at Agra, and the Kanch Mahal and the Tomb of Akbar at Sikandra. Smith's comments on the character of the tiles employed at Agra is however inconsistent, speculating on the one hand on similarities between the Chini-ka Rauza tiles with specimens from Punjab and Sind provinces, while on the other exemplifying commonalities between these tiles and those found on Akbar' tomb that are apparently of a different style and date to Jahangir's period (Smith 1901, 3-26). Chinese influences in the decoration of the building, either directly or through Iran are also frequently alluded to by him in his notes. Notwithstanding these inconsistencies, the illustrations and descriptions provided by him are of great value, permitting an assessment of the tile-work utilized on significant buildings at Agra, as also highlighting their state of preservation.

[5] Both refer to them as 'square tiles'.

Vogel's (1920) lucid account on the tile-mosaics of the Lahore Fort, at the other end of the Badshahi Sadak, not only comprehensively describes the rather exemplary tile-work installed on the fort wall, but provides his view on the history of the craft and its employment in other regions of north India as well, particularly at Delhi. According to him the art of tiling was introduced in India through Persia and commenced around 1500 CE at Delhi, the Tomb of Sikandar Lodhi being an early example, before entering a more elaborate phase under the reign of Akbar (Vogel 1920, 6-15). The tile-work of Lahore and Punjab is opined by him as being a later stage of development of the craft, all of which, including Delhi tile-work, being derived in a way from the faience tradition that was in vogue under the 'Persian Safawi' [Safavid] dynasty. Several examples of tiled buildings are cited by him in support of his arguments. Vogel also interestingly brings to light the existence of *haft rang* tiles on Mughal buildings at Lahore, using these as further evidence of the Persian connection, such tiles having been employed by the Safavids in parallel. Special mention is made by him of tile-work on the fifteenth century tomb of Madani [Madin Sahib] at Srinagar, in Kashmir; the presence of *haft rang* tiles on this building, including an unusual set with animal life represented, being brought to notice.

Mention must be made of the monograph on the antiquities of Sind by Cousens (1929), who covers several interesting tiled buildings in this region in his notes, and of the fine illustrations provided by him in a portfolio devoted to tiles from the same place (Cousens 1906). Although Sind lies in the west and not north of the subcontinent, the details provided by him are still worthy of attention for comparison, the region apparently having a tradition of tiling similar to that of Multan mentioned earlier. Furnival's (1904, 114-133, 223-229) descriptions likewise are noteworthy, less so for original content as he merely reproduces what others have written, but more for the sequential arrangement of the information as a historical narrative. Among the works quoted by him, a report prepared by C. Stanley Clarke of the Victoria and Albert Museum stands out, which provides a list of then known existing tiled monuments in the Punjab and Sind provinces (Furnival 1904, 121-126).

Surprisingly, not much has been added to the body of knowledge on Mughal tiles since the writings of these scholars. Nath (1989), like many others, reproduces their observations in much the same words, although he does draw attention to the presence of tiles on some additional buildings at Agra as well. His efforts are in general more inclined to discussing the aesthetics of the tiles employed and their harmony with the architecture, besides stressing time and again on their Persian connections (Nath 1989, 24-35). Porter (Degeorges and Porter 2002, 254-271) likewise essentially provides a concise summary of earlier published information on Mughal tile-work, his own added suggestions being entirely speculative. His remarks for example, that the Nila Gumbad is probably the earliest tiled monument in the Humayun's tomb complex, and that the tile-work on Amar Singh Gate at Agra Fort dates to the period of Shah Jahan's rule, are unsubstantiated. The chronological summary given by him of Mughal period tiling otherwise well-illustrates the many techniques of application employed in this time. An interesting contribution by him is of the existence of *haft rang* tiles, purportedly installed on the orders of Aurangzeb, at the *dargah* of the saint Qutb al-Din Bakhtiyar Kaki in Delhi, the only known example of the use of this technique in this city (Figure 3.14).

Figure 3.14 Detail of a composition of *haft rang* tiles on the *dargah* of Qutb al-Din Bakhtiyar Kaki in Delhi (from Degeorge and Porter 2002, p. 271).

Parihar's (1985, 1999) writings are worthy of more attention. He brings to notice many less-known tiled Mughal monuments scattered across the provinces of Punjab and Haryana[6] in northern India, giving a brief history and description of these buildings. Details of their tile-work embellishment are also provided by him, as is their location on the monuments. While some limitations in his reporting of colours is observed, he does clearly distinguish between the different application techniques used in Jahangir's and Shah Jahan's times, using these in more than one instance to corroborate the date he ascribes to some undated buildings. Even though the focus is clearly on the buildings, his writings amply highlight the existence of a significant number of tiled Mughal buildings in Indian Punjab, most lying on or alongside the Badshahi Sadak leading to Lahore. A recent publication also meritorious of attention is that of Akhund and Askari (2011), not for additional information that maybe gained though, as it is essentially a compilation of other records, but for the many illustrations provided, which allow an appreciation of tile-work employed in parts of Punjab that now lie in Pakistan.

While opinions on the origin of Mughal tiles has been offered by many, as seen earlier above, very little has been spoken on their manufacturing technology, which is surprising given the great interest shown in other art forms of this period. Smith (1901, 7) is brief, only remarking in his discussions on the Chini-ka Rauza that the tiles have been subject 'to an almost incandescent heat', and are not just made of 'mortar and cement and enamelled over' as thought by others previously. Furnival (1904, 223-229), besides publishing Ali Muhammad Isfahani's narrative on tile making as mentioned in Chapter 2, provides accounts of materials used in the glazing of pottery and tiles from several sources, but all of these only describe the art as practiced contemporary to the period of his writing.

It is through Vogel (1920, 59-60) that we learn of probably the first attempt on the analysis of Mughal tiles, reproducing in an appendix a report prepared by Dr. Center, Chemical Examiner to the Punjab Government[7]. Dr. Center, who apparently

[6] A relatively new province in northern India, carved out of Indian Punjab in 1966.
[7] The report was originally published in Messrs. T.H. Thornton and J.L. Kipling's *Lahore* (1876:148-150).

examined some tiles, writes 'The *Kashi*[8] consists essentially of a layer of glass spread on a hard kind of plaster, - sometimes on a material porcelaneous in structure'. On its analysis he says, '…the glass was found to be an ordinary silicate colored [coloured] by metallic oxides. The plaster was found to be composed of a mixture of lime and siliceous sand, the hardness being due to silication, which accounts for its bearing the heat required to fuse glass.' Dr. Center goes on to describe in more detail the manufacture of specimens that were prepared for him by a potter at Lahore, but expresses his dissatisfaction at the work produced, calling it 'inferior'.

A relatively more useful analysis was undertaken by Sanaullah Khan, Archaeological Chemist to the Archaeological Survey of India, in 1923-1924 CE (Marshall 1926, 114-115). Khan reports on the chemical analyses of seven glaze specimens from the Chini-ka Rauza, comparing these with an earlier and separate published analysis of three Chinese glazes to highlight technological differences between the two. He argues that the soda-glass nature and phosphate-free content of the Chini-ka Rauza glazes is suggestive of the involvement of Persian artisans or their Indian pupils in their making, effectively watering down the possibility of a Chinese connection as alluded to by Smith (1901, 3-21). A single deep blue coloured glaze of a tile excavated at Qutb in Delhi was also analysed by Sanaullah Khan in 1924-1925 CE (Blakiston 1927, 139), who says it is probably late Mughal, but in the absence of clear details not much can be said of its exact context.

Since then only two other analytical works on Mughal tiles in northern India are known to have been carried out, excluding a pilot study undertaken by Gill and Rehren (2011) for the purpose of this research. Lal (1953), in the first of the two works, has reported the chemical composition of one blue and one green glaze each from two tiled buildings, one being a late Mughal mosque at Narnaul in Haryana, and the other the Tomb of Sher Shah Sur at Sasaram in the province of Bihar. Singh *et al.* (2004), more recently, have analysed the glaze layer and 'plaster'[9] of blue tiles from three Mughal monuments at Delhi for the purpose of identifying reasons for

[8] A term commonly used for glazed tiles thought to be of Persian origin or character, *kashi* being short for *kashani*, meaning 'from Kashan' in Iran.
[9] Probably referring to the tile body.

deterioration, one sample each being sourced from Sabz Burj, Arab-ki Sarai, and Khairul Manzil Masjid. Besides these two works, Gulzar *et al.* (2013) have studied the composition and characteristics of some tile glazes from Jahangir's tomb in Lahore, which although not in northern India, is of relevance being from the same context.

Interestingly, cognisance of these analytical studies, howsoever few they may be, has not been taken note of by scholars who write, or have been writing till recently, on the subject. Most, if not all, like Nath (1989), Hasan (1995), and Porter (Degeorges and Porter 2002), do not go beyond quoting the contributions of Smith or Vogel when it comes to describing the technology of Mughal or pre-Mughal tiles. This lack of connect between technological and art historic studies is ever so apparent in the publications that have come out so far, leading to an incomplete understanding and appreciation of architectural tile-work in India in general, and of Lodhi and Mughal tiling in particular.

3.3 Summary and comments

Recorded findings on the use of glazed tiles and bricks on architecture indicate that the art of tiling buildings was introduced in the Indian subcontinent following the establishment of the Delhi Sultanate in the early thirteenth century. Tiles were sparingly used by the Turkic dynasties that ruled Delhi from the commencement of Muslim rule till the end of the fourteenth century, an exception being the Sind-Multan region (Pakistan) where a yet existent tradition of tiling buildings was instituted in the early fourteenth century.

In the fifteenth century, tiling activity of note took place in provincial sultanates at Bidar in the Deccan, and at Mandu in the Malwa region. Tiles employed at this time at Bidar are of a Timurid character, as are some buildings here. Tiles were thereafter employed in both these regions for over a century, continuing in use at Golconda in the Deccan to around the mid-seventeenth century. The range of fifteenth century monochrome tiles used at Bidar encompasses five colours, namely turquoise, dark-blue, yellow, green, and white, while those employed at Golconda at the end of the sixteenth century showcase an additional mellow-terracotta (orange) tone. At Mandu in central India, extant remnants indicate the use of primarily monochrome turquoise and dark-blue coloured tiles that were employed in limited numbers, signs being noted of the transmission of the craft onto Hindu architecture in the region as well.

At Delhi, monochrome tiles began to be consistently employed on buildings during the Lodhi period from around the beginning of the sixteenth century, turquoise coloured tiles predominating in use. Glazed tiles are also found on some Lodhi buildings in Punjab, notably at Sirhind. Tiling was overall restrained in employment in Lodhi times, more elaborate decoration involving the use of tiles of colours other than turquoise being uncommon, and recorded in very few instances. No correlation has yet been established between the material or physical character of Lodhi tiles and the buildings that they embellish. No analytical study on Lodhi tiles is known to have been carried out so far.

Tiles continued to be used by the Mughals, successors of the Lodhis, in the sixteenth and seventeenth century, mainly at Delhi and Agra, and in the region of Punjab to the north-west. Monochrome tiles, often in mosaic compositions, were employed at Delhi and to a lesser extent at Agra over the sixteenth and early seventeenth century, mainly to highlight architectural features of interest. The palette of glaze colours used at Delhi and Agra include turquoise, dark-blue, yellow, green, and white. At Lahore and in the Punjab in general, lavish use of the tile-mosaic was resorted to in the seventeenth century, covering large expanses on architecture and dominating the building form in its wide-scale use. Monochrome tiles of seven colours were made use of here, purple and orange shades existent in addition to the repertory of five colours employed at Delhi. Rare instances of the use of *haft rang* tiles in this time is also recorded, while no underglaze-painted tiles are reported. The era of tiling in northern India practically comes to an end around the last quarter of the seventeenth century. Most published art historical studies on Mughal tiles essentially repeat the observations of authoritative works undertaken a century ago, particularly on the issue of their character. A Persian origin for Mughal tiles is generally assumed. Analytical studies on Mughal tiles are very few; those carried out being constrained in sample numbers and contextual coverage.

From the literature review undertaken it is apparent that little has been attempted in contextualising tiles from northern India within the larger family of Islamic tile-work, and whatever done or proclaimed is insufficiently substantiated. Available published documents and reports of relevance for the most part are concerned with identifying the presence of glazed tiles on buildings, at times providing information on the colour scheme, but rarely going beyond detailing the most obvious stylistic features of the employed tiles. Descriptions have been provided by some scholars that speak of foreign connections and probable influences, but lack depth when it comes to detailing the issue of their origin. Little effort has likewise been spent on examining interrelationships that may exist between tile-work employed regionally. Little has also been attempted in connecting information that can be gained from a study of related traditional crafts in practice, the crucial inclusion of a local context in the interpretation of their technology being completely ignored. The technology of 'Blue Pottery', a revived traditional ceramic craft form exhibiting some similar characteristics (Yadav 1999), has surprisingly not been explored as a source of analogous information. Similarly, no study has yet been carried out on a traditional glass industry that is known to exist, or have existed, in the vicinity of Agra (Sode and Kock 2001), with the objective of informing the technology of glazed tile production.

With the demise and passing of a tradition, available options for the reconstruction of past technologies are few. With little archaeological activity taking place, information that can be gleaned through excavations or excavated objects on the nature of kilns, furnaces, firing conditions, and the tiling industry as a whole are also very limited. It is thus apparent that while detailed surveys of tiled buildings and existent related traditional crafts would assist in bringing forth further information, it is mainly through scientific investigations of extant tiles that a deeper and comprehensive understanding can be gained. While some technical studies on a limited number of tiles have been carried out in the past, much more is needed for conclusive statements to be made on the material character of the tile-work employed, and for inferences to be drawn on matters related to their origin and the industry as a whole at the time of their manufacture.

4. RESEARCH METHODS

While the application of analytical techniques can bring forth desired information on the characteristics of archaeological materials, this is by no means enough for a technological study. For the data generated to be of meaningful archaeological use, it is essential that a more broad-based methodological approach be applied that looks into and appropriately addresses the wider context of the research questions. This chapter, divided over three sections, first outlines the overarching theoretical framework considered for the research, clarifying what 'technology' and the concept of the *chaîne opératoire* are construed to be, and deliberates upon the approaches found suitable for reconstructing the technology of the material being studied. The next section discusses the field methods employed for the study, covering the strategy devised for site selection and sampling, and the means and methods of field data collection. The last section deals with the laboratory methods utilized, discussing the parameters and procedures applied for instrumental analysis, and outlines an explanation for data interpretation.

4.1 Theoretical framework

4.1.1 Technology and the chaîne opératoire

Technology, in its broadest sense, can be defined as Miller (2009, 5) puts it, 'an active system of interconnections between people and objects during the creation of an object, its distribution, and to some extent its use and disposal'. It is not just merely material culture, but a social phenomenon wherein the material and the social are interlinked through a complex web of associations (Pfaffenberger 1988). Technologies, in the opinion of Lechtman (Lechtman and Steinberg 1979), are 'part and parcel of the mainstream of cultural inclinations and are irrevocably bound to the social setting in which they arise'. Lemonnier (1992) too views technological systems as social productions, stressing the need to 'focus on the relation between the forces of production and the social relations of production'. Investigating the people behind actions, meanings of the actions, and reasons and consequences of actions taken becomes as important as the physical action itself. Studies of technology would therefore go beyond researching processes of fabrication of an object, to encompass the organizational arrangements surrounding its production. Lechtman (1977), who in an earlier revolutionary work introduced the concept of 'technological style' as an expression of cultural patterning, emphasizes that in archaeological situations 'defining the parameters of a particular style may help in eliciting from the technology information about its own symbolic message, and about cultural codes, values, standards, and rules that underlay the technological performance'. In the context of archaeological material, a technology study should thus clearly not only provide sound information on the knowledge-systems that go into the development and production of objects, but also an understanding of the social structures related to the invention or adoption of technologies.

Towards the achievement of this goal is the notion of the *chaîne opératoire* propounded by Leroi-Gourhan (1964), a concept that has gained much prominence in material culture studies, which looks equitably at social practices as much as technologies. The term is taken to refer to the chain of processes associated with the creation and consumption of material culture, defining the social acts involved in the production, use, reuse, and discard of an artefact or object. Subscribing to the *chaîne opératoire* concept for an overall approach would hence entail employing a methodological framework for reconstructing processes of manufacture and use, and examining the inter-relationships between human lives and technology (Schlanger 2005). Conceptually, the *chaîne opératoire* envisages traces of these processes or acts to be manifest in the archaeological record, the analysis of which then makes it possible to document the steps and progression of past operations. The conversion of materials into cultural products through a series of gestures or actions is itself viewed as a technological activity influenced by social traditions, with choices - technological choices - exercised by individuals being seen as a physical rendering of specific knowledge acquired through socialization (Dobres 2000). Technical decisions in the making of an object can thus theoretically be revealed through a *chaîne opératoire* study that combines three levels of analysis, the object itself, the gestures enacted, and the shared technical knowledge of its production (Sellet 1993). Sillar and Tite (2000), on examining factors that determine technological choices, reason that *chaîne opératoire* oriented studies stand to greatly benefit by employing material science as a tool for understanding technology in the societal context. Such *chaîne opératoire* centric approaches with inputs from scientific investigations have in fact been quite successful in the past in the study of archaeological ceramics, and as an extrapolation would be equally effective in research pertaining to glazed tiles, material remains and associated technologies being largely the same in both instances (Figure 4.1).

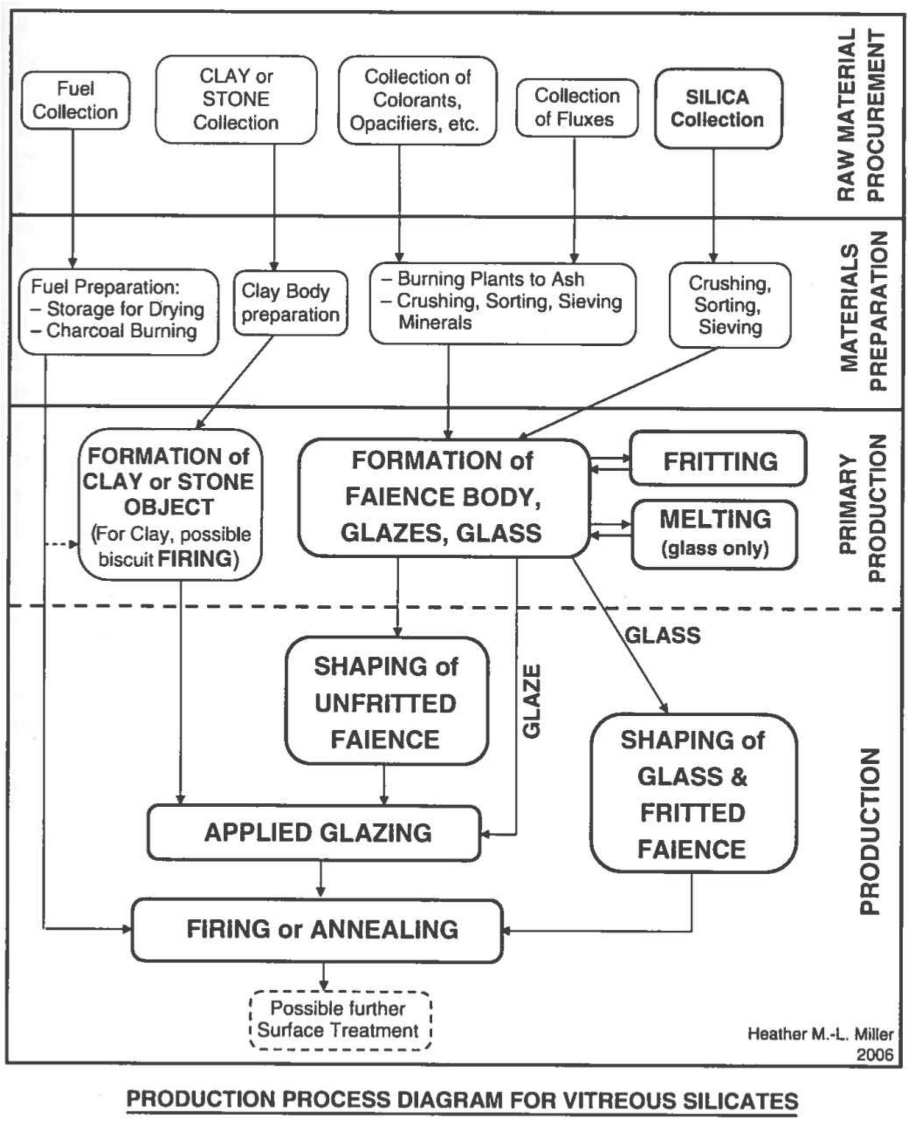


Figure 4.1 Generalized model illustrating the processes involved in the production of vitreous silicates. A *chaîne opératoire* model on the same lines would hold for the production of glazed tiles as well (from Miller 2009, Fig. 4.9, p. 131).

4.1.2 Approaches to technology

In the study of archaeological material, a systemized approach can be facilitated through the application of established techniques and methods. Depending on the research questions that are being considered and the material remains that are to be examined, techniques employed can be quite diverse, ranging from reconstructions based on ethnographic accounts to those informed through historical research or through applications of archaeological science. While the entire gamut of actions and processes in the life cycle of objects, including vitreous silicates such as glazed tiles, are unlikely to be fully understood in a single study, the utilization of select time-tested methods, as discussed below, has the ability to contribute to their better understanding.

Archaeological Science

In the case of the current study on glazed tiles, given the conditions and criteria defined above, the employment of scientific methods was deemed the most appropriate primary approach, the role and potential of material science in aiding an understanding of technology having been briefly mentioned earlier. In more specific terms, as Sillar and Tite (2000) point out, material science studies can not only provide the methodology for the reconstruction of past technologies, but also evaluate the extent to which physical and chemical performance characteristics influence past technological choices. Such information becomes particularly vital, as in the current context, when conventional archaeological approaches cannot be applied due to the lack of availability of sufficient local resources, and difficulties on the ground in the implementation of standardised archaeological field procedures.

That said, it may be clarified that archaeological science is by no means an end in itself in seeking answers to technology, even in circumstances where it is just about the only avenue offered. As with any other discipline it has its share of exponents and critics, the latter generally lamenting on its inability to arrive at socially meaningful interpretations. Such a sweeping generalisation on its limitations is perhaps extremist and not really applicable as a rule to all science-centric technological studies, particularly when other approaches that shed light on social aspects are employed in conjunction. In fact the increasing utilization of laboratory techniques by archaeologists and conservators is a testimony to the growing realization of the efficacy of archaeological science in the study of material and their technology. Undoubtedly however, it must again be emphasized that it is the social interpretation of technology that is of paramount interest, and that scientific approaches have the capacity to provide holistic meaningful interpretations of technology provided societal aspects are adequately looked into. Full justice can perhaps best be done when additional approaches, as discussed in the succeeding paragraphs, are applied in parallel.

Survey

The first of two complementary approaches considered was that of surveying, a technique commonly employed in field archaeology for the identification and recording of material remains. From the perspective of archaeology, the biggest benefit obtainable through this approach is the ability to study humans and their interactions across a larger landscape, rather than being restricted to a smaller geographical area, or at times even a single settlement. The actual methods employed for this approach in the field are varied and case-specific, ranging from the most basic such as walk-overs across a landscape to the much more sophisticated involving the use of satellites and aeroplanes for imaging and mapping of terrains and settlements. Materials collected or examined through these methods are then investigated in more detail to address typical archaeological queries such as information on production and consumption, or thematic technological issues such as trade, exchange, and distribution patterns (Miller 2009).

Surveys are oft-used in tandem or as a prelude to laboratory-based studies to provide supplementary information on materials being examined. Significant information can be derived in the field on studying the material in its context and recording data of relevance. Interpretations are better informed, as is an understanding of the setting. The identification and devising of sampling methods and appropriateness of samples being taken can also be guided by a field survey. Not only can sampling be enabled, but the issue of sample representativeness also addressed in their selection and recovery. In other instances such as the current study, surveys provide the opportunity to record the physical state or features of the materials being examined, such documentation being utilized in the interpretation of technology in conjunction with scientific analysis.

Ethno-archaeology

The final approach considered for the research was the employment of ethno-archaeology, a practice that has gained prominence over the last century in which ethnographic observations on contemporary societies are used to develop hypotheses for interpreting the archaeological record. In principle, ethno-archaeology entails drawing analogies through studies of living cultures with materials and technologies of the past, the centrality of analogous reasoning in the making of interpretations being emphasized upon (Ascher 1961, David and Kramer 2001). Since the coining of the term at the turn of the last century, ethnographic analogues have been used with a fair degree of success in exploring the technology of a wide range of archaeological material, including ceramics, in terms of both social and technological aspects.

The application of ethno-archaeology in the study of particularly ceramic production has been discussed in length by Costin (2000), highlighting its usefulness in addressing queries related to social organization and technological choices. The same discussions as an extrapolation are equally applicable to this research. Costin at the same time however, like many others, warns against the uncontrolled use of analogies, stating that the ethnographic present may not be necessarily representative of activities or organizational modes of the past. Such transformations in technology are indeed found to have occurred with time in several ethnographic studies undertaken on ceramic production, for reasons of changes in demand, production economics, and material availability.

Caution may hence be exercised in drawing too much from ethnographic observations and enquiries, be it documenting live demonstrations of traditional crafts in practice or the recording of oral histories and folklore. Such caution is particularly advisable in the context of this research that is being carried out in a country like India, where live and vibrant traditional craft industries are known to exist, and where the extent to which these craft practices actually replicate past traditions is hard to judge. In summation it may be stated that although a noteworthy role exists for ethno-archaeology in the study of technology, discretion may be exercised in making inferences on past practices through analogies from current ethnographic observations.

4.2 Field methods

4.2.1 Site selection

The necessity of defining the boundaries of the research area at the outset was obvious given that northern India is a vast expanse of land covering hundreds of thousands of square kilometres. On the understanding, through past surveys and published studies, that tiled monuments in the region were largely restricted to urban centres that lie along historic trade and travel routes, the geographic limits of the study were reduced to include cities and settlements located on or alongside the Badshahi Sadak, the main overland trade route passing through northern India. The stretch of the Badshahi Sadak from Agra to Lahore via Delhi, a distance of approximately seven hundred kilometres, would have served as the ideal extent of the research. This would have included all the three capital cities of the Mughals, allowing an appreciation of the tile-work installed on their buildings at each. However as Lahore is now in Pakistan, it falls beyond the administrative purview of what is currently India, and for reasons of difficulties in access was excluded from the study. The Sind-Multan region, home to a distinct regional blue-and-white style of tile-work, being in Pakistan, was similarly omitted. The spatial confine of the area to be considered for study was thus fixed to encompass Agra in the east, and the region along the road via Delhi to the settlement of Sarai Amanat Khan near Amritsar in the west, just short of the Pakistan border. The area so defined comprised two distinct geographical zones, the first being the area encompassing the modern province of Delhi and the region to its south up to Agra, and the other roughly corresponding to the modern province of Indian Punjab that lies to the north-west of Delhi (Figure 4.2). It may be noted that although this selection does not by any means cover all tiled buildings located in the north of the country[10], it suffices for the purpose of the gaining a comprehensive understanding of Lodhi and Mughal tiling traditions, the majority of tile-decorated structures from their respective periods of rule being located in the region covered.

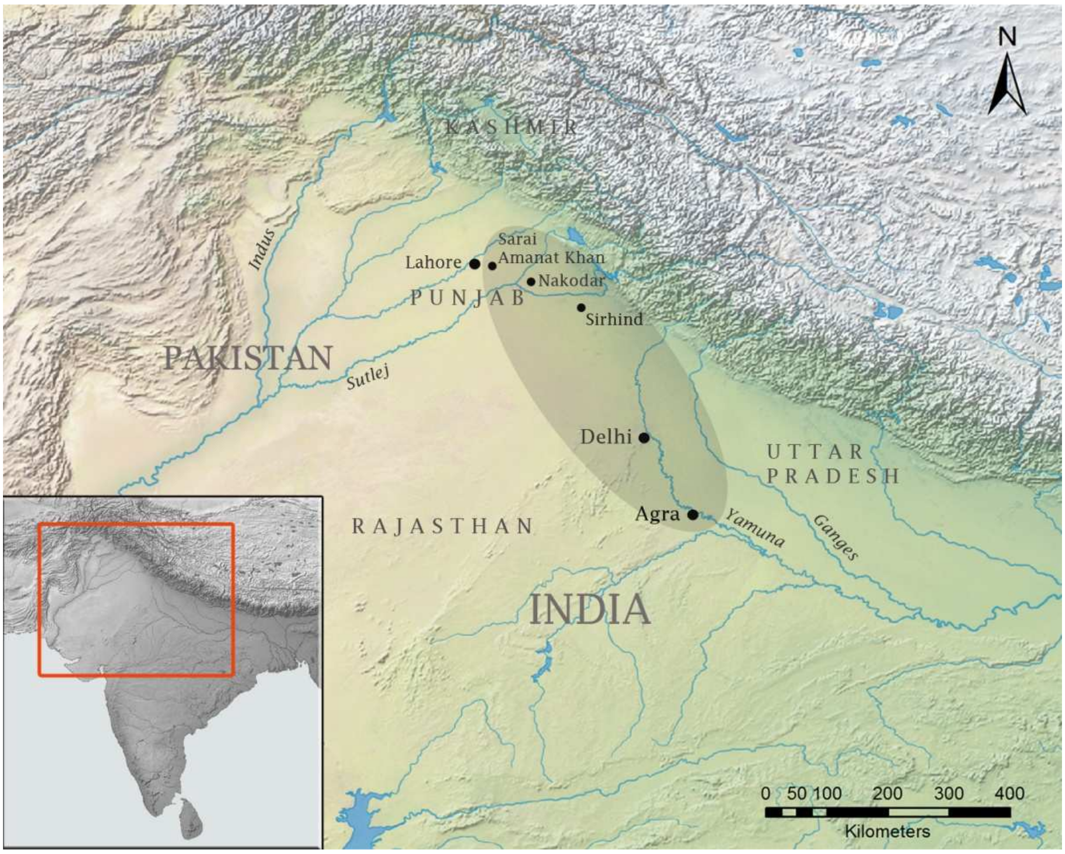


Figure 4.2 Map of northern India. The shaded area marks the region taken up for this study.

With the possibility of obtaining samples through excavations being improbable, in the absence of archaeological activity, and none available in local museums as fragments of tiles are considered to be of little collectible value, it was clear that sampling was only achievable on monuments where remnants of tile-work still existed. The target population would theoretically thus have comprised all standing Lodhi and Mughal period buildings with extant tile-work, a number certainly beyond the constraints of a time-limited research project. Further, although an approximate estimate of the numbers of tiled buildings could be determined from available

[10] At least two tiled buildings are known to exist in Kashmir, a mountainous region located to the north of Punjab. Few tiled buildings are also reported at some locations in the province of Haryana that abuts Punjab, but these are in settlements a fair distance away from the main highway.

information, the lack of any published inventory was a major impediment in the initial phase of the study. A physical survey of the entire region was accordingly first undertaken to attempt identify with reasonable accuracy the numbers of tiled buildings that existed, and the characteristics of the tile-work they exhibited. Following this, the structures from which the samples were to be sourced was narrowed down to include four Lodhi and six Mughal buildings. Their selection was based on criteria of location, chronological range, variety in tiled decoration, area of extant tile work that in turn determined the likelihood of adequate numbers of samples, and the ease of access in terms of obtaining sampling permissions from the controlling authorities.

In the case of Mughal buildings, the number of samples to be collected from each of these 'primary' monuments was fixed to be not less than ten and not more than twenty, so as to be fairly representative for the structures individually while minimizing the bias towards any one locality or period. For Lodhi buildings, between five to ten tiles per building were deemed sufficient, the tiles here being relatively much fewer in numbers and difficult to source. The selection in the case of Mughal buildings was however found somewhat skewed in favour of monuments dating to the first half of the seventeenth century. This, although undesirable, was not surprising, considering that the period coincides with an era of greater proliferation of Mughal tile-work, most buildings with significant numbers of extant tiles dating to this time. To impartially represent a wider chronological span, it was then decided to add-on as many as possible tiled Mughal buildings to the sampling pool, even if samples that could be potentially obtained from these would be less than the desirable numbers. The purpose of the additional sampling was to generate information to supplement that obtained from the primary dataset. Eleven additional buildings spanning the period of early Mughal rule, including one attributed to the Sur dynasty, were added with this intention. Three additional tiled Lodhi buildings were likewise added on. With this strategy it was reasoned that the samples taken would be fairly characteristic of surviving tile-work, and as a consequence the data generated from their analysis would allow rational conclusions. A list of buildings included in this manner for the study is given in Table 4.1.

Table 4.1 List of buildings with glazed tile embellishment from the Lodhi and Mughal era included in the research. Primary buildings, from which relatively higher numbers of samples have been sourced, are highlighted in bold.

No.	Building	Period	Region	Date
1	Bagh-e Alam-ka Gumbad	Lodhi	Delhi	1501 CE, 16th century
2	**Sheesh Gumbad**	**Lodhi**	**Delhi**	**c. 1500 CE, 16th century**
3	Madhi Masjid	Lodhi	Delhi	undated, 16th century
4	**Tomb of Sikandar Lodhi**	**Lodhi**	**Delhi**	**c. 1518 CE, 16th century**
5	**Jahaz Mahal**	**Lodhi**	**Delhi**	**undated, 16th century**
6	**Bibi Taj-ka Maqbara**	**Lodhi**	**Punjab**	**undated, 15th/16th century**
7	Hathi-ka Maqbara	Lodhi	Punjab	undated, 15th/16th century
8	Humayun Darwaza	Mughal/Sur	Delhi	undated, 16th century
9	Tomb of Isa Khan	Sur	Delhi	1547-1548 CE, 16th century
10	Arab-ki Sarai	Mughal	Delhi	c. 1560 CE, 16th century
11	Khairul Manzil Masjid	Mughal	Delhi	1561-1562 CE, 16th century
12	Tomb of Atgah Khan	Mughal	Delhi	1566-1567 CE, 16th century
13	**Sabz Burj**	**Mughal**	**Delhi**	**undated, 16th century**
14	**Nila Gumbad**	**Mughal**	**Delhi**	**c. 1625 CE, 17th century**
15	Tomb of Quli Khan	Mughal	Delhi	undated, 17th century
16	Kanch Mahal	Mughal	Agra	undated, 17th century
17	Naubat Khana	Mughal	Agra	undated, 17th century
18	**Chini-ka Rauza**	**Mughal**	**Agra**	**c. 1639 CE, 17th century**
19	**Doraha Sarai**	**Mughal**	**Punjab**	**undated, 17th century**
20	Fatehabad Sarai	Mughal	Punjab	c. 1606 CE, 17th century
21	Tomb of Ustad	Mughal	Punjab	1612 CE, 17th century
22	**Sheesh Mahal**	**Mughal**	**Punjab**	**c. 1634 CE, 17th century**
23	Dakhini Sarai	Mughal	Punjab	undated, 17th century
24	**Tomb of Shagird**	**Mughal**	**Punjab**	**1657 CE, 17th century**

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4.2.2 Sampling and recording

Following the preliminary survey and site selection, letters of permission for access and sample collection were sought in December 2011 from the authorities under whose jurisdiction the buildings fell. A visit to the locations was made in December 2011 and then again over March-April 2012, with the intention of making contact with local caretakers and to develop a framework for recording data *in situ*. Debris around the buildings from building conservation works and offices of the local conservation officers were identified as potential sample sources with some being collected in the first visit itself. While the caretaking authorities were co-operative and willing to extend all possible assistance, it was clear than more than one visit to each site would be required to gather the required numbers of samples. Field work of a longer duration was thus planned and executed over the summer of 2012 and 2013, two visits being made to each of the buildings in each of the seasons. Fragments of tiles that were in the custody of the local authorities, and specimens that could be found lying on the ground around the buildings, were collected for the study. With the buildings being individually located at a considerable distance from each other, samples taken through surface collection could comfortably be attributed to the structure in the vicinity of which they were found. This was true even in instances when more than one tiled building was located within a single complex, as in the case of the Tombs of Ustad and Shagird at Nakodar, and for the tiled gateways in the Purana Qila complex at Delhi[11]. The distance between individual buildings in all such cases was far enough to eliminate the possibility of incorrect contextualization of the samples.

Samples collected in this manner from all the buildings were taken up for analysis in furtherance of the research questions posed. It may be noted that all the samples collected were not complete tile fragments, as in comprising both the body and glaze layer, about half the numbers being just glaze fragments that had fallen-off on delaminating or separating from the tile bodies.

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[11] Although samples were collected from only one of the gateways in the Purana Qila complex, namely Humayun Darwaza, glazed tiles are found to embellish the other gateways as well.

The period of field work was also utilized to document details of the tile-work on the buildings. Emphasis was laid on identifying and differentiating between various forms of tile-work noticeable, and the colours of the tile glazes found employed on each building. Of the latter, a total of seven colours could be identified as having been used. These include a light blue, a dark blue, purple, yellow, green, orange, and white colours, the last being of a dirty-white or grey-white shade as opposed to being milky-white. To clearly differentiate between the light and dark blue shades, which are distinct from each other, the former was assigned the colour ‘turquoise’ during recording while the latter designated as ‘dark-blue’ (Figure 4.3). No other sub-shades were taken cognisance of for colour categorization, other variations being random in occurrence and limited to a few examples only where present. Tiles of both a light and dark green colour that were noticeable only on the Tomb of Shagird for instance, are classified as being of a ‘green’ colour only, the variations in the shade however being brought out in observations and discussions on the tile-work of the building.

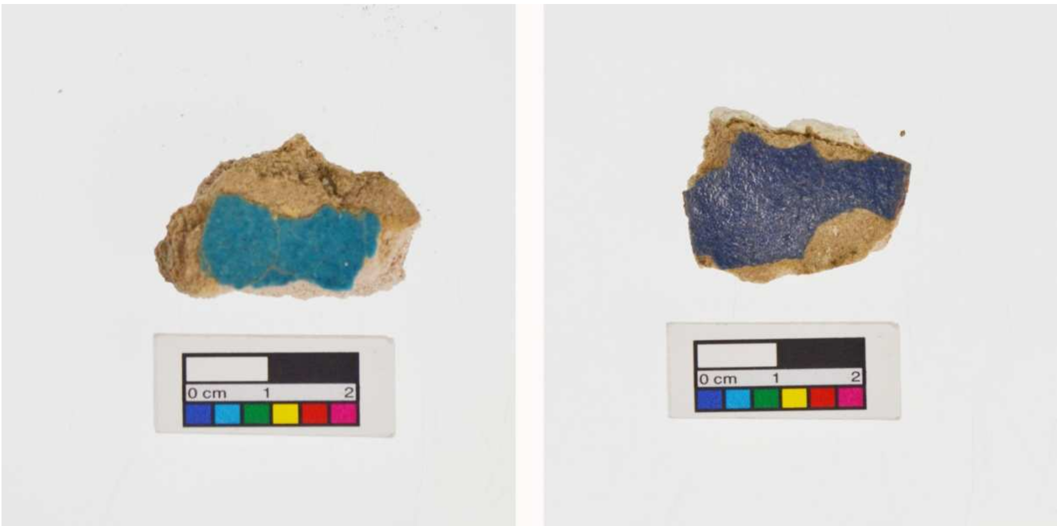

Figure 4.3 The two shades of blue, distinct from each other as shown in the examples above, are consistently found across Lodhi and Mughal tile-work. The glazed tile on the left has a ‘turquoise’ coloured glaze layer, while the glaze on the specimen to the right is of a ‘dark-blue’ shade.

In addition to the recording of colours, remnants of tiles *in situ* were documented to determine variations in their typology, patterns and designs depicted, and the technique utilized in their application on the building to the extent discernible. For their typological classification the tiles have been considered as being monochrome, underglaze-painted, or *haft rang*, depending upon the number of colours exhibited on an individual tile, and the technique of their colouring or painting. Monochrome tiles, which are the vast majority, are those that carry a single glaze colour only and are usually opaque. Underglaze-painted tiles are those that have a transparent glaze through which a design or drawing executed in one or more colours on the body, slip or engobe can be seen. The term '*haft rang*' has been used to describe individual tiles that exhibit two or more opaque glaze colours, separated from each other by a black line. The distinction between *haft rang* and *cuerda seca* tiles that was brought out in Chapter 2 has not been considered while documenting, all opaque polychrome glazed tiles where seen or known to exist in the region being referred to as *haft rang* in this study.

The size or shape of individual tiles, or the precise geometry of compositions formed, has not been paid attention to in the survey or documentation, this being worthy of a study by itself. Emphasis has been laid instead on determining colour preferences within a period or region, and highlighting the most apparent features of the tile-work. Details of individual colours and the laying of tiles in monochrome or polychromatic arrangements have been remarked upon in all cases, and characteristic stylistic features brought to notice. The depiction of stylized floral and vegetal motifs that are very obvious on the Tomb of Shagird for instance are mentioned in the description on its tile-work, as is the widespread representation of floral forms in the case of the Chini-ka Rauza. The use of a medley of different typologies of tiles on the Tomb of Akbar has been similarly deemed worthwhile recording, as is noting the presence of tiled inscriptions on some buildings.

In documenting techniques of application, attention has been paid to noting features that inform the mode of assembling and fitment of the tiles on the buildings, such characteristics being reflective of technological traditions of a particular period or region and assisting in interpretations accordingly. Evidence of application techniques that are a departure from the conventional method of embedding tiles individually in plaster have likewise been highlighted, these illustrating the range of methods that were being utilized at a given time and place (Figure 4.4). An appraisal of the physical location of the tiles on architecture, and features of the architecture that they serve to embellish, has been carried out for similar reasons. Notes have also been made on the decay found associated with tiles on individual buildings to correlate with results of laboratory analyses, and gauge if a connection can be made between the technology of the tiles and their deteriorated physical state.

The recording of field data in this manner has enabled a better contextual understanding of the tile-work under study. It may be noted that observations made in the field were constrained by an inability to examine the tiles from close quarters in quite a few cases, the tile-work often being located on the upper portions of building facades with no means of access to them. Observations in such circumstances could be made from ground level only.

Figure 4.4 A tiled panel from the Tomb of Atgah Khan (1566-1567 CE) at Delhi illustrating the employment of tiles inset in marble, one of the many techniques of application used in this period.

4.2.3 Ethno-archaeological surveys

A connected yet distinct aspect of field work involved studying traditional craft forms that were considered related to the technology of the tile-work under study. As mentioned in Chapter 3, the existence of a traditional glazed pottery and a traditional glass production industry in the region (of northern India) were considered meritorious of an ethno-archaeological study, to assist in the interpretation of technologies connected with Lodhi and Mughal tile-work. The study of these two craft forms was crucial to provide a much needed local context in the elucidation of technologies of the material under study. Historical descriptions of past technologies typically used otherwise for interpretations, notably that of Abu'l Qasim's, although certainly relevant, describe practices followed at places located a considerable distance away from the context of this study. That some locally existent practices of a different kind may have influenced the production of Lodhi and Mughal tiles was a possibility that needed to be examined. Benefit from the two studies was further enhanced on learning that similar works had been undertaken in the nineteenth century as well at the behest of government authorities, and were available in the form of published reports. These earlier reports[12] besides describing production techniques being followed in the region closer to the period of existence of the Mughal tile-work industry, permitted an appreciation of transformations that had occurred in the crafts over the last century and a half, allowing interpretations to be better informed accordingly.

In the case of the glazed pottery industry, a field visit was made to Jaipur for a survey of workshops engaged in the traditional manufacture of glazed ceramics and tiles marketed under the name of 'Blue Pottery'. Information on the materials used, the physical nature of the wares, and observations on their methods of production were recorded. Sources of the raw material being employed and their working properties were discussed with artisans engaged in the craft. A fairly recent published report on the craft (Yadav 1999) was made use of for an evaluation of technologies in place. Notice was paid to the shape, design, and functioning of furnaces or kilns that were being used for the production of glass frit and firing of the

[12] The reports are discussed in Chapter 5, which deals with the ethno-archaeological studies.

ware. Observations on live demonstrations of some of the production processes carried out by the artisans enabled a better appreciation of the procedures and acts involved in the manufacture of the ware (Figure 4.5). Information gathered through past and recent publications further assisted in illuminating the history and technologies associated with the craft, inferences then being drawn from the whole to assist inform the technology of Lodhi and Mughal tile-work.

Less success with regard to documenting live procedures of a craft in practice was met at Jalesar, the last reported centre of traditional glass production in India (Sode and Kock 2001). Glass manufacture employing traditional methods had apparently ceased to exist in and around Jalesar about two decades ago. All glass made for local consumption was now being manufactured in the nearby town of Firozabad, the site of an immense modern glass industry, where less traditional and more modern methods are known to be employed for the manufacture of glass and glass objects. Nonetheless, a great deal of information on traditional manufacture could be gathered through a comprehensive survey of the region. Remnants of few non-functional old furnaces were discovered at the towns of Purdalpur and Akrabad in the vicinity of Jalesar, where traditional glass manufacture was apparently being undertaken on a fairly substantial scale before its decline and disappearance. These furnace remnants were measured and documented to compare with Sode and Kock's (2001) published account on the craft. Oral accounts of glass-making as recounted by senior living past-practitioners (Figure 4.6), who had first-hand knowledge of the craft, were taken note of to compare against details reported in Sode and Kock's study. Comparisons of findings determined through the survey, including the information gathered from the artisans, were then made with details provided in nineteenth century government reports on the status of the industry and the technologies prevalent at that time. A fuller appreciation of the materials and methods utilized in traditional glass manufacture could be made in this manner, the findings assisting in the reconstructing of some of the technologies involved in the production of tiles during Lodhi and Mughal times.

Figure 4.5 Artisans engaged in the crushing of coarse grains of quartz to a fine powder using a traditonal stone hand-mill. Live demonstrations of production processes, such as this one, enabled a better appreciation of the technologies involved in the original manufacture of Lodhi and Mughal tiles.

Figure 4.6 Discussions with glass-makers such as Samiullah Khan, shown here, were a useful source of information for reconstructing the technology of traditional glass manufacture.

4.3 Laboratory techniques

4.3.1 Instrument selection

Technological advancements and research in recent years have seen a host of instruments employed for the analysis of archaeological material ranging in size from as large as the massive synchrotron to the handy portable X-ray fluorescence spectrometer, each with its own peculiar advantages and limitations. The selection of appropriate instruments from among these, and the analytical methodology to be followed for any study is generally a trade-off between factors of economics, efficiency, accessibility, and time, with a more or less equal emphasis on all. Choice is decisively also guided by the nature of the material being examined, the size and quantity of available samples, and level of detail necessary in the data to be retrieved. Quite understandably, in the decision making process, preferential weightage is ascribed to techniques that have been standardized through years of research and study.

Against this framework of consideration, the primary instruments to be used for the current study were narrowed down to the scanning electron microscope and electron probe micro-analyser, the established efficacy of electron microscopy and ready availability of the systems being key determinants in their selection. In addition, laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) was also considered for employment as a subsidiary technique on a limited scale, its ability to provide relevant supplementary data being of interest.

Electron microscopy

The scanning electron microscope (SEM) has over the last few decades proven to be a highly effective tool for the study and characterisation of ancient glass and ceramics. From the pioneering work carried out at the British Museum in the 1980's (Bimson and Freestone 1983, Tite *et al.* 1983, Tite and Bimson 1986), the combination of imaging and quantitative analysis using an SEM has over the years developed to be the standard technique for the examination and compositional analysis of microstructures and mineral phases in glazed ceramics. The principles of electron light microscopy by which the SEM operates involves the bombardment of a prepared sample with electrons, to generate either a secondary image through knocked out electrons from the sample surface, or a backscattered image through electrons bounced back from relatively deeper within the sample, the former indicative of surface topographical details, whereas the latter provides qualitative information on chemical composition (Pollard *et al.* 2007, 109-113). Analysis is carried out through an attached spectrometer which detects X-rays that are also generated on the bombardment of the samples with electrons.

Qualitative and quantitative analytical data is obtained through energy dispersive spectrometry (EDS), the energy of the X-rays detected by the spectrometer being characteristic of the elements they are emitted from allowing their identification, while the peak intensities are a measure of their proportional presence in the sample. Since recent years most analysis related to glass or glazes is however now carried out using an electron microprobe micro-analyser (EPMA), a more accurate instrument with a higher spectral resolution that is generally operated using wavelength dispersive spectrometry (WDS). Quantitative analysis is enabled through crystal spectrometers fitted to the instrument, elements being distinguished on the basis of their characteristic X-ray wavelengths when diffracted through crystals within. The sequential isolation of X-rays from individual elements on passing through the crystals, and their individual counting on being directed to a detector, allows lower detection limits making the technique especially useful for detecting and quantifying minor elements.

Inductively coupled plasma-mass spectrometry

Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) has of late become an increasingly important technique in the study of archaeological glass and ceramics, offering benefits not attainable through conventional electron microscopy. The technique involves the ablation of a tiny part of a solid sample, the vaporised products of which are transported to a plasma torch being maintained at a temperature of 10000 ^{o}C. The high temperature breaks down most of the molecular species effectively ionizing about half the number of atoms present. Representative numbers of the positive ions are then transferred to a mass spectrometer where they are separated based on their mass-to-charge ratio and quantified through a detector, the ions reported being proportional to their concentration in the sample (Pollard *et al.* 2007, 197-199). An optical microscope coupled to the laser allows the user to select a suitable area of the sample for analysis. The biggest advantage gained through this technique is trace level detection. Measurements are possible on one or more selected isotopes of elements present, which is particularly useful for provenancing studies. Rapid sample interchange is possible as the instrument is capable of simultaneously measuring all elements present in a sample at a time. Although sample damage through ablation is a limitation posed, craters created on the samples through the use of this technique are actually quite small. Such craters typically range over 5 to 400 µm in diameter, and are virtually invisible to the naked eye (Pollard *et al.* 2007, 199).

With emphasis being laid on the analyses of the glazes, EPMA-WDS was the prime technique employed for the purpose of this study, utilized for the chemical analyses of the glaze layers. The SEM-EDS system was used for characterising the tile bodies and for detailed investigations of mineral phases present in the body and glaze layers. LA-ICP-MS was employed to assist in provenancing one of the determined tile groups, distinguished through compositional analysis. Raman spectroscopy was also employed for analysis, but only in the specific instance of a case study related to glaze colorants and not otherwise used as an analytical tool.

4.3.2 Analytical procedures

Sampled fragments taken for analysis were first examined macroscopically using a hand lens and stereomicroscope to study distinguishing features. Sections of the fragments, cut through the body and glaze, were then mounted in epoxy resin (Metprep Eposet 11-10-61) blocks and prepared for examination by standardized grinding and polishing procedures using silicon carbide discs and diamond paste. Polished samples were then carbon coated to make them conductive and examined in a JEOL SEM/EPMA (JXA 8600) equipped with a JEOL wavelength dispersive spectrometer, and a JEOL JSM6610LV SEM with an attached Oxford Instruments X-Max energy dispersive spectrometer.

Chemical compositions of the tile bodies were determined through SEM-EDS operating in the backscattered electron (BSE) mode, at an accelerating potential of 20 kV, count time 60 s, and average dead-time of 35-40 %. Stability of the beam current was monitored by repeated calibration against a cobalt standard. The same parameters were maintained for spot and small area analyses of interparticle glass in the bodies and mineral inclusions in the bodies and glazes. As the tile bodies were considerably thick, their bulk analyses could conveniently be undertaken at 100x magnification, the area covered in each analysis being c. 820 x 1140 µm. Area coverage in spot and small area analysis on the other hand was variable, and was dependent on the size of the phases being measured. Pigment particles in the glazes for instance were typically analysed through a single spot only, while well-developed regions of interparticle glass were subject to scans that could cover areas of up to 30 x 30 µm at a time. Phases present in the body matrices could be distinguished on the basis of differences in atomic number, appearing in varying shades of grey, brighter areas signifying higher mean atomic number vis-à-vis relatively darker ones. Particles of pigments and other minerals dispersed in the glazes could be likewise distinguished by their relatively brighter appearance than the rest of the glaze layer. BSE images of relevance that were illustrative of the investigations and microstructure of the samples were taken when required. Textural characteristics of inclusions, notably grain shape and size and their distribution within the matrices, were recorded using the most accepted ceramic thin-section description system as a standard (Whitbread 1989, 1995).

The concentrations of elements detected were measured using the auto-id mode option in the software (Aztec) used. Each detected element was confirmed by checking for the presence of its characteristic peaks in the spectrum generated. This was especially required for elements present in low concentrations. Elements that at times were not automatically detected but had clearly identifiable peaks present were added to the list of elements being measured, whereas those that were detected by the software but had no distinct peaks in the corresponding spectrum were removed from the list. The list of the main elements[13] found in the tile bodies in

[13] The name and chemical formula of their derivative oxides are given in parentheses against each.

concentrations measurable by EDS include silicon (silica, SiO_2), sodium (soda, Na_2O), potassium (potash, K_2O), magnesium (magnesia, MgO), calcium (lime, CaO), aluminium (alumina, Al_2O_3), and iron (iron oxide, Fe_2O_3). Besides being utilized to determine the chemical composition of the tile bodies, and for the identification of mineral phases, EDS was also used for the preliminary analyses of glazes, to assist determine the list of elements to be analysed through EPMA-WDS.

Quantitative analysis of the glaze layers was carried out by area scans through WDS using a rastered beam at 15 kV, 50 nA, and a count time of 20 s per element with 10 s on the peak and 5 s on the background on either side. A sufficient number of counts per element could be attained at these settings making the data generated statistically reliable. The list of elements[14] considered for WDS analysis include silicon (silica, SiO_2), sodium (soda, Na_2O), potassium (potash, K_2O), magnesium (magnesia, MgO), calcium (lime, CaO), aluminium (alumina, Al_2O_3), iron (iron oxide, Fe_2O_3), titanium (titania, TiO_2), copper (copper oxide, CuO), cobalt (cobalt oxide, CoO), manganese (manganese oxide, MnO), lead (lead oxide, PbO), tin (tin oxide, SnO_2), nickel (nickel oxide, NiO), zinc (zinc oxide, ZnO), arsenic (arsenic oxide, As_2O_5), barium (barium oxide, BaO), phosphorus (as phosphates, P_2O_5), and sulphur (as sulphates, SO_3).

Antimony (antimony oxide, Sb_2O_5), although undetected in preliminary analysis through EDS, was added to the list of elements, having a history of use as a decolourant and opacifier in glass since ancient times. Chlorine (Cl, as chlorides) although determined present through preliminary analysis was found to be eliminated on stoichiometric modelling by the software employed. Its expected presence in the glaze layers, typically in concentrations of between 0.5 to 1.5 wt% as proposed by Tanimoto and Rehren (2008), was a feature that was attempted to be made use of to distinguish between original and what appeared to be later additions in some of the tile-work. All specimens with glaze compositions that did not conform to typical groupings were accordingly additionally checked for their chloride content by SEM-EDS analysis, as were some original specimens from the

[14] The name and chemical formula of their derivative oxides are given in parentheses against each.

same context. No distinction could however be made in this manner, all the glazes found to contain chloride in the expected range, mostly lying between 0.9-1.2 wt%.

Sodium migration during analysis was minimised by being the first element checked and limiting area scan magnification in WDS to an optimal 800x (Shugar and Rehren 2002) that corresponded to c. 100 x 140 µm of scanned expanse on the sample surface. Analyses at lower magnifications could not be carried out on account of the thinness of many of the glaze layers being examined. Magnification was in fact increased from 800x to 2000x, and the current correspondingly lowered to 15 nA, in circumstances where the glaze layer was either too thin or had an overabundance of bubbles present leaving less area available for analysis. Bulk area scans of the glaze layers otherwise typically included pigment or opacifier particles when present, while avoiding bubbles, pores, quartz grains, and visible minor inclusions.

All quantitative results of bulk chemical analyses are reported as oxides by stoichiometry, being the average of 3-6 analyses spread over the bodies and glaze layers. High analytical totals, typically between 96-98 wt%, and consistent measurements were achieved in the analyses of the glaze layers, the glazes being homogeneous and generally free of corrosion except for randomly present tiny pores at places. Results for their bulk composition are reported as measured. The tile bodies, although similarly homogeneous, were considerably porous and returned low totals, in the range 50-60 wt% on an average. Results for their bulk composition have been normalized to 100 wt%. As mentioned earlier, no fixed magnification could be applied for chemical analyses of the interparticle glass in the tile bodies, the areas available for analysis being generally quite small and at times virtually non-existent. Results obtained through small area and spot analyses of these areas, although likely to have depleted soda values on account of its migration and elevated silica concentrations from adjacent quartz grains, have still been reported, being useful at the very least for qualitative comparisons. Spot analyses of pigment particles in the coloured glazes, where present, are reported in both atomic and weight percent. Although detection limits of the systems employed are known to vary across elements and be influenced by current and program settings, the lower thresholds for the EDS and WDS are generally considered to be 0.3 wt% and 0.05 wt%

respectively; analytical results below this have accordingly not been presented for discussions, except for comparative purposes where required.

Precision and accuracy of the systems employed were checked against reference material (Corning A, B, and C glass standards, and Sheffield Glass No. 3) closest in composition to the samples by comparing analytical results with published values. Reasonably good results were obtained on analyses of the standards, the departure from accepted values being in the range 2-5 % relative for major elements and mostly lower than 10 % relative for elements present at 1 wt% or less (Tables 4.2 to 4.4, Appendices 4.1 to 4.3). Inconsistencies are only reported for elements that lie around or below the detection limit ascribed to the instrument, such results in any case not being taken into consideration for discussions. The overall low values calculated for both precision and accuracy, representative of measurement repeatability and the agreement between true and measured values respectively, indicate that the data obtained on analyses is valid and well-representative of the material analysed.

LA-ICP-MS analysis, for the provenancing of a select group of samples, was carried out by Dr. Bernard Gratuze at the Institut de Recherche sur les Archéomatériaux, CNRS/Université d'Orléans. The LA-ICP-MS system used comprised a Thermo Fisher Scientific ELEMENT XR ICP-MS coupled to a Resonetic M50E 193 nm ArF excimer laser source. The spot size of the laser beam varied over 30-100 μm, and the frequency was set to 7 Hz.

Raman analysis of select samples was carried out under the auspices of the Conservation Centre of the National Museum of China for a specific case study related to colorant particles found dispersed within yellow, green, and orange coloured glazes. Spectra of colorant particles in a few such glazes were obtained with a Nicolet Almega XR dispersive Raman spectrometer equipped with a charge-coupled device detector, and attached to an Olympus Raman microscope. Raman spectra were excited at 532 and 780 nm, using a Nd:YAG laser at an exposure time of 10 s. The laser power was set to vary between 4 mW and 25 mW.

Table 4.2 Chemical compositions of glass standards as published and analysed by SEM-EDS. Results, normalised to 100 wt%, report the average of seven analyses spread out over the period of use of the instrument. Analytical results below the detection limit of the instrument are given for comparison only. '-' indicates 'not published' or 'not detected' on analysis.

Session/details	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CoO	CuO	Sb_2O_5	ZnO	P_2O_5	SO_3	BaO	PbO
Corning A																	
Analysed (n=7)	14.1	2.6	0.9	68.1	3.0	5.1	1.0	1.1	1.0	0.2	1.3	1.7	-	-	-	-	-
Published	14.5	2.7	1.0	67.6	2.9	5.1	0.8	1.0	1.1	0.2	1.2	1.8	-	-	-	-	-
Std. Deviation	0.22	0.02	0.02	0.48	0.09	0.21	0.04	0.06	0.02	0.04	0.03	0.11	-	-	-	-	-
RSD/Precision %	1.5	0.9	2.2	0.7	3.0	4.1	4.4	5.1	1.7	22.0	2.6	6.8	-	-	-	-	-
Accuracy %	-3.1	-2.8	-15.7	0.6	4.2	-0.5	24.2	7.3	-7.2	-6.2	7.7	-5.6	-	-	-	-	-
Corning B																	
Analysed (n=7)	17.0	1.1	4.1	62.7	1.1	8.9	-	0.2	0.3	-	2.8	-	0.2	0.9	0.7	-	-
Published	17.3	1.0	4.4	62.6	1.0	8.7	-	0.3	0.3	-	2.7	-	0.2	0.8	0.5	-	-
Std. Deviation	0.40	0.04	0.11	0.13	0.03	0.15	-	0.06	0.01	-	0.16	-	0.06	0.14	0.07	-	-
RSD/Precision %	2.4	3.4	2.8	0.2	2.7	1.7	-	24.9	3.8	-	5.8	-	27.3	16.0	10.1	-	-
Accuracy %	-1.8	1.0	-8.0	0.1	8.4	2.4	-	-7.8	-4.7	-	2.4	-	10.7	6.5	29.8	-	-
Corning C																	
Analysed (n=7)	1.0	2.6	0.8	33.6	2.9	5.1	0.8	-	0.3	0.2	1.2	-	-	-	-	12.4	39.2
Published	1.1	2.8	0.9	35.6	2.9	5.2	0.8	-	0.3	0.2	1.2	-	-	-	-	11.6	37.4
Std. Deviation	0.03	0.05	0.02	0.19	0.04	0.04	0.10	-	0.04	0.08	0.03	-	-	-	-	0.17	0.28
RSD/Precision %	3.4	1.8	2.8	0.6	1.3	0.8	12.3	-	11.3	46.5	2.9	-	-	-	-	1.4	0.7
Accuracy %	-7.3	-8.3	-11.5	-5.6	-1.1	-0.6	1.7	-	-10.6	-6.3	0.3	-	-	-	-	6.7	4.6

Table 4.3 Chemical compositions of glass standards as published and analysed by EPMA-WDS at a magnification of 800x. Results given report the average of eight analyses spread out over the period of use of the instrument. Analytical results below the detection limit of the instrument are given for comparison only. '-' indicates 'not published' or 'not detected' on analysis.

Standard	**Na_2O**	**CaO**	**K_2O**	**MgO**	**Al_2O_3**	**Fe_2O_3**	**SiO_2**	**TiO_2**	**Sb_2O_5**	**MnO**	**CuO**	**CoO**	**SnO_2**	**PbO**	**NiO**	**ZnO**	**BaO**	**P_2O_5**	**SO_3**	**As_2O_5**	**Total**
Corning A																					
Analysed (n=8)	14.28	4.90	2.89	2.72	0.93	1.01	66.15	0.76	1.58	0.95	1.18	0.12	0.17	0.07	0.03	0.06	0.44	0.08	0.10	-	98.39
Published	14.30	5.03	2.87	2.66	1.00	1.09	66.56	0.79	1.75	1.00	1.17	0.17	0.19	0.12	-	0.04	0.56	0.13	-	-	99.43
Std. Deviation	0.13	0.24	0.11	0.08	0.06	0.11	0.69	0.02	0.16	0.07	0.07	0.02	0.01	0.04	0.03	0.04	0.04	0.04	0.03	-	
RSD/Precision %	0.90	4.83	3.73	2.93	6.82	10.45	1.05	2.26	9.85	7.52	5.52	12.91	6.69	65.02	100.13	73.65	10.03	54.51	33.22	-	
Accuracy %	-0.13	-2.53	0.68	2.12	-7.14	-7.40	-0.62	-3.96	-9.84	-5.03	0.65	-28.16	-11.18	-45.52	-	41.25	-22.17	-41.92	-	-	
Corning B																					
Analysed (n=8)	17.05	8.62	1.04	1.06	4.50	0.31	61.59	0.10	0.43	0.22	2.64	0.03	0.02	0.43	0.10	0.18	0.07	0.83	0.44	-	99.66
Published	17.00	8.56	1.00	1.03	4.36	0.34	61.55	0.09	0.46	0.25	2.66	0.05	0.04	0.61	0.10	0.19	0.12	0.82	0.54	-	99.77
Std. Deviation	0.19	0.13	0.02	0.07	0.21	0.04	0.54	0.01	0.07	0.02	0.15	0.02	0.02	0.05	0.02	0.04	0.02	0.10	0.14	-	
RSD/Precision %	1.14	1.56	2.24	6.64	4.74	13.05	0.87	12.42	16.31	9.56	5.70	52.14	129.66	11.38	24.65	24.46	27.70	11.84	30.42	-	
Accuracy %	0.28	0.65	4.18	2.95	3.14	-10.15	0.07	6.39	-6.58	-10.15	-0.77	-32.00	-52.81	-29.10	-1.88	-3.82	-41.25	1.04	-17.69	-	
Corning C																					
Analysed (n=8)	1.25	5.10	2.91	2.87	0.89	0.28	35.24	1.00	-	0.01	1.15	0.13	0.13	36.62	0.05	0.04	11.60	0.11	-	-	99.37
Published	1.07	5.07	2.84	2.76	0.87	0.34	34.87	0.79	0.03	-	1.13	0.18	0.19	36.70	-	0.05	11.40	0.14	-	-	98.43
Std. Deviation	0.03	0.09	0.10	0.09	0.12	0.04	0.79	0.14	-	0.01	0.07	0.01	0.04	0.99	0.04	0.05	0.27	0.07	-	-	
RSD/Precision %	2.44	1.72	3.57	3.14	13.25	13.99	2.25	14.34	-	143.98	6.15	10.93	30.30	2.70	78.19	130.86	2.36	62.37	-	-	
Accuracy %	16.61	0.57	2.46	3.85	2.59	-16.65	1.05	27.15	-100.00	-	1.38	-28.89	-31.71	-0.23	-	-16.00	1.76	-22.77	-	-	
Sheffield Glass # 3																					
Analysed (n=8)	0.18	0.01	11.17	-	0.02	0.03	56.15	0.01	-	0.01	0.03	-	-	31.75	0.02	0.03	0.02	0.01	-	0.80	100.23
Published	0.22	0.10	11.12	0.04	0.13	0.02	55.33	0.02	-	-	-	-	-	31.70	-	-	-	-	-	0.67	99.35
Std. Deviation	0.02	0.01	0.14	-	0.02	0.03	0.49	0.02	-	0.02	0.02	0.01	-	0.74	0.03	0.05	0.03	0.03	-	0.06	
RSD/Precision %	9.43	143.86	1.24	-	134.15	85.35	0.87	146.76	-	186.54	83.19	180.69	-	2.33	183.55	167.48	129.21	185.31	-	7.79	
Accuracy %	-18.13	-93.38	0.46	-100.00	-88.27	73.75	1.47	-41.25	-	-	-	-	-	0.16	-	-	-	-	-	19.26	

Table 4.4 Chemical compositions of glass standards as published and analysed by EPMA-WDS at a magnification of 2000x. Results given report the average of five analyses spread out over the period of use of the instrument. Analytical results below the detection limit of the instrument are given for comparison only. '-' indicates 'not published' or 'not detected' on analysis.

Standard	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	SiO_2	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
Corning A																					
Analysed (n=5)	14.33	5.04	2.88	2.64	0.91	1.04	67.57	0.77	1.71	0.94	1.16	0.13	0.19	0.12	0.04	0.05	0.46	0.15	0.14	-	100.27
Published	14.30	5.03	2.87	2.66	1.00	1.09	66.56	0.79	1.75	1.00	1.17	0.17	0.19	0.12	-	0.04	0.56	0.13	-	-	99.43
Std. Deviation	0.39	0.22	0.06	0.11	0.03	0.06	0.79	0.02	0.16	0.08	0.12	0.03	0.05	0.12	0.05	0.05	0.04	0.12	0.07	-	
RSD/Precision %	2.73	4.31	2.10	4.20	3.27	5.64	1.17	3.21	9.61	8.48	10.09	19.91	29.29	100.10	124.21	107.16	8.91	84.45	48.33	-	
Accuracy %	0.22	0.27	0.35	-0.58	-8.96	-4.39	1.52	-2.46	-2.14	-6.10	-0.56	-25.06	-1.89	-3.50	-	22.00	-17.82	13.38	-	-	
Corning B																					
Analysed (n=5)	17.12	8.78	1.02	1.06	4.30	0.27	62.85	0.11	0.50	0.21	2.56	0.05	0.01	0.48	0.12	0.14	0.10	0.88	0.47	-	101.03
Published	17.00	8.56	1.00	1.03	4.36	0.34	61.55	0.09	0.46	0.25	2.66	0.05	0.04	0.61	0.10	0.19	0.12	0.82	0.54	-	99.77
Std. Deviation	0.41	0.31	0.11	0.06	0.09	0.05	1.05	0.02	0.05	0.03	0.12	0.04	0.02	0.10	0.04	0.10	0.05	0.22	0.05	-	
RSD/Precision %	2.42	3.53	11.14	5.36	2.10	16.60	1.67	17.76	10.77	14.40	4.72	86.09	137.87	20.44	30.48	68.63	50.51	24.32	9.98	-	
Accuracy %	0.73	2.53	2.28	3.17	-1.38	-19.18	2.11	25.11	7.78	-14.88	-3.86	-5.20	-67.00	-21.90	17.00	-25.26	-18.33	7.90	-13.24	-	
Corning C																					
Analysed (n=5)	1.18	5.06	2.95	2.88	0.87	0.36	36.54	1.09	-	0.04	1.20	0.17	0.11	36.42	0.08	0.05	11.36	0.10	0.02	-	100.49
Published	1.07	5.07	2.84	2.76	0.87	0.34	34.87	0.79	0.03	-	1.13	0.18	0.19	36.70	-	0.05	11.40	0.14	-	-	98.43
Std. Deviation	0.18	0.31	0.06	0.04	0.02	0.07	0.75	0.05	0.00	0.04	0.11	0.04	0.03	1.44	0.06	0.09	0.55	0.09	0.05	-	
RSD/Precision %	14.95	6.22	2.07	1.46	2.73	18.41	2.04	5.04	-	102.82	9.49	25.21	24.00	3.95	72.97	178.91	4.83	89.51	223.61	-	
Accuracy %	10.24	-0.16	4.01	4.49	0.44	7.00	4.78	37.75	-100.00	-	6.55	-7.44	-42.11	-0.77	-	-3.60	-0.32	-28.00	-	-	
Sheffield Glass # 3																					
Analysed (n=5)	0.17	0.01	10.91	0.01	0.05	0.03	54.95	0.02	-	0.01	0.02	0.01	-	31.56	0.01	0.03	0.04	0.10	-	0.81	98.73
Published	0.22	0.10	11.12	0.04	0.13	0.02	55.33	0.02	-	-	-	-	-	31.70	-	-	-	-	-	0.67	99.35
Std. Deviation	0.04	0.01	0.17	0.02	0.04	0.04	0.46	0.02	-	0.02	0.03	0.01	-	0.45	0.02	0.03	0.04	0.12	-	0.18	
RSD/Precision %	23.20	173.21	1.59	223.61	73.42	143.52	0.84	97.55	-	127.60	152.47	223.61	-	1.42	196.42	77.46	82.08	119.75	-	21.99	
Accuracy %	-24.73	-95.00	-1.89	-74.50	-61.69	48.00	-0.68	4.00	-	-	-	-	-	-0.46	-	-	-	-	-	21.28	

4.3.3 Data interpretation: An explanation

A glazed tile, in its most basic form, consists of a ceramic body, the surface of which carries a deliberately added-on thin layer of glass, referred to in ceramic parlance as a glaze. In most tiles, the glaze layer is coloured by means of metal oxide colorants added specifically for the purpose, more elaborate specimens being further painted and decorated in a variety of ways. The manufacture of a glazed tile may similarly be broadly viewed as consisting of a two stage process, *viz.* the preparation and formation of the ceramic body, and the application of the glaze layer on it through a firing sequence. This is however by no means a standard description of the processes involved as many variations are known to be employed. Tile bodies can sometimes be pre-fired to a 'biscuit' stage before the glaze-application firing for example, while tiles that are already glazed can be subject to a second firing for the application of over-glaze decoration. Technological studies, such as this one, attempt to identify the materials and processes that have gone into the creation of the tiles through an objective interpretation of data generated on the analysis of their bodies and glazes.

For tile bodies, technological information can be studied and interpreted not only by an analysis of their chemical composition, which helps identify fabric groups and materials used, but also and at times more importantly by examining the nature and identity of non-plastic inclusions that lie in the body matrix. In the case of stonepaste tiles, the bodies of which comprise almost entirely of quartz grains, an equitable emphasis is laid on the study of textural characteristics of the grains distributed within the matrices as on chemical composition. This assists in corroborating grouping and classification determined through chemical analyses, and also allows conjectures on possible sources of the raw material used. Relative roundness of the quartz grains in a stonepaste fabric for instance is a reflection of their erosional history and can provide information on their likely geological origin. Similarities in size and distributions of the grains in the matrices likewise can be used to discriminate between fabric groups. Such information when read in conjunction with results of chemical analysis can be further interpreted with additional data from texts, reports, and ethno-archaeological surveys to reconstruct manufacturing processes and technologies.

For the glaze layers on the other hand, the reconstruction of past technologies is mainly carried out through an interpretation of the results of their chemical analysis. Two lines of investigations are normally followed in this case; the first concerned with determining the processes and materials employed for the production of glass in a raw pre-fritted state, and the other looking at the technologies that go into the transformation of the raw glass into the glaze, *viz.* its colouring and application. Much of this is possible through a reading of the element oxide concentrations determined on the quantitative analysis of the glaze layers. Of the major and minor oxides reported, silica, soda, potash, magnesia, lime, alumina, and iron oxide are construed to be the base glass forming oxides concerned with the production of raw glass[15]. Their concentrations and presence in the glaze bulk composition are utilized as a measure and means of identification of the raw materials used in the manufacture of the glass/glaze frit. Silica, the main ingredient and glass-former, sourced from either quartz-rich sand or rock, comprises the bulk of the composition. Soda, potash, and magnesia values provide information on the nature of the flux that was employed for the melting of silica.

The other glass forming oxides, namely lime, alumina, and iron oxide are generally considered incorporated as contaminants with the silica source, and are usually interpreted to shed light on the same. The possibility that lime can have been purposefully added as an individual ingredient, to impart stability to the glass, is however kept open, and investigated. Oxides of other notable elements that are also present in minor concentrations in the glaze bulk are typically associated with the pigments that would have been employed for the colouring of the glazes, and inform the same accordingly. In some cases, the most likely source of the colorant can be determined through the presence of associated impurities that are also present in the glaze bulk.

Besides assisting in identifying the nature, origin, and proportions of the raw material used, the oxide values of one or more elements in the bulk composition are also utilized for classification and grouping, to distinguish between regional typologies, and assist in determining the organization of production. Additional

[15] Applicable to glass of the soda-silica type, the prevailing typology in the region.

interpretive information, such as determining the presence of oxidising or reducing conditions within a furnace, or estimating the temperature at which a firing was carried out, can similarly be gained through other related investigative analyses. Compositional characteristics of the glazes can therefore not only reveal much about the main glass-forming ingredient, fluxes, and colorants utilized, but also provide data on the technologies and processes that shaped their making, the latter notably assisted by information gained through macro and microstructural studies. Such technical data, with supplementary information on the context, facilitates the larger ‘cultural’ and ‘socio-cultural’ explanations and meanings desired from the study.

5. TRADITIONAL GLASS AND TILE MANUFACTURE

This chapter, divided over two sections, describes findings of ethno-archaeological studies undertaken for the appraisal of technologies of two known living traditional crafts in northern India, that of raw glass manufacture, and the Blue Pottery ceramic industry. The first section explicates details of the raw material and processes employed in the production of glass, determined through a field survey cum study, supported by inputs from some earlier published reports of note. The next section details technologies involved in the manufacture of Blue Pottery, determined through a study visit to workshops located at the current hub of the industry, and by carrying out a review of the history of the craft. Findings of the two studies are subsequently utilized in the chapter on discussions (Chapter 8) for a better interpretation of the technology of the historical material being researched.

5.1 Traditional raw glass manufacture in northern India

5.1.1 Introduction

In the context of northern India, the technology of local or ‘Indian Glass’ manufacture as currently understood, is primarily based on observations of an earlier ethnographic study carried out by Sode and Kock (2001) on glass-making at a town called Jalesar, purported to be the last centre of traditional glass manufacture in the region. Their study in summary reports the use of two distinct ingredients, siliceous sand and locally available mineral-soda, being mixed together to a batch that was then melted in a circular tank furnace to produce raw glass. Extrapolations of the materials and processes reported in their study have since been used in making wider interpretations in the production of ancient glass in general.

A preliminary survey of the region carried out for the purpose of this research quickly revealed that a reassessment of the technologies involved in local glass production was warranted. Although traditional glass manufacture had apparently ceased to exist, the knowledge of the materials and processes involved was found to be still available with living past-practitioners of the craft. Conversations with these glass-makers revealed that just one ingredient, and not two as reported by Sode and Kock, was traditionally employed in the production of raw glass. *Reh*, the mineral-soda rich deposit professedly employed, apparently contained in itself all the necessary ingredients that were required for the formation of glass. Details on the processes of manufacture recounted by the glass-makers were also found to vary from those reported by Sode and Kock, although the furnaces are described similarly. Interestingly, the use of *reh* as a sole ingredient, and processes of manufacture similar to those described by the glass-makers, is clearly given in a detailed official report on the status of the local glass industry, prepared at the behest of the government in nineteenth century British India (Dobbs 1895). Dobbs' writings and other connected reports, although mentioned by Dikshit (1969, 130-148) in his exhaustive compilation on Indian glass, seem to have been overlooked so far in the assessment of technologies concerned with traditional glass production in northern India.

A detailed ethno-archaeological study was accordingly undertaken in an attempt to more accurately reconstruct the technology of raw glass production, which apparently prevailed in the region for quite a while, before dying out around the time of Sode and Kock's work. A survey of the region (Firozabad-Jalesar-Purdalpur) associated with glass-making was therefore carried out, discussions with identified artisans initiated, and remnants of a few discovered extant furnaces examined. Accounts of glass-making as narrated by two master artisans, Samiuddin Noori (Samiuddin) and Gulam Jilani (Jilani), both residents of Purdalpur[16], were also recorded, and compared against details given in Sode and Kock's (2001) and Dobbs' (1895) reports. Findings of the study, including a brief overview of the region and the craft, are given in the succeeding paragraphs.

5.1.2 The region

Jalesar, the site of the ethnographic study undertaken by Sode and Kock, is a small town located about forty kilometres north-east of Agra, and about the same distance from Firozabad, the current hub of the glass and bangle industry in the country

[16] Also known as Purdilpur or Purdil Nagar.

(Figure 5.1). Firozabad itself lies forty five kilometres to the east of Agra. North of Jalesar, and about forty kilometres away, is Purdalpur, a bead production centre, where bead-making is still a traditional craft, apparently practised in much the same manner as would have been in older times (Figure 5.2). Further north-west, on the route from Purdalpur to Aligarh, is the small settlement of Akrabad, whose association with the traditional glass and bead industry is intertwined with that of Purdalpur through extended family ties. All these towns or settlements are located in what is now the Indian province[17] of Uttar Pradesh, the western extremities of which border Delhi. The territory of modern Uttar Pradesh, including its former hilly tracts that are now a separate province, broadly conforms to the region administered as the 'North-western Provinces and Oudh' in nineteenth century British India, Delhi and the region beyond west being considered as the Punjab at that time.

Figure 5.1 Map of Uttar Pradesh and surrounding areas illustrating locations known to be associated with the manufacture and consumption of raw glass. The shaded area marks the region surveyed for this study.

Although the few ethnographic studies carried out in the later part of the twentieth century identify only the Jalesar-Purdalpur region as being associated with

[17] In modern India, a province is called a state. Uttar Pradesh is thus formally referred to as the state of Uttar Pradesh or Uttar Pradesh State.

traditional raw glass production, Dobbs' (1895) report indicates that an industry of substantial proportions was thriving in a much larger area in the western half of the Gangetic plains of Uttar Pradesh, in the then North-western Provinces and Oudh. Nine districts[18], Aligarh, Agra, Bulandshahr, Etah, Etawah, Fyzabad [Faizabad], Mainpuri, Meerut, and Rae Bareli, are named by him as being locations of manufacture of 'crude native' glass[19]. Among these, Aligarh, Etawah, and Mainpuri are mentioned as being centres of considerable manufacture, their produce being transported and distributed all over India as blocks of crude glass through the railways. A portion of the yield was also apparently consumed locally in an existent bead and bangle industry. The chief reason for these nine districts being engaged in crude glass manufacture, according to Dobbs, was for the network of canals that criss-crossed their lands, causing the efflorescence of a crude carbonate of soda on the soils irrigated by them, and for the local availability of a sufficient supply of fuel.

Much seems to have changed between the times of Dobbs' report and the closure of the traditional industry in the last quarter of the twentieth century. The arrival of new technologies with the onset of the modern era (Figure 5.3) allowed the mechanised production of glass that was superior and more economical than that manufactured traditionally. This gradually led to the establishment of a new industry centred on Firozabad, the current glass capital of the country, and a commensurate decline in traditional glass manufacture. From Samiuddin and Jilani's accounts it seems that by the third quarter of the twentieth century, raw glass was being manufactured in traditional furnaces at very few places in the region, mainly at Purdalpur, and on a lesser scale at only two other places, Akrabad and Jalesar. Purdalpur, perhaps the last outpost of glass manufacture on an industrial scale, was finally just producing enough glass to meet the requirements of the bead and bangle industry in the town, before shutting down in entirety in the face of competition from cheaper and better quality glass coming in from Firozabad.

[18] A district is a sub-division of a province or state.
[19] Known as *kanch* locally.

Figure 5.2 A traditional glass-working furnace in operation in Purdalpur. Traditional furnaces for bead and bangle-making, such as this one, still abound in the region. The glass being worked in these furnaces is now sourced from factories at Firozabad.

Figure 5.3 A modern gas-fired glass furnace in a factory at Firozabad.

5.1.3 The furnaces

Barring some minor discrepancies pointed out by Samiuddin and Jilani, Sode and Kock's detailed description and illustration of a furnace holds well. Dobbs' relatively briefer account also largely conforms to the specifics provided by them. The furnace[20] is described as being a kind of a conical structure constructed of sun-dried mud bricks, with a circular base, and flattened at the apex. It is typically around two metres in height externally, and about five metres in diameter at its base (Figure 5.4). Both its interior and exterior surfaces are plastered. The interior is divided over a firebox that covers about a third of the space within, partitioned from a larger melting chamber by a low semi-circular wall, also constructed of mud bricks.

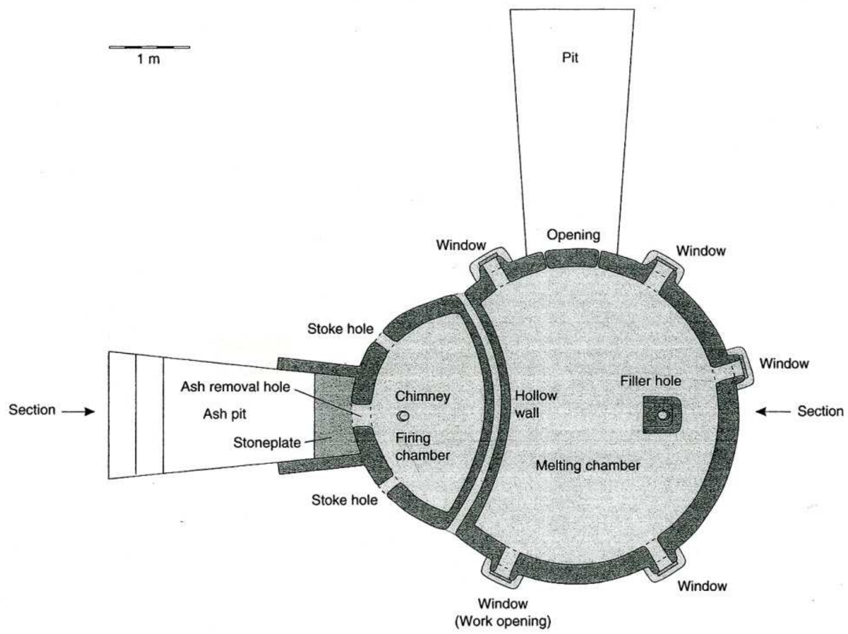

Figure 5.4 Plan of a typical furnace used for the traditional manufacture of glass (from Sode and Kock 2001, 161).

On the outside and at the middle of the firebox is a pit, provisioned for the removal of ashes from the burnt fuel, as well as for funnelling air into the firebox for combustion. On either side of the ash pit is a stokehole for fuelling the fire. A second pit is located on the left side of the furnace, provided with an opening into the melting chamber, entering the latter at its bottom. Ranged around the 'walled' lateral

[20] Referred to as a '*haud*' locally.

surfaces of the melting chamber is a series of ‘windows’ that function as work-openings, and allow the even distribution of heat in all directions in the melting chamber. A filling-hole opening, through which the ingredients are introduced into the melting chamber, is located high up on the crown of the furnace, opposite to the firebox.

Ruins of two discovered partially extant furnaces that were examined for this study, one each at Akrabad and Mohanpura[21], were found to match the described typical furnaces in their ground plan. Their superstructures being mostly lost could not be used for making comparisons. At Mohanpura, only the base of the furnace is found to have survived, embedded in the ground but sufficient to appreciate its original size and design. The original circular shape can be evidenced here, as can part of the partition wall separating the firebox from the melting chamber. The inner diameter of this furnace is five and a half metres, slightly larger than the archetypal, the shortest distance between the partition wall and the side opposite being slightly more than three and a half metres.

More can be determined at Akrabad, where a part of the furnace above the ground level is extant (Figure 5.5). The ground plan here too is found similar to that of the typical, the inner diameter being five and quarter metres in this case. Almost the entire partition wall survives here, as does a part of the superstructure, the latter appearing as low circular wall around the melting chamber. The interior sides of the melting chamber, including the partition wall, are coated with several layers of green and black coloured glass (Figure 5.6), about four centimetres thick in total, suggesting that the furnace was probably used for several firings. Exposed portions of the walls indicate that the furnace was constructed of sun-dried mud bricks having considerable crushed stone content (Figure 5.7), the latter ostensibly being added to enhance the refractory properties of the bricks. The joints between the bricks are filled with mud mortar, of similar consistency as that used to plaster the inner and outer surfaces of the furnace.

[21] A settlement close to Purdalpur where raw glass was manufactured on a fairly large-scale in the third quarter of the twentieth century by an eminent glass-maker named Habib Khan. Habib Khan is the father of Gulam Jilani. As per Gulam Jilani his father was visited by Peter Francis (1982) on several occasions.

Figure 5.5 Remains of the furnace at Akrabad.

Figure 5.6 Detail of a portion of the interiors of the melting chamber of the Akrabad furnace. Note the layers of black coloured glass that coat the sides of the furnace.

Figure 5.7 Close up of the exterior of the Akrabad furnace illustrating the use of sun-dried mud bricks for its construction.

5.1.4 Raw materials

The chief anomaly in Sode and Kock's projection of traditional raw glass production in the region comes forth hereinafter. The selection, use, and preparation of raw materials as described by Samiuddin and Jilani, corroborated further through Dobbs' report, are quite different from details given by Sode and Kock (2001). The two artisans and Dobbs all agree that just one main ingredient, *reh*, a naturally occurring mineral-soda deposit was utilized in the production of glass, while Sode and Kock report that two distinct ingredients, sand and soda, were used. The use of just one ingredient has also been noted by Peter Francis (1982), while researching bead-making at Purdalpur, and by Brill (2003, 267) while interviewing an owner of a glass factory at Firozabad. The matter was however not further pursued by either.

Dikshit (1969, 139-144), besides relating information from Dobbs' report, provides several other examples of efflorescent alkaline deposits being employed as the sole or principal ingredient in glass manufacture at other places in India in the nineteenth and early twentieth century. All these however involve the heating of the alkali in earthen pots or crucibles to melt and form glass. The use of tank furnaces is not described in any of these cases. It is interesting to note in this regard that excavations at Kopia in eastern Uttar Pradesh, a glass production site determined active for a considerable period from around the third century BCE onwards, have also yielded crucibles apparently used for manufacturing glass (Roy and Varshneya 1953, Kanungo *et al.* 2010). The discovery of crucibles, purportedly for glass melting or production, is also reported by Chaudhuri (1983) for sites elsewhere in the country, some of which date up to pre-modern times. On the other hand, no tank furnaces of the kind found in the Jalesar-Purdalpur-Akrabad region are reported anywhere. The available evidence seems to suggest that the coming of tank furnaces was a later development, closer to modern times, building on a more ancient crucible-based technology, in which *reh* was also probably the prime or main ingredient utilized to obtain glass. Such at least appears to be the case for glass produced in the Gangetic belt of Uttar Pradesh.

5.1.5 Batch preparation

Elaborate methods for the harvesting of *reh* are described by Dobbs, entailing the controlled flooding of small patches of land with canal water for a while, the evaporation of water from the pans causing the *reh* to effloresce and form a kind of flaky crust on the surface. This was then scraped off the surface of the land for use. At places where canal irrigation was lacking, *reh* was first collected from the surface on its efflorescing naturally and stored in small heaps. Well water was then added to the heaps and the mixture made to stand for five to six days, the evaporation of water resulting in the formation and collection of a purer form of *reh* on the surface. Samiuddin and Jilani's methods are in comparison more rudimentary, both describing *reh* being collected from the surface on its natural efflorescence, the best time to collect apparently being during the course of a sunny spell following heavy rains. No dearth in the availability of the raw material apparently existed, the Gangetic region being replete with *usar* (alkaline) lands in which *reh* is known to occur and effloresce cyclically (Coggin Brown and Dey 1955, 512-513). The character of the region has only changed recently with increased areas being brought under cultivation. Even now, patches of land exhibiting the efflorescing of *reh* are found to exist in the region (Figure 5.8).

Figure 5.8 A crust of *reh* on a patch of soil near Akrabad. Its muddy-brown compacted appearance seen here is on account of recent rain.

Once collected, the *reh* could be stacked and stored for a while under cover for use at a later date. Some prior preparation, before the melting stage, was apparently necessary for the *reh* to be converted to either green or black coloured glass, as required. No colours other than these two could apparently be attained through traditional manufacture. Further colouration of the green coloured glass, if necessary, was undertaken separately at a later stage. Black glass could not be coloured further, and was an end product in itself. The association of only green and black coloured glass with traditional manufacture is corroborated through glass debris found in the vicinity of the two examined furnaces (Figure 5.9), chunks or lumps of glass of only these two colours being seen scattered around.

Figure 5.9 A lump of green coloured glass partially buried in the soil, adjacent to the Mohanpura furnace.

To get green coloured glass, the artisans state that the *reh* had to be first scorched or roasted in the furnace. Small quantities of the ingredient were added at a time through the filling-hole to be roasted for twenty four hours, before being scooped out into the side pit[22] adjacent to the melting chamber, using the opening provided there. This process continued for seven to eight days, the roasted *reh* being removed daily and stacked to make up the quantity required for its introduction into the furnace *en masse*. Dobbs, while mentioning the roasting process, does not specify on its requirement for green coloured glass only. He states that scorched *reh* was used for

[22] See Figure 5.4 for location of the pit.

both green and black glass. The usual batch prepared for green coloured glass, in his opinion, comprised essentially of scorched *reh*, to which was added some four percent of saltpetre (Dobbs 1895, 32). Samiuddin and Jilani unequivocally declare that nothing other than roasted *reh* was needed to make green glass. Sode and Kock (2001) too speak of the roasting process, but connect it with the roasting of sand before its mixing with soda to form the batch, the action of the introduction and removal of sand from the furnace being similarly described otherwise.

To get black coloured glass, according to the artisans, one part of roughly mashed goat dung[23] was added to four parts of *reh*, both being mixed well to make up the batch before its introduction into the furnace. The use of goat or sheep dung in similar proportion is also reported by Dobbs (1895, 32), who states that the same was used to produce a relatively inferior version of black glass, the better or first quality version being manufactured by adding one to four percent of black iron oxide and a small quantity of saltpetre to scorched [sic] *reh*. A typical batch, as per the artisans and Dobbs, consisted of about four hundred *maunds*[24] of the raw material, principally *reh*, prepared in the manner as applicable for the colour variety of glass desired.

5.1.6 Melting and consumption

According to the artisans, the batch, when prepared in the required quantity, was loaded into the melting chamber in one go through the filling-hole, differing from Sode and Kock who remark that the batch was introduced in stages over some days, and melted accordingly. Otherwise all agree that once introduced, the batch was spread out evenly in the melting chamber by means of a long-handled iron hook, utilizing the windows as work-openings. The openings were then sealed and a fire lit in the firebox of the furnace to burn day and night, fed continuously with dry stalks of mustard, maize, and lentil plants through the stokeholes. The use of similar fuel is mentioned by Dobbs as well. Rotatory shifts, employing two to three men at a time, are said to have ensured that the fire kept going. The progress of melting was monitored through the work windows. Some working was apparently necessary in

[23] The source is locally referred to as *bakri* manganese, *bakri* meaning ‘goat’ in Hindi-Urdu.
[24] Approximately fifteen tons (1 *maund* = 37.3 kilograms).

the initial stages. As the batch would begin to fuse at the surface, the artisans state that it would be raked time and again with the long-handled iron hooks to create furrows, exposing the underlying portions to the heat of the furnace. When the heat was deemed to have penetrated enough, and the melting evened across the thickness of the batch, the raking would be stopped, the whole mass then being left alone to bubble and form glass. No let-up in the fuelling of the fire occurred at any stage.

A notable step in the sequence of operations that is not mentioned in Sode and Kock's report, or by Dobbs, would have been taking place at around the same time. Samiuddin and Jilani both state that the pit utilized for the extraction of roasted *reh* had a secondary function as well. The opening from the pit into the melting chamber while being sealed for the firing would have had a small hole left open, into which a metallic tube would be fitted, connecting the melting chamber with the pit outside. As the *reh* or batch would begin to fuse, some part of the alkali would turn runny and separate from the mass, exiting as a liquid through the tube into the pit outside. Here it would crystallize to what was locally called *namak*[25], a by-product of the process, to be utilized as a home-remedy by the artisans, or sold in the local market, as a cure for indigestion[26].

By the middle to the end of the third week[27] the melting would be complete, no bubbling now taking place in the molten glass. At this stage, as per the artisans, a large fruit or vegetable such as a pumpkin would be skewered at the end of a long iron rod and inserted into the molten mass, causing it to bubble violently for a while as the fruit burnt and decomposed. The churning of the melt apparently caused leftover impurities to rise to the surface and move to the sides of the furnace, to be ladled off through the work windows, cleansing the glass in the process. Once cleansed, the fire was extinguished and the furnace cooled for two weeks to allow the glass to be removed[28]. A portion of the side wall of the melting chamber would

[25] Literally 'salt', taken to mean sodium chloride, but could also be sodium bicarbonate, or a mix of sodium chloride and sodium sulphate (Tanimoto and Rehren 2008), in this case.
[26] Crude bicarbonate of soda is still prescribed as an antacid to treat indigestion in many parts of rural India.
[27] Dobbs (1895, 32) mentions eighteen days, while the artisans say about three weeks. Sode and Kock (2001, 165) assign a period of melting of thirty days.
[28] Dobbs' version differs here. He mentions, perhaps erroneously, that the melted glass was made to run out into a pit to cool.

then be broken, and the glass removed in chunks using crow bars, hammers and chisels as tools. Cracks and recesses that appeared in the slab with its cooling facilitated its breaking into smaller pieces.

As per the artisans, the yield from four hundred *maunds* of *reh* would typically be about three hundred *maunds* (approximately eleven tons) of usable raw glass, similar figures being quoted by Dobbs (1895, 32) in his report. The lowermost layer or portion of the glass slab, being contaminated through contact with the earthen flooring of the furnace, was normally recycled. Only a part of the produce is said to have been retained for the local bead and bangle industry, the overall production far outstripping local demand and mostly meant for consumption elsewhere. Green glass was exported to established centres of ceramic manufacture in the region around, such as Hapur and Khurja, to be used for the glazing of pottery, and transported to other centres of bead and bangle-making in the larger region around as well. A substantial portion of the produce of black glass was destined for bead-making centres in southern India.

Interestingly, the glazing of pottery that was being carried out at centres such as Hapur and Khurja at the time of Dobbs' report, are said to have been making use of mainly clear glazes; the only colorant added at times being copper oxide to obtain turquoise coloured glazes. The local bead and bangle industry on the other hand was apparently utilizing a variety of colorants. These were being added to raw green glass to achieve glass of different colours (Dobbs 1895, 32-33), a practice that continued until fairly recently before the arrival of the modern glass industry. No manufacture of ceramics, or their glazing, was apparently carried out in the Jalesar-Purdalpur-Akrabad region. The current local population is unaware if such a practice was ever followed here. No mention of the same is also made by Dobbs.

5.1.7 Chemical composition and comments

Sode and Kock (2001, 165) report the chemical composition of glass frit [sic] collected during their study at Jalesar to consist of: SiO_2, 71.3 wt%; TiO_2, 0.49 wt%; Al_2O_3, 6.7 wt%; Fe_2O_3, 1.5 wt%; Cr_2O_3, 0.014 wt%; MgO, 0.6 wt%; CaO, 2.0 wt%; Na_2O, 16.0 wt%; K_2O, 1.5 wt%; and SO_3, 0.14 wt%. Their results, notably the alumina and magnesia values, match what is generally considered a typical ‘Indian Glass’ composition, such values being reported by Brill (1987) and others (Dussubieux *et al.* 2010, Kanungo and Brill 2009) on the analysis of glass specimens or objects said to be of an Indian origin. The high alumina content is typically attributed as being characteristic of a local variety of sand used, while the low magnesia values are ascribed to the employment of a local mineral-soda flux. The use of a two-ingredient batch, comprising sand and soda, is insinuated in all these reports.

Given the findings of this study, there is a however a greater likelihood that the above-described composition is associated with the use of just *reh* for the manufacture of glass. The high-alumina and low-magnesia peculiarity of Indian glass in that case should be related to *reh* and the impurities that it carries alongwith. While the low-magnesia of Indian glass can be maintained as being an indicator of the use of mineral-soda flux, *reh* in this case, the high-alumina can be explained as reflecting the alumina content of the soil from where the *reh* was collected, introduced in the batch by virtue of being a contaminant in the latter. The earlier presumption of high-alumina arriving in the composition on account of the use of a local sand variety is certainly less tenable. Going further, it may be tentatively assumed that similar high-alumina and low-magnesia values in a soda glass composition, where found, reflect the use of an efflorescent alkaline deposit as a single ingredient in glass production. More investigations, on the compositions of the soils from where *reh* is collected, and the analysis of primary production remains, are however required before the same can be stated with certainty.

An unanswered question that remains is then what exactly did Sode and Kock document. From their report and given evidence it seems that they were probably privy to a very late and recent development in glass manufacture in the region, in which the raw materials were drawn from contemporary glass production, while the furnaces remained traditionally constructed and operated. It is worthwhile noting in this regard that glass being now produced in Firozabad, although following the modern sand-soda technological model does not actually use sand as described by

Sode and Kock, rather makes use of crushed quartz that is commercially mined in the province of Rajasthan.

If on the other hand, what Sode and Kock report as being sand, is considered to be actually *reh*, then all the procedures described by them fit well with the findings of this study. The use of soda as a second and distinct ingredient in fact seems to be more of an assumption than an observation in their report, very little detail being provided in this respect (Sode and Kock 2001, 165). It may also be noted that Sode, who documented the processes in 1995, was present at the site for only three days, and could not possibly have observed all the stages involved in the entire production cycle. Whether subsequent visits made by him during 1997 and 1999 were spent in observing other furnaces in operation is also not mentioned clearly in their report, emphasis instead being laid on describing some non-functional furnaces for this time. Whatsoever the case, it is clear that the two-ingredient sand-soda model proposed by them cannot be deemed applicable to glass manufactured traditionally in the surveyed region, findings to the contrary being determined through this study.

5.1.8 Glass production in the Punjab

Although traditional glass manufacture is not ordinarily known to be associated with the region of Punjab that also lies in northern India, Hallifax (1892) writing for the government of British India at around the same time as Dobbs (1895), indicates that raw glass in notable quantities was also being produced in the undivided Punjab in the nineteenth century, primarily to meet the requirements of a local bangle industry. While many centres of glass-working in this region, such as Ambala, Amritsar, and Lahore, had apparently opted for cheaper glass coming in from Delhi or Agra, some traditional forms of manufacture were also being employed at other places here. At Mooltan [Multan] and Dera Ghazi Khan in western Punjab for instance, Hallifax (1892, 23) says that glass or *kanch* was being manufactured using equal parts of locally available powdered ‘sandstone’ [sic] (probably a quartz-rich stone) and *sajji*, a local carbonate of soda. In the easternmost district of Gurgaon, which abuts Delhi and modern Uttar Pradesh, raw glass is described as being manufactured using just *reh*, suggesting the employment of processes similar to those discussed by Dobbs.

More details of the technology prevalent in the parts of Punjab away from Delhi is provided by Hallifax in his description of glass production at Hoshiarpur, a city and district in what is now Indian Punjab. Here, in the first step of a two-stage process, three parts of *sajji*[29] are said to have been pounded with two parts of quartz to which was then added some water and the whole well-mixed. The mixture so obtained was shaped into small balls that were first heated in a furnace to red heat to fuse, and then cooled and pounded to a powder. The second stage apparently involved adding one and a quarter parts each of borax, saltpetre, and *kallar*[30] to this powder, the whole then being placed in earthen vessels and fired in a furnace for three days to obtain *kanch*, or glass. The second stage seems to have been carried out with the intention of cleansing or refining the glass.

While no such manufacture is now known or witnessed in contemporary Indian Punjab, Rye and Evans (1976, 94-96) have documented similar procedures being employed by artisans working in the traditional tile industry at Multan in recent times. A two-stage process is reported here too, the first entailing the preparation of semi-fused balls in much the same manner as given by Hallifax, although equal parts of a crushed 'quartzite' stone (*karund* or *kurand*) and soda (*khar*) are used in this case, the soda notably identified as being derived from a plant ash source. The second firing, following the pounding of the balls to powder and the addition of small quantities of borax[31], is similarly carried out in earthen vessels or crucibles as described by Hallifax. The interiors of the crucibles are reported as being pre-coated with a layer of sand-clay mix before the introduction of the *karund-khar* batch and its melting (Rye and Evans 1976, 96). This allowed the glass or glaze frit being formed within to part easily when the crucibles were broken for its removal[32]. Rye and Evans (1976, 97) further inform that the glass frit was either fused in the same kiln as used to fire pottery or tiles (Figure 5.10), or in special small frit furnaces constructed for the purpose (Figure 5.11).

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[29] The source of soda is not mentioned but is most likely to have been commonly available plant ash soda, referred to locally as *khar*, *sajji*, or *sajji khar*, mineral-soda being less-known for use in the region.

[30] An alkali efflorescence found on local soils.

[31] A typical proportion is said to comprise one sixteenth part of borax to one part of the *karund-khar*.

[32] Remarkable similarities exist between the processes described here and those utilized for Late Bronze Age glass production in ancient Egypt three millennia or so earlier (Rehren and Pusch 2005).

The use of equal proportions of crushed *kurand* stone and *sajji* or *khar* as the primary raw material are also mentioned by Khan (1985, 48) in his description of the preparation of glazes for tiles used in a restoration project at Multan, a consistency and continuity in technology apparent in the industry in Pakistan Punjab. In contrast, no traditional glass-making or glazed ceramic manufacture is known to exist anywhere in Indian Punjab in the current date.

Figure 5.10 A typical kiln employed in the traditional pottery and tile industry in Pakistan. Glass frit to be used for glazing is usually manufactured in-house, mostly utilizing the same kiln (from Akhund and Askari 2011, 66).

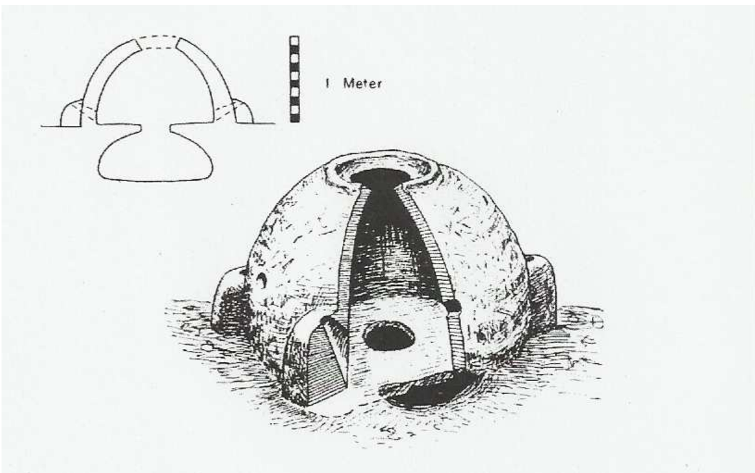

Figure 5.11 A Multan frit furnace with part-sectioned perspective view. The firebox is below the ground level while the chamber lies above (from Rye and Evans 1976, 97).

5.1.9 Summary

Different technologies are recorded as being employed in traditional glass manufacture in the northern Indian regions of modern Uttar Pradesh and Punjab over the nineteenth and twentieth century. In Uttar Pradesh, raw glass (*kanch*) was being produced until recently in circular tank furnaces, the Jalesar-Purdalpur belt being its last known location of manufacture. A reassessment of technologies gained through this study indicates that only a single ingredient, namely *reh*, was employed in glass production in this region. *Reh* occurs naturally as efflorescence on saline soils in the region, and was collected from the surface through a variety of methods for use in glass manufacture. The fusing of *reh* on its firing in a furnace would yield either only green or black coloured glass, of which only green glass could be further coloured through a secondary melting with added colorants. High-alumina and low-magnesia content in a glass composition, a typical feature of Indian glass, tentatively seems to be a characteristic of glass manufactured utilizing *reh*, or a similar sodic efflorescent, as a single ingredient. Glass manufactured utilizing *reh* was typically employed for traditional glass bead and bangle-making, and for the glazing of pottery.

In Indian Punjab, traditional glass is recorded as being manufactured in the nineteenth century utilizing a two-stage process, such a practice still prevailing in the traditional tile industry at Multan that lies in Pakistan Punjab. In the first stage, balls made of approximately equal parts of crushed quartz and plant ash soda are heated in a kiln to a semi-fused state, and then crushed to a frit powder. In the next stage the powdered frit is mixed with borax, and at times other fluxes, and fired in earthen crucibles to attain raw glass of a better quality than the earlier prepared frit. Firing is undertaken either in specially constructed frit furnaces, or in the same kiln as that used for the firing of ware.

Glass manufacture in eastern parts of the earlier undivided Punjab, adjoining what is now modern Uttar Pradesh and Delhi, was carried out using technologies similar to that recorded for traditional production in contemporaneous Uttar Pradesh. No traditional glass manufacture is known to exist now in Indian Punjab.

5.2 Traditional glazed tile manufacture in northern India

5.2.1 Introduction

While many centres of traditional pottery manufacture are known to still exist in northern India, it is only at Jaipur[33] that an industry engaged in the production of glazed tiles is found, which utilizes technologies associated typically with Islamic ceramics. The Blue Pottery industry centred on Jaipur, so-called for the dominance of blue colour in its products (Figure 5.12), is popularly believed to have been established around the same time as the founding of the city in 1727, when artisans from around the country were invited by the then ruler Sawai Jai Singh I to make the new city their home (Bordia 2014, 79). Substantive evidence of its existence is however first encountered only in the nineteenth century after the advent of British rule in India, when locally crafted products began to be displayed in various exhibitions for the promotion of Indian arts and crafts. Notable of these expositions was the Jeypore [Jaipur] Exhibition of Indian Crafts held in 1883, the catalogues of which provide us with information on the raw materials being used in the ceramic industry in Jaipur at that time. Two kinds of pottery, of stone and clay, were apparently being made locally, the former type closely resembling modern Blue Pottery in description. The bodies of this stone pottery reportedly constituted five parts of locally mined 'feldspar' [sic] (probably quartz), one part each of *multani mitti* (fullers earth) and glass, half part each of borax, marble, and *katira* (a tree gum), and a quarter part of sugar candy. The bodies were moulded to shape, and then coated with a transparent glaze through a kiln firing to obtain the desired ware (Bordia 2014, 88). It is said that a similar Blue Pottery industry, on a more modest scale, was also once prevalent in Delhi, but little of this exists now, the craft being reduced to little more than a studio art form here.

The peculiarity of Blue Pottery ware that sets it apart from other local traditionally manufactured glazed ceramics is the use of crushed-quartz in the preparation of its bodies, as opposed to the use of clay elsewhere. It is thus the only stonepaste industry known to exist in the region, and in the country. Watt (1903, 90), writing for

[33] The city of Jaipur is located 250 kilometres south-west of Delhi, in the province of Rajasthan.

the catalogue on the Indian Art exhibition held in Delhi in 1903, suggests that the origins of this stonepaste technology lay in Delhi, where it was being traditionally used for the manufacture of *martabans*, a kind of pickle jar. Its transmission to Jaipur is stated by him as being likely facilitated by an apprentice of a master potter at Delhi, who was induced to join the School of Art at Jaipur set up for the promotion of local arts and crafts. Some additional information on the state of the craft in nineteenth century northern India can also be gained from the report of Hallifax (1892), who besides commenting on glass production as discussed in the previous section, provides an insight into the organization of the pottery industries in the Punjab, including Delhi, at that time. An industry at Delhi is noted by him as differing from all others in choice of raw material, utilizing powdered rock (*burbura*) to produce vessels and dishes under the name 'Kam Chini' (Hallifax 1892, 18-19). Mention is also made by him of an earlier report on the craft by Baden-Powell (1872, 227), who calls it 'Hindustani Chini' (literally 'Indian Porcelain'), made up of what he calls 'disintegrated feldspathic rock', that was glazed with *kanch* and quartz, and utilized mainly for the production of inkpots (*dawats*). Very little of any such industry exists in Delhi today, the craft virtually relegated to an art form here as mentioned earlier, and practised only by a few individuals.

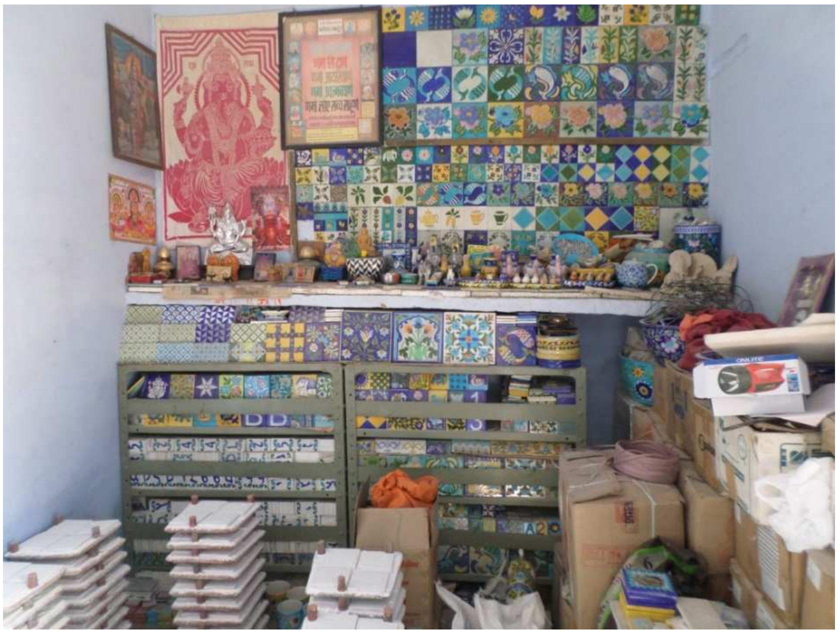

Figure 5.12 Samples of a range of tiles produced in a Blue Pottery workshop at Jaipur. The dominance of blue colour in the products is said to give the craft its name.

Some transformation in the craft are likely to have occurred in post-independent India, in the second half of the twentieth century, when efforts were made for its resuscitation to create new markets for the benefit of the artisans. Notwithstanding the changes that are likely to have taken place over time, the materials and processes currently employed in the manufacture of Blue Pottery are still worthy of a detailed study to assist shed light on technologies associated with glazed tile production in the region in the past.

For this study, a survey of two small workshops at Jaipur associated with Blue Pottery manufacture was carried out. An earlier published report on the craft by Yadav (1999) was made use of for a preliminary evaluation of practices being currently followed. Although Yadav's report was prepared on the state of the craft at Delhi, details given therein sufficed for carrying out a general comparison with production operations at Jaipur too, technologies employed at both places known to be quite similar. Additional information was collected by observing the live manufacture of some Blue Pottery tile specimens, and through discussions with artisans engaged in the trade. These details and demonstrations were primarily provided by two senior artisans, Ramgopal Verma (Ramgopal) and Anil Jain (Anil)[34], both of whom have been involved in the manufacture of Blue Pottery ware for the local market for long. Notes that were made were subsequently cross-checked against details provided in a more recent publication (Bordia 2014) brought out by the key player and promoter of the Jaipur Blue Pottery industry. Information thus gained on the technologies involved in traditional Blue Pottery manufacture is discussed in the succeeding paragraphs.

5.2.2 Preparation of the bodies

The bodies, as indicated earlier, consist essentially of crushed or powdered quartz, to which are added other ingredients to aid in shaping and forming. A typical body comprises forty parts of crushed quartz[35], four parts of raw green glass (*hara kanch*) or eight parts of white glass powder (*safed kanch*)[36], one part of *sajji mitti* (crude

[34] Proprietors of Laxmi Blue Potteries and Arihant Potteries respectively.

[35] Of 100-150 mesh size, equivalent to 150-100 microns particle size.

[36] Obtained by the crushing of cullet of cheap quality white glass, the kind used in local tea stalls.

bicarbonate of soda), one part of *katira gond* (a tree gum), and one part of *multani mitti* (Fuller's earth). While all the ingredients are nowadays commercially available in more or less ready-to-use form in the market, these were earlier procured in a raw state from suppliers engaged in the trade of each. Quartz for instance, is said to have been obtained as rocks from quarries at Beawar and Kishangarh in the province, and then broken down and crushed for use in workshops using a traditional stone hand-mill or an iron mortar and pestle. Green glass, interestingly, is said to have been imported in chunks from Jalesar in the past, but has now been replaced by white glass cullet as an ingredient, being no longer available in the market.

To prepare the bodies, the ingredients, after being pre-ground down to a fine powder, are mixed together using a little water, and kneaded to the consistency of dough. After leaving overnight, the dough is flattened to a slab of desired thickness using a wooden block or a rolling pin. Smaller slabs of required size are then cut from the dough, and pressed into moulds for the shaping of articles (Figure 5.13). Joints are applied where needed to obtain more complex forms[37]. The finished article or object is then left to dry slowly, usually outdoors, for a day or two, before applying a slip, and then an engobe[38].

Figure 5.13 Tile bodies being prepared. Note the rolled piece of dough in the shadow in the foreground.

[37] The stages involved in the shaping and forming are illustrated in detail by Bordia (2014, 104-107).
[38] Called *asthar* locally.

The slip is similar to the body in composition, essentially being slurry of the same ingredients, in which the object is dipped to fill pores and other surface defects to finish, before being dried once again. The engobe differs somewhat from the body and slip, consisting of only crushed quartz, of finer grain-size[39], and white glass powder. This is applied to provide a smooth even surface for painting on colours. A typical engobe coating is prepared by mixing well ten parts of crushed quartz with one part of white glass powder, some flour paste being added for binding. The whole is then diluted with some water to attain slurry of the right consistency. The finished articles are dipped in this slurry resulting in the application of a white coloured coating on the body surface (Figure 5.14). The articles are then dried again in the manner as before.

Figure 5.14 A set of relief-embossed tiles coated with an engobe.

5.2.3 Decorating and colouring

On drying, in the case of underglaze-painted pottery or tiles, outlines of motifs and patterns are stencilled or drawn by hand on the engobe, and then filled in with colours of different oxides using fine brushes. All the colours are commercially available metal oxide pigments procured from the local market. Ramgopal informs us that in the past a copper-blue pigment was prepared in a traditional manner by scraping off the corrosion product on copper vessels and utensils, and then grinding

[39] Of 300 mesh size, equivalent to 50 microns particle size.

the powder collected further[40]. No such in-house manufacture is however known to exist today, even this pigment being now sourced from the local market.

Of the procured colorants, the oxides of copper, cobalt, and chromium, responsible for turquoise, dark blue, and green colours respectively, are to undergo some preparation before they can be used for underglaze-painting. These are subject to grinding with a mortar and pestle for up to a week to obtain a particle size of appropriate fineness. A little water is added to facilitate the grinding process. When ready, the pigment-paste is mixed into a solution of *katira* (Tragacanth gum) in water, added to improve its binding, and applied on the engobe with a brush. Grinding is apparently necessary even when the pigments are used for the direct colouring of glazes, being mixed into the glaze powder only after an appropriate particle size has been achieved.

5.2.4 Preparation of glass frit

Glass frit used for the glazes is not sourced directly readymade, but is prepared in the workshops using raw material procured from the market. A typical batch comprises forty parts of cullet of white glass, twenty parts of lead oxide (*sindoor*), and twenty parts of borax (*suhaga*), the cullet being coarsely ground separately and then well mixed with the other ingredients for use. The prepared batch is then loaded in a graphite crucible and fired in a furnace for melting. Yadav (1999), while stating that artisans at Delhi use the same kiln for firing of objects as well as for the preparation of frit, goes on to add that a separate furnace for frit-making is known to be employed at Jaipur. The functioning of one such frit furnace operated by Ramgopal was observed, bringing to light the technology involved in the fritting process.

A small cylindrical-shaped furnace resting on a square base was employed for the purpose. The furnace was about a metre and a half in height, constructed of fired bricks and plastered over (Figure 5.15). The crucible containing the batch, and with a small hole provisioned in its base, was placed on top of a hollow stoneware pipe fitted vertically in the centre of the furnace (Figure 5.16). The pipe was supported on

[40] Anil is unaware if such a process was ever followed.

its lower end by a steel plate inserted into the furnace wall, creating a one-sided-open chamber in the lowermost portion of the furnace in the process. A hole of a diameter less than that of the pipe was beforehand cut out from the centre of the steel plate, the pipe being positioned over the hole while being fitted accordingly. A steel pan containing some water was placed in the chamber below the pipe and plate. The pipe, near its upper end, was supported by a series of iron bars that were laid horizontally like a mesh, and fitted into the furnace wall for support. Two sets of openings were provided in the furnace wall, one set just above the rim of the crucible, and the other just above the steel plate. The openings above the crucible were used to replenish the batch, as required, and to fuel the furnace as well, by constantly piling charcoal around the crucible. The lower set of openings was utilized to extract the spent fuel of charcoal ash from the furnace. The top of the furnace was loosely covered by a second steel plate.

Figure 5.15 A traditional Blue Pottery glaze frit furnace.

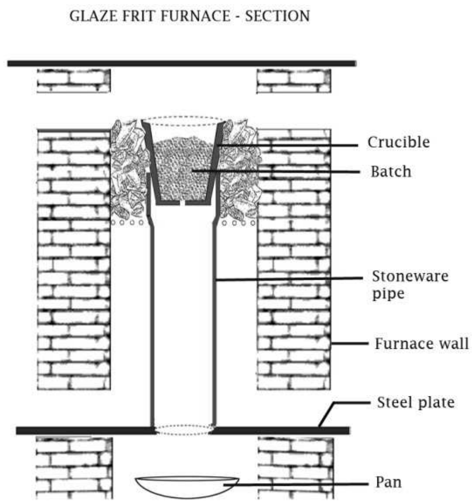

Figure 5.16 Schematic representation of a typical Blue Pottery glaze frit furnace.

On sealing of the openings and firing of the furnace, the batch began to fuse (Figure 5.17). After about two hours of firing an appropriate temperature was reached, wherein molten glass started being formed in the crucible. This began to fall first in drips and then as a long continuous molten filament, flowing through the hole in the bottom of the crucible into the pan of water below, where it immediately cooled to a glass frit (Figure 5.18). As the batch reduced in quantity in the crucible, the artisan would simultaneously replenish it by ladling in additional quantities through the work-opening (Figure 5.19), this continuous filling and melting cycle ensuring an uninterrupted production of frit till such time the desired quantity was obtained. The frit being formed in the pan was meanwhile also being removed from time to time and placed in the sun for drying (Figure 5.20), for short-term or later use.

Figure 5.17 Fusing of the batch in the crucible.

Figure 5.18 Molten glass dripping into the pan.

Figure 5.19 The batch being replenished as the frit is formed.

Figure 5.20 Glaze frit collected from the pan.

5.2.5 Glaze application and firing

For glazing, the glass frit is typically ground in a stone hand-mill to a fine powder, colorants being added and mixed into the powder at this stage in case a coloured glaze is desired. The powdered frit is otherwise mixed into a glutinous paste obtained by boiling refined flour in water, the whole then being diluted with some more water to attain slurry of the right viscosity. The articles are then individually dipped and swirled in the slurry to be covered in a glaze-coat (Figure 5.21), and allowed to dry well prior to their firing.

Figure 5.21 A glaze coat being applied on a tile body by dipping it in slurry of the powdered frit.

While firing is nowadays often carried out in modern kilns to a maximum temperature of 800 ^{o}C, as described by Bordia (2014, 112-113), traditional updraft kilns are also employed, though in much lesser numbers than before. A typical traditional kiln, as used by Anil, is a brick-constructed and plastered cylindrical structure[41], about two and a half metres in diameter and a metre and a half in height, with a firebox provided below ground level (Figure 5.22). Its chimney opening on the top is left large enough to allow an artisan to enter and load the kiln. The articles are stacked on shelves, props, and other kiln furniture, and a fire lit in the firebox below, stoked from the outside with a supply of wood. The firing lasts about five to six hours[42], during which time a temperature of around 750-800 ^{o}C is attained (Yadav 1999, Bordia 2014, 112). The kiln is then allowed to further cool for another thirty six hours before the articles can be removed.

On examination, the finished articles are found to have cream or white coloured bodies, with glaze layers that are about a millimetre thick. The glazes are bright,

[41] Yadav (1999, 14) describes a kiln at Delhi as being cuboidal in shape from the outside, and round or cylindrical within.
[42] As per Anil, each firing typically consumes about five and a half quintals of wood.

likely on account of their significant lead content, well-adhered, and mostly free of blemishes. The artisans inform us that efforts are currently on to develop lead-free glazes in the industry.

Figure 5.22 A Blue Pottery kiln at the workshop of Anil Jain in Jaipur. The wooden boards on the floor adjacent to the kiln cover the stokehole, the firebox being located beneath the kiln, below ground level.

5.2.6 Summary

The traditional Blue Pottery industry, centred on Jaipur and with likely antecedents in Delhi, is engaged in the manufacture of glazed ware, including tiles, utilizing stonepaste technology. While oral tradition attributes the beginnings of this craft industry to the first half of the eighteenth century, physical evidence of its existence is first recorded only in the second half of the nineteenth century. Some changes in the craft technology have apparently occurred over time, from the period of its first recording to practices being currently followed.

The bodies of Blue Pottery ware are now made using primarily crushed quartz and cullet of white glass, in proportions of ten parts to two parts respectively, some clay, crude soda, and gum being also added in minor quantities. Raw green glass was earlier used instead of cullet, in half its proportion, but is no longer available in the market. The bodies are coated with a slip of similar composition, and then with an engobe made up of crushed quartz and glass, the engobe being applied to facilitate the application of underglaze-painting. Pigments and colorants employed are typically subject to grinding before use. All colorants used are of modern make, sourced from the local market.

Glass frit to be used for glazing is manufactured through a distinct process, utilizing a traditional frit furnace. A typical glaze batch comprises two parts of glass powder, and one part each of lead oxide and borax. The batch is loaded in graphite crucibles and fired for five to six hours in the furnace to attain molten glass. The molten glass is then introduced into cold water to form frit. Glass frit is powdered and liquefied to slurry, into which the finished bodies are dipped to obtain a glaze coating on their surface. For coloured glazes, the colorants are mixed with the glaze powder in dry form, prior to its liquefying to slurry. The glaze-coated objects or articles are then fired in traditional updraft kilns, nowadays more often in modern kilns, for between five to six hours for the glaze to melt. A maximum temperature of around 800 ^{o}C is attained in the kiln during the process. Finished articles are removed from the kiln after a cooling period of a further thirty six hours.

While the technologies associated with the craft have clearly altered significantly over time, making it difficult to carry out comparisons with earlier Islamic traditions, some of the methods employed for the production of the ware are still worthy of attention. The use of green (raw) glass alongwith crushed-quartz in the preparation of the bodies for instance, is reminiscent of practices described by Abu'l Qasim for the manufacture of stonepaste bodies in medieval times, the proportions of the ingredients being remarkably similar in the two cases. The sourcing of the green glass from Jalesar likewise, in a way corroborates Dobbs' (1895) statement on the interdependence of the glass and ceramic industries in the region in the nineteenth century, although he does mention that the glass being imported into ceramic centres at that time was being mainly used for glazing purposes. It is quite possible that the glass that was being used in the bodies of Blue Pottery ware till recently was at a point being used for their glazes as well, before the advent of the lead oxide and borax based technology.

What is also useful from the study is the information gained on production processes that become virtually invisible during subsequent analysis. The addition of an organic binder to the glaze slurry to attain a better application and glaze-fit for example, or the use of natural gums for the application of the pigments for painting, cannot be determined by just examining the material at a later stage. Such information, and others determined through live observations, is highly beneficial in aiding interpretations when the reconstructions of past technologies are attempted through analysis.

6. LODHI TILE-WORK: SURVEY AND ANALYSES

This chapter, divided over three sections, describes findings of field and laboratory investigations carried out on Lodhi tile-work in northern India, as a prelude to discussions on their history and technology. The first section of this chapter provides a broad appraisal of Lodhi architecture and tiling determined through a generic survey. The next section expounds findings of a more detailed assessment carried out on tile-work embellishing the buildings specific to this study. The third section provides the results of laboratory investigations and analyses carried out on tile samples sourced for the study.

6.1 Lodhi architecture and its tiling

Although the exact number of Lodhi buildings remains an issue of speculation, it is undoubted that the vast majority of these are to be found in the city of Delhi, Ara’s (1982) survey and calculations indicating the presence of more than a hundred such structures here. In contrast only one Lodhi building, in a ruinous state, is known to exist in Agra, and only a few, about half a dozen or so, are reported present in the Punjab. The Delhi buildings can be said to be broadly distributed over three main clusters in the city, as described by Peck (2005, 103). One group is located around the old city of Siri[1] in south Delhi and areas to its west, past Hauz Khas and beyond, another extends to the north of Siri encompassing parts of central Delhi, while a third cluster is located around the quarter of Mehrauli, to the south-west of Siri (Figure 6.1). All these buildings that would have been once located in open plains, beyond the periphery of habitation, are now situated in densely populated areas, either surrounded by modern residential buildings, or found in parks and small islands of green created for their protection within the city.

[1] A fortified city complex built during the reign of Ala al-Din Khalji in the early fourteenth century. It is considered to be the second of the seven cities of medieval Delhi, the ruins of which are now located in South Delhi.

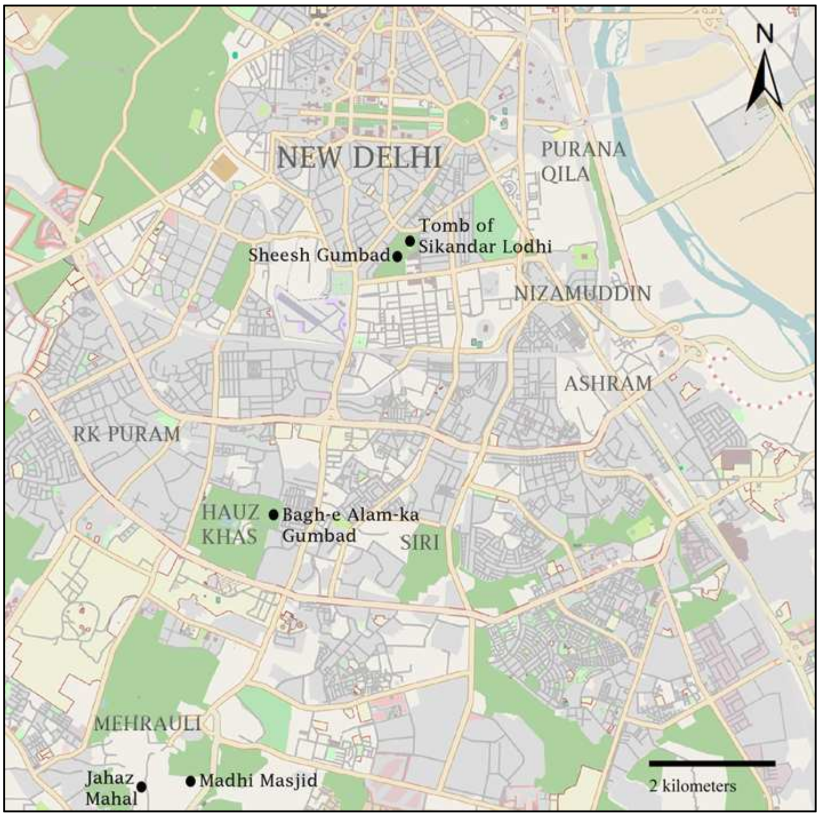

Figure 6.1 Map of parts of south and central Delhi. The black dots, denoting the locations of the Lodhi buildings subject to a detailed study, also mark the approximate locations of the three clusters in which most buildings of this era are found.

The preponderance of tombs and mosques in the architecture of the Lodhis, as brought out in Chapter 3, is quite evident from a survey undertaken on their buildings at Delhi. Equally evident is a general consistency in their form and style, as remarked upon earlier as well. Ara's (1982) contention that Lodhi tombs at Delhi, and possibly mosques too, are of a similar girth and form is however apparently an overgeneralization, such an argument seemingly applicable to the larger tomb-buildings of this period only. Mosques particularly are found to vary considerably in size and style of construction, a substantial number of those existing being unexceptional wall-mosques only. A relatively greater uniformity is noticeable for the tombs, but only if one were to consider those of an imposing size as representative of their typology. In fact the majority of tombs are much smaller than the usual quoted examples, the larger and better known tomb-structures such as Bagh-e Alam-ka Gumbad and Sheesh Gumbad being a class or category of Lodhi buildings by themselves.

Notwithstanding these anomalies, an overall similarity in the appearance and construction of Lodhi buildings is apparent, allowing them to be distinguished from earlier Sultanate specimens. The building material is clearly one such defining feature, a good number of their tombs and mosques exhibiting similar characteristic exterior finishes of grey ashlar stone masonry. Other distinct structural and modal features ascribed to architecture from this era allow most of the surveyed buildings at Delhi to be fairly conclusively identified as indeed belonging to the Lodhi era. Such identification is crucial given the lack of inscriptions on most of the structures and the little information generally available on the identity of their patrons. Of the two main building typologies present here, it is certainly the tombs that are most numerous, square-shaped specimens among these, supposedly meant for nobles of high rank, being the overall dominant building form. The Tomb of Sikandar Lodhi stands out in this regard, being of an octagonal shape, a design that was apparently reserved for use by royalty (Brown 1964, 26-27).

The few Lodhi buildings in Punjab, almost all of which are known to be located in Sirhind[2], are generally of a similar form and style as those found in Delhi. A key difference is that most of them here are brick structures, brick being the preferred medium of construction in Punjab as opposed to stone at Delhi. Only two of the Sirhind buildings, namely the Bibi Taj-ka Maqbara and the Tomb of Subhan, are of a size comparable to the large tomb-buildings at Delhi. Both of these are square-shaped structures, the former being a brick building while the latter is built of stone, a rarity in these parts. Several other brick buildings that are in a fairly ruinous state also dot the landscape of Sirhind all around, but all these are of a comparatively smaller size with little embellishment, some being from the Mughal period as well.

[2] The old town of Sirhind, as known in medieval times, is the area around the modern town of Fatehgarh Sahib, which is where the Lodhi buildings and others of antiquity are located.

Besides their distinctive architectural features, Lodhi buildings can also be identified through the presence of turquoise coloured tiles on their surfaces. The existence of such tiles on some securely dated Lodhi buildings, on the Bagh-e Alam-ka Gumbad (1501 CE) at Delhi for instance, or on the Tomb of Subhan (1496-1497 CE) at Sirhind, corroborate the stylistic assignment of these tiles to this period. Not all Lodhi tombs or mosques are however decorated with tile-work. This survey, which takes into account published references and field observations, reveals the existence of a total of only fourteen such buildings at Delhi, one at Sonepat in Haryana, and another four in Punjab, of which three are at Sirhind and one at Machhiwara. The presence of additional tiled buildings beyond those listed cannot be ruled out, as no comprehensive inventory of such buildings is known to exist. That some lesser known or unprotected tiled structures have been overlooked remains a possibility. The possibility that some Lodhi buildings that have no tile-work decoration now but were tiled at some point in the past also cannot be ruled out. A prime example that illustrates this case is the Tomb of Khwaja Khizr (1524 CE) at Sonepat, which although mentioned as a tiled building constantly since Vogel's (1920) first observation around a century ago, has no tiled decoration currently to speak of. Had the existence of tile-work on this building not been noted earlier, it would not have qualified for consideration. The little known tomb-building of Bara Lao-ka Gumbad at Delhi similarly has only a single tile extant in place, the loss of which would place this building in the non-tiled category. The list of nineteen Lodhi period buildings identified through this study as bearing tiles or being tiled at some point in the past is given in Appendix 6.1.

On all the listed buildings, glazed tiles are found to be only sparsely applied, limited to highlighting architectural features of interest. No restrictions on their use on account of building typology can be determined, these being found applied on tombs and mosques alike. While a connection between building size and the use of tiles cannot be clearly defined, it is clearly the grander and more imposing structures of the time that have been tiled. In fact just one Lodhi tiled structure, the Tomb at Rajon-ki Baoli, is found to be of an unpretentious size, all the others being of significant proportions. A consistency in application can also be evidenced within the overall restraint that marks the tiling of this period. The most common apparently is the laying of tiles in a horizontal row or band on the upper reaches of structures, usually below the parapet. Such an application is exemplified in the row of tiles found on the portals of Chhote Khan-ka Gumbad (Figure 6.2), and by the band that runs across the facade of Nili Masjid, both of which noticeably lie just below the parapet of each building.

Figure 6.2 The restraint that marks Lodhi tile-work, and its common form of application, as a single row or band, are both well-illustrated in the case of tiling on Chhote Khan-ka Gumbad seen above.

Elsewhere, tiles have been judiciously used to break the monotony of flat building surfaces in combination with architectural details. At Bagh-e Alam-ka Gumbad (1501 CE) and Machhiwara Masjid (1517 CE) for example, tiles have been placed in recesses and panels provisioned in building exteriors, emphasizing their existence. At Sheesh Gumbad, the space above the central archways is found to contain blue-and-white painted tiles set within sunken rectangular panels, accentuating the portals. In other but lesser instances as reported earlier, tiles have been used to decorate *chhatri*-features that either form part of the building, as at Jahaz Mahal where such *chhatris* are located on the roof of the structure, or are stand-alone entities as at the Tomb of Sikandar Lodhi (d. 1517 CE) where they flank the entrance gateway (Figure 6.3).

In colour scheme, except for few cases where the tiling is more elaborate, only turquoise coloured tiles are found used on the buildings. All the Lodhi Punjab tiled buildings and the vast majority of their Delhi counterparts are thus adorned with tiles of a turquoise colour only. Only on three Delhi buildings, namely Sheesh Gumbad, Tomb of Sikandar Lodhi, and Jahaz Mahal, is an extension of the palette found, some dark-blue, yellow, and green tiles determined present here as well. These three building and their tile-work decoration are described in more detail in the next section, along with the other buildings taken up for study. It may also be noted that a few tiled buildings that have the characteristics of Lodhi architecture were apparently constructed or at least completed after the end of Lodhi rule, in Mughal times. The departure of the Lodhis apparently did not signal the abrupt end of the tiling traditions associated with their times.

Figure 6.3 One of a pair of tiled *chhatris* located at the entrance to the Tomb of Sikandar Lodhi. This building is one of a few where tiles other than those of a turquoise colour are also found used.

In terms of preservation, most of the tile-work has suffered much, the majority of the tiles on most of the buildings being missing, either having fallen off on account of deterioration of the plaster in which they are embedded, or having been removed through some act of vandalism. Of those in place, the glaze layer is found to have separated and lost in many, leaving only an intact tile body behind. Some intrinsic deterioration of the glaze layer is also noticeable, the glaze colour of some turquoise tiles having altered to a shade of green, but such instances are rare and limited to very few examples. Vegetal growth and blocked water outlets at some of the deteriorated areas of tile-work indicate that not all losses are on account of natural causes, increased damp conditions and a general lack of maintenance on some buildings seemingly aggravating the issue. This particularly seems applicable for structures that are yet unprotected. The necessity of some actions or interventions to ensure their betterment cannot be enough emphasized.

6.2 The buildings and their tile-work

Seven of the listed Lodhi tiled buildings were taken up for a detailed study. Five of these, namely Bagh-e Alam-ka Gumbad, Sheesh Gumbad, Madhi Masjid, Tomb of Sikandar Lodhi, and Jahaz Mahal, are located in Delhi[3], while two others, Bibi Taj-ka Maqbara and Hathi-ka Maqbara are located at Sirhind in Punjab. A brief description of each building and observations on their tile-work decoration, as determined through field work, is given as follows:

6.2.1 The Delhi buildings

i) Bagh-e Alam-ka Gumbad

Alternately at times referred to as the Tomb of Shihab al-Din Taj Khan, Bagh-e Alam-ka Gumbad is a typical square type Lodhi tomb-structure located in the Deer Park at Hauz Khas in south Delhi (Figure 6.4). The building, stated by Ara (1982, 71) to be the tallest of its kind in Delhi, is one of the few securely dated specimens of the period, an inscription on the upper reaches of its western wall naming its patron and ascribing its date of completion to 1501 CE. In construction, the exterior dressed stone walls of the building are relieved by three horizontal rows of arched recesses on each side, with

[3] The locations of these buildings within the city of Delhi are indicated on the map given at beginning of this chapter.

openings provided at the ground floor level. On the roof, a crenellated battlement acts as a parapet, the whole structure being crowned by a hemispherical dome. The interiors of the tomb can be accessed through doorways provided in central projections on three of its sides, the western wall with a *mihrab* in its interior being sealed. The precise identity of Shihab al-Din Taj Khan is not known, but he probably would have been an upper class noble in the court of Sikandar Lodhi, during whose reign the structure was completed.

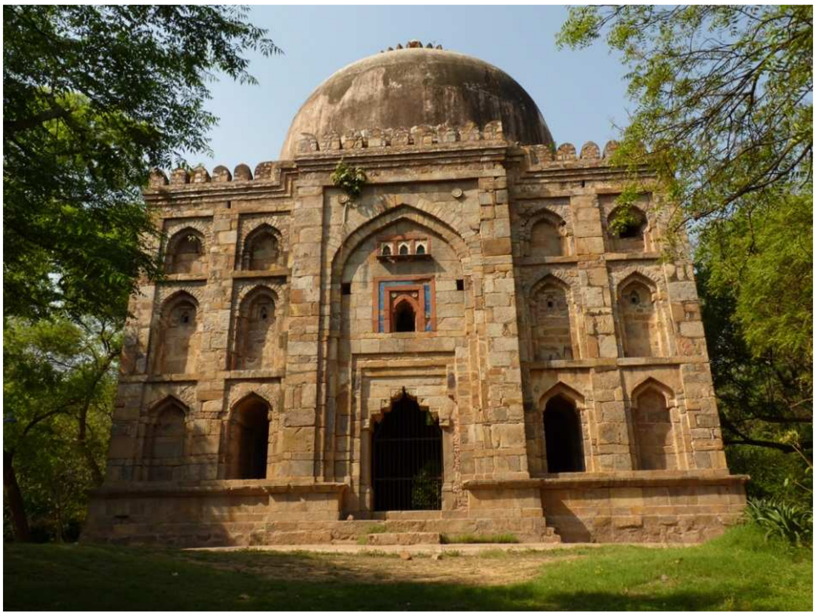

Figure 6.4 A general view of Bagh-e Alam-ka Gumbad.

The turquoise coloured tiles found to enliven the exteriors would have complemented the exemplification of this Lodhi model had the surviving tiles been in greater numbers. In the current state only scant remnants of tile-work can be seen on the building, mainly on the eastern and southern facades, where they are found in sunken panels highlighting the features on which they are affixed or embedded within. The best-preserved tiles are found on a panel on the southern facade, the principal entrance to the tomb, where a band of rectangular-shaped tiles is found sandwiched between two narrow red sandstone borders that frame an arched ventilator-type opening (Figure 6.5). Few tiles are also noticeable in a small niche provided just below the inscription on the west wall (Figure

6.6). It seems probable that tiles of a similar kind were also employed on the upper storey of the building as a narrow band of recessed stonework can be seen below the parapet to run all around the building. Such bands are found to contain tiles in some other Lodhi buildings but in their complete absence here this remains a matter of speculation.

Figure 6.5 Detail of the tile-work on the arched opening on the southern wall.

Figure 6.6 Detail of the tile-work below the inscription on the western wall.

ii) Sheesh Gumbad

Sheesh Gumbad, an imposing tomb located in the Lodhi Gardens at Delhi is perhaps the best known of all Lodhi structures, finding mention repeatedly as a prime example of Lodhi architecture. Built on a square plan, the building follows the pattern of the nearby Bara Gumbad from the same period, and houses the remains of an unidentifiable family from nobility. Externally, the facade of dressed stone masonry is divided by a string course giving it a double-storeyed semblance, the division further enhanced by the placement of blind arched recesses in each (Figure 6.7). The roof bears a large plastered dome. Openings on three sides have been provided in the central projecting middle portions as in other Lodhi monuments, the parapet also being the common crenellated battlement with merlons. The exact date of construction of the building is not known, but is generally ascribed to the period of reign of Sultan Sikandar Lodhi and believed to date to around the turn of the fifteenth century (c. 1500 CE). The tomb has been proposed by Digby (1975) to be that of the first Lodhi sultan, Bahlul Lodhi, a contention that is still subject to debate and not yet accepted by the Archaeological Survey of India.

Figure 6.7 A general view of Sheesh Gumbad.

The attraction of this well-proportioned building is enriched by its tasteful tiled decoration. Extant remnants indicate the original presence of a band of square-shaped blue coloured tiles at two levels all around the exteriors, an upper one below the parapet of the building, and a lower below the protruding string course in the middle. The upper band is more elaborate on the central projecting portions, forming a frieze along with a set of nine underglaze-painted and inscribed[4] blue-and-white tiles on each side (Figure 6.8). Although the name Sheesh Gumbad, which translates as 'Glass Dome', has been considered by some to be suggestive of the original application of tiles on the existent plastered dome, it seems unlikely to have been so, the restrained application as described above quite consistent with prevalent tastes. No use of tiles on the dome can anyway be discerned.

[4] No translation of the inscriptions, which are fragmentary, is known to exist.

A notable aspect of the tile-work of this building is the employment of significant numbers of dark-blue coloured tiles, either alternating with turquoise coloured tiles in application or comprising an entire row by themselves (Figure 6.9). This is probably the first instance of the use of dark-blue coloured tiles in the region. Only on one other known Lodhi building, the Tomb of Sikandar Lodhi, are tiles of a dark-blue colour found. The use of underglaze-painted blue-and-white tiles here likewise has no known precedent, such tiles certainly not being found on any other building erected in the Lodhi era[5].

Figure 6.8 Detail of one of the friezes on the central projecting portions containing underglaze-painted blue-and-white tiles.

Figure 6.9 Detail of a band of dark-blue coloured tiles employed on the building, a colour rarity for Lodhi tile-work.

Not many of the underglaze-painted blue-and-white tiles now survive. Deterioration of the tile-work elsewhere on the building seems equally divided between the loss of complete tiles and the loss of a glaze layer only.

iii) Madhi Masjid

Located in the quarter of Mehrauli in Delhi, the Madhi Masjid, as the name suggests[6], is a mosque, this particular one being a combination of an open wall-mosque and a covered type, having flat-roofed cells provided on either side of an open prayer wall

[5] The only other building at Delhi with painted blue-and-white tiles is the Tomb of Jamali-Kamali (1528-1529 CE) erected in the early Mughal period, such tiles being found here on the exteriors below the eaves. These are however square-shaped and not rectangular or inscribed as in the case of Sheesh Gumbad.
[6] The word 'masjid' translates in Urdu and Hindi to mean a mosque.

(Figure 6.10). At the centre of the relatively loftier wall-mosque is a large arched *mihrab*, flanked on either side by blind arches of smaller size, and of dimensions similar to the openings into the cells on their sides. A battlemented parapet runs the length of the entire structure. The complex, besides the wall-mosque and its ancillary cells that are located at one end, includes a large central rectangular courtyard and an impressive gateway on the east. A pair of projecting windows flanks the main entrance of the gateway, the roof of which is capped by a dome. High walls and corner turrets enclose the entire complex lending it a fortified appearance. No date has been ascribed to this building, but is generally believed to be either of the Lodhi or early Mughal period.

Figure 6.10 A general view of Madhi Masjid.

A single band of turquoise coloured tiles running the length of the mosque-structure, below the battlemented parapet, is the most conspicuous decoration in the complex (Figure 6.11). These tiles, which are of a rectangular shape, appear to be of a darker than usual tone, of a shade that lies between turquoise and dark-blue. Other than this band, small cut-pieces of turquoise tiles are also found employed as insets in elaborately carved stucco medallions that adorn the spandrels of the arches (Figure 6.12), and in small niches that frame or flank them. Turquoise coloured glazed tiles cut to small sizes are also used on the gateway, inset in niches and stucco compositions in a manner similar to that noticed for the mosque-structure, and as a narrow band outlining the profile of the large arched openings here. These are however few in surviving numbers, particularly in comparison to those remaining on the wall-mosque.

Figure 6.11 A close-up view of the band of turquoise coloured tiles employed on the wall-mosque.

Figure 6.12 A stucco medallion on the spandrel of an arch on the mosque-structure, exhibiting tiny turquoise coloured tiles inset in the carving.

iv) Tomb of Sikandar Lodhi (Sikandar Lodhi's Tomb)

This tomb is an octagonal-shaped stone structure also located in the Lodhi Gardens, not far from Sheesh Gumbad. The similarity of its form to tombs of the rulers of the preceding Sayyid Dynasty associates it with royalty, a reason for its acceptance as the tomb of Sultan Sikandar Lodhi although being devoid of any inscription saying so. The building and its adjoining garden form a small complex, enclosed by a high wall and pierced by gates on all sides. The southern principal entrance gate is built on a large raised platform, the whole complex in a way being elevated from the grounds outside. A pair of *chhatris* is provided on the platform, one at each of its forward corners. Inside the enclosure, the tomb-structure comprises an inner octagonal-shaped chamber surrounded by a verandah of similar shape, with openings leading into the interiors (Figure 6.13). On the roof is a large double dome that rises from a sixteen-sided drum.

Figure 6.13 A general view of the Tomb of Sikandar Lodhi.

In the interiors, the upper portion corresponding to the drum is provided with a series of recessed blind arches. The wall surfaces below have a large arch with an entrance and a ventilator-type opening on each side, except for the west-facing side which is sealed. The building is believed to date to around the year of demise of Sikandar Lodhi (d. 1517 CE), its association with the sultan being widely accepted, although yet to be conclusively proved.

In keeping with its so-ascribed royal status, the building is profusely ornamented with glazed tiles, the vast majority of which are employed in the interiors. Individual turquoise, dark-blue, yellow and green tiles have been used here to outline the profile of recessed arches and the rectangular panels that frame them (Figure 6.14). Traces of tiles can also be evidenced on carved stucco medallions located on the spandrels of the arches, the same application technique having been noticed used on the Madhi Masjid. Interestingly, besides their colour scheme which is unique for the period, many tiles in the interior are found laid in a manner to form polychromatic mosaic patterns, marking perhaps the first instance of such use in the region. This type of application is found extensively repeated in later tiling carried out under the Surs and Mughals. Besides the interiors, the two *chhatris* on the outer forecourt, and the southern gateway, were also once decorated with significant numbers of tiles, very few of which now remain. The use of a similar colour scheme as that in the interiors can be determined here, remnants of tiles still affixed to the roof of the *chhatris* exhibiting the same four glaze colours as those found within.

Figure 6.14 Detail of the tile-work in the interiors of the tomb, illustrating a relatively lavish use of tiles of turquoise, dark-blue, yellow, and green colours.

Notably, the tile-work in the interiors of the tomb is found to be in a fairly good state of preservation, most of it being extant, whereas the *chhatris* and the southern gateway that are exposed to the vagaries of nature are almost completely shorn of their glazed embellishment.

v) Jahaz Mahal

Also located in Mehrauli in Delhi, the Jahaz Mahal or 'Ship Palace' is so-called for its design as an elongated rectangular-shaped structure and for its placement in a reservoir, giving it the semblance of a ship in water (Figure 6.15). The exact original function of this building is unclear, as is its patron, the structure said to be either a *sarai* (inn) for travellers constructed during the Lodhi era, or a pleasure palace of the early Mughals. Part of the originally rectangular building has now collapsed exposing a central courtyard around which are placed many rooms or chambers. A *mihrab* on a wall of one of the western chambers denotes the original presence of a small mosque within. Turrets that look like mini-bastions mark the corners of the building, each terminating in a small dome with merlons carved in plaster on its sides. On the roof, a series of ornamental *chhatris* are found added-on, the largest being above the entrance doorway, lending an element of grace to the architectural composition.

Figure 6.15 A general view of Jahaz Mahal.

To decorate, a band of turquoise coloured tiles is found employed below the parapet all around the building, the corner turrets also bearing individual tiles of the same colour embedded in the merlons provided thereon. All five of the originally six *chhatris* on the roof also bear evidence of being profusely tiled in the past as remnants of turquoise coloured tiles can be seen on the square drum bases of each. A difference is noticeable in the colour tone of the tiles used on the *chhatris* as compared to those employed on the main building, the latter appearing darker, as in the case of Madhi Masjid. A single green coloured tile can be discerned on one of the *chhatris* on the roof, but whether the colour is attributable to a deliberately produced green coloured tile or is a result of deterioration of a turquoise coloured specimen cannot be made out. Few tiles are found provided in the ceiling of the largest *chhatri* as well, embedded in small niches that encircle the base of its dome. Each of these niches is adorned with a set of three tiles, an upper and lower of turquoise colour, and a small yellow coloured specimen sandwiched between – these in a way reflecting the palette of glaze colours employed on this building.

6.2.2 The Punjab buildings

i) Bibi Taj-ka Maqbara

This is one of two tiled structures of brick construction attributed to the Lodhi period, and which is located near the village of Dera Mir Miran in the old town of Sirhind in Punjab. The building is a large square-shaped structure, of imposing height and girth, and distinctive in its style of construction and decoration (Figure 6.16).

Figure 6.16 A general view of Bibi Taj-ka Maqbara.

Three of its sides, excluding the western one, are provided with elaborate horseshoe-profiled arched openings in their middle, through which the interiors can be accessed.

The portions of the walls flanking the central entrances are provided with two storeys of blind arches, delineated from each other through a row of decorative merlons. On the roof, each of the four corners has been provisioned with a square cupola, the centre being occupied by a large hemispherical dome. Decorative merlons are found added at the junction of the dome and drum, and at the base of the small domes that cap the cupolas as well. Bits and patches of lime plaster that remain at various places on the building indicate that its external surfaces were probably originally plastered. No grave is now found within, the identity of Bibi Taj unknown, as is the date of erection of the structure. Parihar (2006, 108) dates the building to the late fifteenth or early sixteenth century[7] based on its stylistic resemblance to the nearby Tomb of Subhan, which is assigned to the Lodhi period and dated to 1496-1497 CE based on an inscription given thereon. The architectural parallels between the two buildings, and the general resemblance of their form to notable Lodhi structures at Delhi, are taken by him as being indicative of a style with origins in Delhi. The possibility that the converse may have occurred has not been discussed.

Figure 6.17 Detail illustrating the use of glazed tiles in conjunction with glazed bricks, the latter being the ones laid horizontally.

[7] Goetz (1939, 315) dates it to the early fifteenth century.

The chief decorative attraction of this building is the generous use of turquoise coloured tiles on its surfaces, the scale of their employment rather unusual for this period. The numbers of tiles seen here apparently exceed those found on the Sheesh Gumbad at Delhi, usually considered the prime specimen of Lodhi tiling. Square-shaped tiles can be seen to have been originally embedded in recesses in all the merlons on this building, as well as in niches provided in the walls above the arched entrance openings. A band of square tiles set between two rows of horizontally placed protruding glazed bricks was also provided to run all around the building (Figure 6.17), below the upper row of merlons. The same decorative technique is seemingly repeated on the drum of the dome, and on a smaller scale on the side walls of the cupolas, where additional rows of glazed bricks can also be evidenced. A band of square tiles was probably also utilized below the lower row of merlons as a provision for their presence can be seen, but no tiles are extant here now, the building and its tile-work overall being in an acute state of disrepair. A few individual tiles were apparently applied in the interiors as well, one in the middle of each side, and one in each squinch.

ii) Hathi-ka Maqbara

The Hathi-ka Maqbara is the second of the tiled brick tombs of the Lodhi period located at the old Sirhind town in Punjab[8], this one situated near the village of Talanian. Square in plan, the building is now in a ruinous state with a collapsed dome, but in its time of glory would have been a fine specimen of brick architecture (Figure 6.18). Not much of the architecture can be determined in its current state except that the horseshoe-shaped arches seen at the Bibi Taj-ka Maqbara are found repeated here, as is the general profile of the arched entrances. As in the other tombs, openings to access the interiors are only provided on three sides, the west-facing wall or side having none. A single sarcophagus is found within, its unusually large size lending the tomb its locally assumed name; Hathi-ka Maqbara literally meaning ‘Tomb of the Elephant’. Little else is known of the

[8] The other two tiled Lodhi buildings in Punjab, namely the Tomb of Subhan and Machhiwara Masjid, are stone constructions with little surviving tile-work. No samples could be sourced from these two sites, hence their exclusion from the detailed study. These are otherwise similar in form and appearance to the Lodhi buildings of Delhi.

history of the tomb. Parihar (2006, 102) dates it to the mid-fifteenth century based on its cut-brick decoration[9], its architecture however indicating that it could be of a later date, contemporary to that assigned to the Bibi Taj-ka Maqbara.

Both glazed tiles and cut-bricks were used for embellishing this building. The tiles, all of which are of turquoise colour, are found to have been employed in a style similar to that evidenced on the Bibi Taj-ka Maqbara, as a band circumventing the building. While some of the glazed bricks that would have bordered the band are extant in place, the square-shaped glazed tiles that they should hold between them are entirely lost on the building surfaces (Figure 6.19). Their original presence can however be confirmed through the many fragments that lie in the debris around.

Figure 6.18 A general view of Hathi-ka Maqbara.

The possibility that some merlons, which are partially extant on the parapet, also contained a single tile each as seen at Bibi Taj-ka Maqbara seems likely, although none can now be found *in situ* which is not surprising considering the overall poor state of the

[9] Goetz (1939, 315) believes it to be older, of the late fourteenth century.

building. Parihar (2006, 102), curiously, while noting the common use of glazed bricks on both these buildings, does not make use of the information in his proposed dating.

Figure 6.19 Detail illustrating the original use of glazed tiles in a band set between horizontally placed glazed bricks, the technique being the same as that used at the Bibi Taj-ka Maqbara.

6.2.3 Summary of observations

A variety of techniques have been employed for the tiling of the examined Delhi buildings, consistent with those known to be utilized for Lodhi tile-work in general. The most common and ubiquitous is the application of tiles individually in rows and bands on building facades, others including the inlaying of tiles in stucco and in mosaic compositions. The only securely dated tiled building among those examined is the Bagh-e Alam-ka Gumbad, dated 1501 CE, this also being the oldest known Lodhi building at Delhi. The others are all attributed to the Lodhi period based on their architectural features, some uncertainty associated with the exact sequence of their erection. All the examined buildings, except Jahaz Mahal, Sheesh Mahal and Tomb of Sikandar Lodhi, are found embellished with turquoise coloured tiles only, as in the case of all other known Lodhi buildings. The turquoise coloured tiles on Madhi Masjid are found to be of a darker tone than others found elsewhere. Jahaz Mahal, which is of the late Lodhi or early Mughal period, has a few yellow coloured glazed tiles in addition to predominantly turquoise coloured ones. The Sheesh Gumbad, believed by some to be the tomb of Sultan Bahlul Lodhi, has dark-blue and underglaze-painted blue-and-white tiles besides turquoise coloured specimens. The Tomb of Sikandar Lodhi has turquoise, dark-blue, yellow, and green coloured tiles used relatively more lavishly, and found employed mainly in the interiors. The laying of tiles in polychromatic mosaic compositions appears for the first time on this building.

The two examined buildings in Punjab, the Bibi Taj-ka Maqbara and Hathi-ka Maqbara, are of brick construction, as opposed to being of stone like the buildings of Delhi. Both are decorated with turquoise coloured glazed bricks in addition to turquoise coloured glazed tiles, a similarity noticeable in the technique of application of the glazed bricks and tiles on them. The Bibi Taj-ka Maqbara and Hathi-ka Maqbara are undated but are ascribed to the fifteenth or sixteenth century based on stylistic features of their architecture. The similarity in size and form of the Tomb of Subhan to the Bibi Taj-ka Maqbara has been used to suggest that they were built in contemporary times, the former known to date to 1496-1497 CE. The Hathi-ka Maqbara is less convincingly dated, features of its tile-work decoration not being taken cognisance of for the purpose.

A summary of the principal features of the tile-work on the buildings investigated in detail is given in Tables 6.1 and 6.2 that follow:

Table 6.1 Summary of the tile-work decoration on the Delhi buildings.

No.	Building	Typology	Date/Period	Glaze colours	Application
1	Bagh-e Alam-ka Gumbad	Tomb	1501 CE	i) Monochrome: turquoise.	(i) As individual tiles - in recessed panels on facade, possible band below parapet.
2	Sheesh Gumbad	Tomb	c. 1500 CE	i) Monochrome: turquoise. ii) Polychrome: blue-and-white.	(i) As individual tiles - band at two levels on facade. Polychrome tiles in sunken panels on central projections of facades.
3	Madhi Masjid	Mosque	16th century	i) Monochrome: turquoise.	(i) As individual tiles - band on wall-mosque below parapet, in niches on facade. (ii) As inlay - in stucco medallions on arch spandrels.
4	Tomb of Sikandar Lodhi	Tomb	c. 1518 CE	i) Monochrome: turquoise, dark-blue, yellow, green.	(i) As individual tiles - in interiors in arched recesses and their frames. In exteriors on roofs of *chhatris* and gateway. (ii) As inlay - in stucco medallions on arch spandrels. (iii) As tile-mosaic - on arched recesses in interiors, roofs of *chhatris* in exteriors.
5	Jahaz Mahal	Inn or royal apartment	16th century	i) Monochrome: turquoise, yellow.	(i) As individual tiles - band below parapet, in merlons on turrets, on roofs of *chhatris*.

Table 6.2 Summary of the tile-work decoration on the Punjab buildings.

No.	Building	Typology	Date/Period	Glaze colours	Application
1	Bibi Taj-ka Maqbara	Tomb	15th/16th century	i) Monochrome: Turquoise.	(i) As individual tiles - band between glazed bricks on facade below parapet, on drum of dome and on cupolas. In niches and merlons on facade. Few tiles in interiors.
2	Hathi-ka Maqbara	Tomb	15th/16th century	i) Monochrome: Turquoise.	(i) As individual tiles - band between glazed bricks on facade below parapet. Possible use in merlons on facade.

6.3 Results of analyses

A total of 35 samples from the Lodhi buildings under study were taken up for analyses. Of these, 18 samples were complete tile fragments, comprising both the body and glaze layer, while 17 samples were just fragments or pieces of tile glazes without the underlying body. On account of the sampling restraints, as outlined in Chapter 4, complete tile fragments could only be sourced from three of the buildings, namely Sheesh Gumbad, Bibi Taj-ka Maqbara, and Hathi-ka Maqbara, tile-work on the remainder four monuments being represented by samples of their glazes only. Results of the investigations carried out on the 35 samples are detailed as below:

6.3.1 Macroscopic examination

Macroscopically, all the complete tile fragments appear similar, consisting of dirt-encrusted bodies covered on one side by a coloured glaze layer. Differences are however apparent when they are examined in detail through their sections. The Sheesh Gumbad (SG) bodies are clearly whiter than the others, varying in tone from an ordinary to dazzling white colour in freshly cut sections (Figure 6.20). The Bibi Taj-ka Maqbara (BT) and Hathi-ka Maqbara (HM) bodies, in comparison, are of a duller grey-white shade (Figure 6.21). Some textural differences are evident too, the BT and HM bodies being rougher to feel, and of an overall coarser appearance, as compared to the SG specimens. All the bodies across the three buildings are otherwise fairly porous, being lightweight, and having matrices that are marked by fine holes. These are also apparently not as durable as they seem to be, as scratching with even a thumbnail suffices to remove a fine layer of the material of which they are composed. Samples of BT and HM are found to closely resemble each other, but this is not surprising given the similarities evidenced earlier in the style of their original installation. A few of the samples that are complete through their sections indicate that the tiles of each of these buildings (SG, BT, and HM) were of an original thickness of around two centimetres each.

Figure 6.20 Cross-section of a tile sample (SG/02) from Sheesh Gumbad. Note the bright white colour of the body.

Figure 6.21 Cross-section of a tile sample (BT/01) from Bibi Taj-ka Maqbara. Note the grey-white colour of the body.

The glazes, distinguished from the bodies by their bright and vibrant colours, appear as a distinct layer even in sections. All the glazes are fairly consistent in their thicknesses, and are either turquoise or dark-blue in colour (Figures 6.22 to 6.24). Those with underlying bodies are visibly opaque and have a somewhat roughened surface finish that can be gauged by running a finger over their surfaces. The individual glaze fragment samples are also of a similar texture and thickness as the tile glazes, and similarly opaque in spite of being devoid of a body below. No major weathering is noticeable for any of the samples, although micro-pores, appearing as pin holes, can be found distributed over the glaze surfaces of many of them.

Figure 6.22 A turquoise coloured glazed tile (SG/03) from Sheesh Gumbad.

Figure 6.23 A dark-blue coloured glazed tile (SG/05) from Sheesh Gumbad.

Figure 6.24 A turquoise coloured glazed tile (HT/01) from Hathi-ka Maqbara.

Of the glaze colours, only samples from SG and Tomb of Sikandar Lodhi (SL) are determined as having dark-blue coloured glazes in their pool. This concurs with findings of the field survey, dark-blue glazes being found on the tile-work of these two Lodhi buildings only. The other samples being turquoise coloured can be associated with the individual buildings to which they belong, glazes of this colour being found on all Lodhi buildings. Some variation from a light to dark tone is noticed between some of the turquoise coloured glazes from different buildings, but whether this is on account of some kind of glaze deterioration or differences in chemical composition cannot be easily determined macroscopically (Figure 6.25).

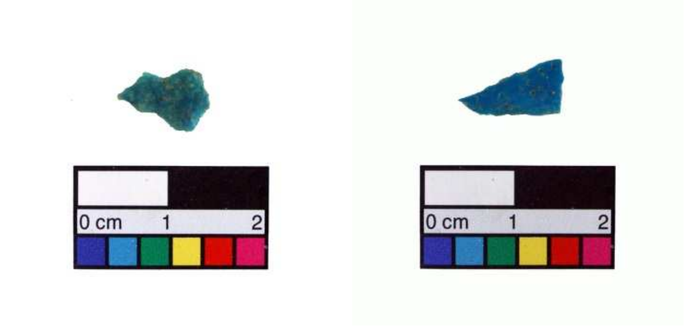

Figure 6.25 A turquoise coloured glaze sample from (left) Tomb of Sikandar Lodhi (SL/02) and (right) Jahaz Mahal (JM/05). Note the difference in colour tone of the two glazes.

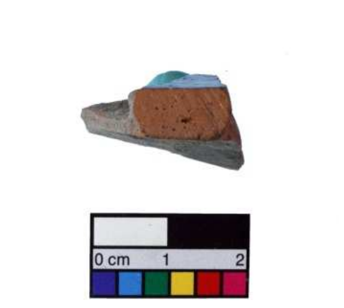

Figure 6.26 A glazed terracotta fragment (HM/03) from Hathi-ka Maqbara in section.

Two fragments from HM (HM/03 and HM/04) are different from all others, their brick-red coloured bodies indicating that they are specimens of glazed terracotta (Figure 6.26). These are therefore representative of the glazed bricks that are reported on this building. Their body matrices are however clearly more refined than those of ordinary bricks used in the construction of buildings, being more compact or densely-packed and having fewer visible voids or inclusions. Their glaze layers also differ from all the others, being comparatively much thinner and having a smoother surface texture with fewer blemishes.

6.3.2 Tile bodies: Microstructure and chemical composition

Analyses confirm that all the tile bodies are highly porous and made up primarily of grains or particles of quartz that are connected to each other by a filament like phase of interparticle glass. The glaze layers are distinct from the bodies, but contain a lower interaction zone or layer of quartz particles on account of the penetration of the glazes into the bodies (Figure 6.27). The existence of a similar interaction layer in all the individual glaze fragment samples indicates that these were also originally provided with underlying quartz-rich bodies, the fragments apparently having separated at the glaze-body interface. All the samples are thus determined as being of the stonepaste variety, having bodies that conform to the description known to be associated with this ceramic type.

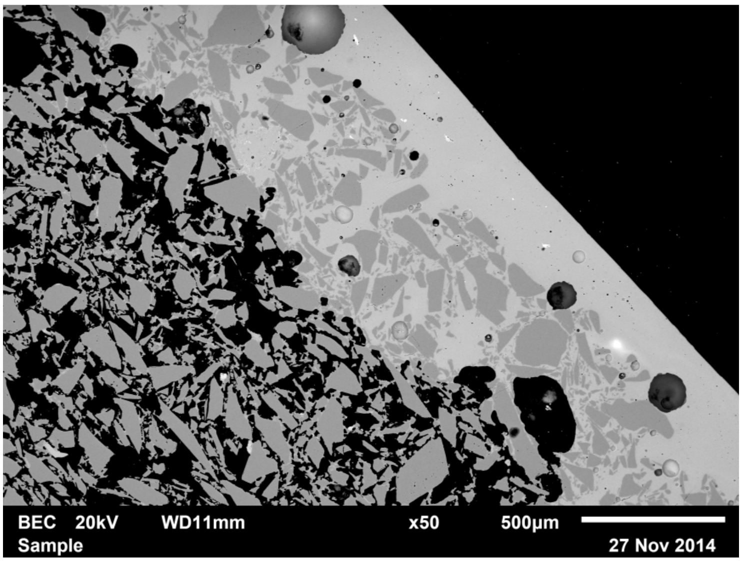

Figure 6.27 SEM photomicrograph through the section of a tile sample (SG/05) from Sheesh Gumbad. The bright upper glaze layer is distinct from the body below, the latter seen to comprise almost entirely of quartz particles. Black or dark areas in the body are pores. An interaction zone of quartz particles is noticeable in the lower portion of the glaze.

Variations in the body compositions are seen to exist across samples from individual buildings, primarily in the shape and size of the quartz grains and in the degree of development of interparticle glass. The quartz particles in the SG tile bodies are conspicuously angular and elongated, but also apparently less well-bonded through interparticle glass. A poor to moderate degree of formation of the glassy phase is noticed in these body matrices, sufficient to ensure the fusing of adjacent particles where it is better-formed (Figure 6.28), but providing only a weak and feeble bond where it is less seen. The glassy phase is actually quite indistinct in most of the samples from this building, often to the point of being considered non-existent (Figure 6.29). In size, the quartz particles are found to vary over a fairly wide range, the coarser ones, which are also few in numbers, being between c. 300-450 µm along their longer edges. Most of the particles in the SG bodies are otherwise divided over two size categories in roughly equal proportions, about half being of a medium size of 100-250 µm, while the rest are finer ones that range from 25-75 µm across.

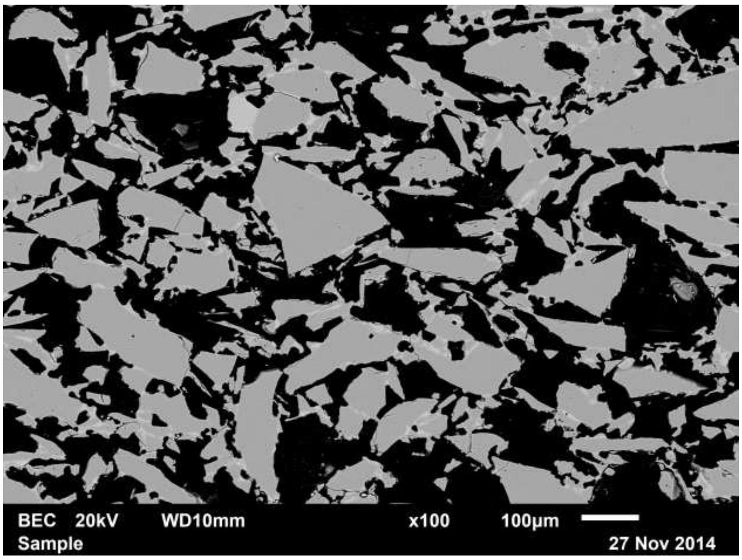

Figure 6.28 SEM photomicrograph of a tile body (SG/02) from Sheesh Gumbad. Note the shape and angularity of the quartz particles. The moderately developed phase of interparticle glass seen here is less common for samples from this building.

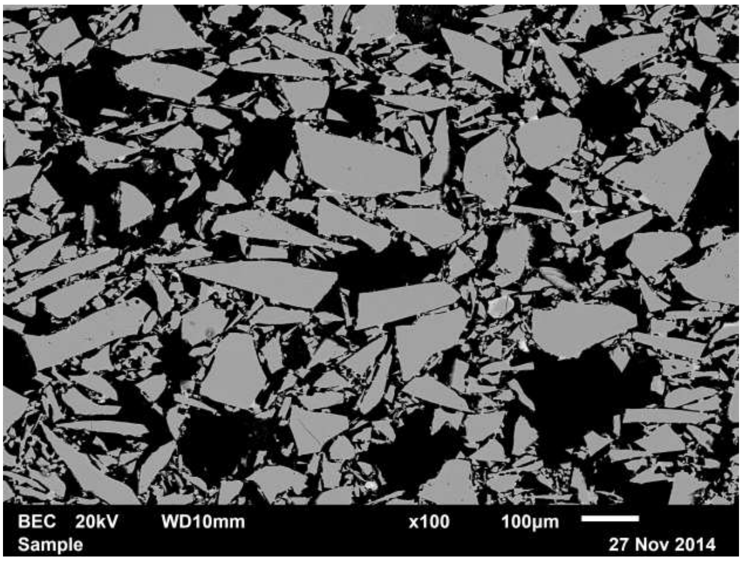

Figure 6.29 SEM photomicrograph of a tile body (SG/03) from Sheesh Gumbad illustrating the near absence of interparticle glass in a body matrix.

The particles that lie in the interaction layer of the samples from Bagh-e Alam-ka Gumbad (BAG), Madhi Masjid (MM), Jahaz Mahal (JM), and SL, are generally of a similar shape and form as noticed for the SG specimens. The only distinguishing feature is that relatively greater numbers of coarse particles are found here, signifying the likely increased presence of coarser quartz particles in the bodies of these tiles as compared to those determined in the SG samples (Figure 6.30).

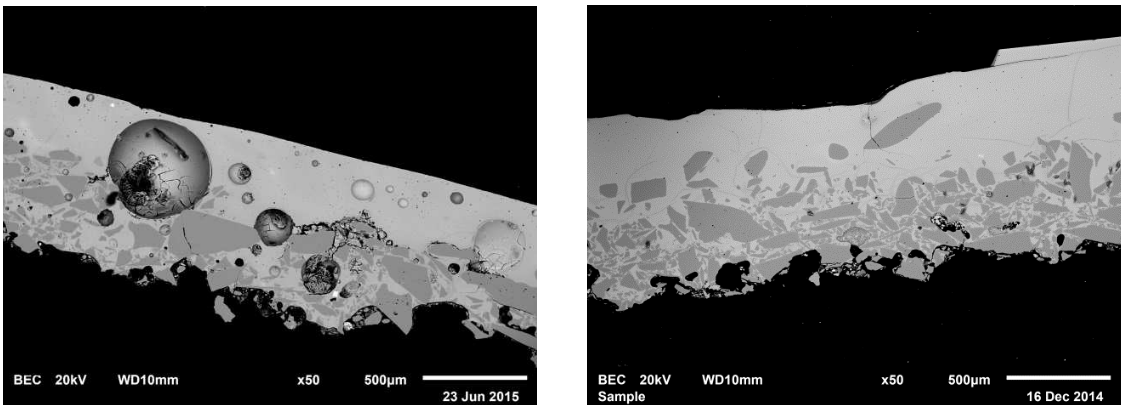

Figure 6.30 SEM photomicrographs of individual glaze fragment samples from (left) Tomb of Sikandar Lodhi (SL/06) and (right) Jahaz Mahal (JM/04). Note the quartz particles that lie in the lower portion of the glazes, reflecting the nature of their original underlying bodies. A relatively higher proportion of coarse particles are noticeable in these glazes as compared to the SG samples.

The particles in the bodies of samples from the two Punjab buildings (BT and HM) on the other hand are clearly of a different textural character, being noticeably rounded along their boundaries and of a tendency to be equant in shape. A relatively higher degree of development of interparticle glass is also noticed associated with these bodies, the glassy phase often extending to envelop the finer quartz particles present in the matrices (Figure 6.31). The particles in the bodies from both BT and HM are otherwise generally of a similar size range as recorded for the Delhi samples, from 25-450 µm or so across, but differ somewhat in the ascribed size groupings and their relative abundance. While finer particles of a size as in the SG samples are noted as being consistently present here as well, it is the medium size particles, which vary over a relatively wider size range of 100-350 µm, that dominate these matrices.

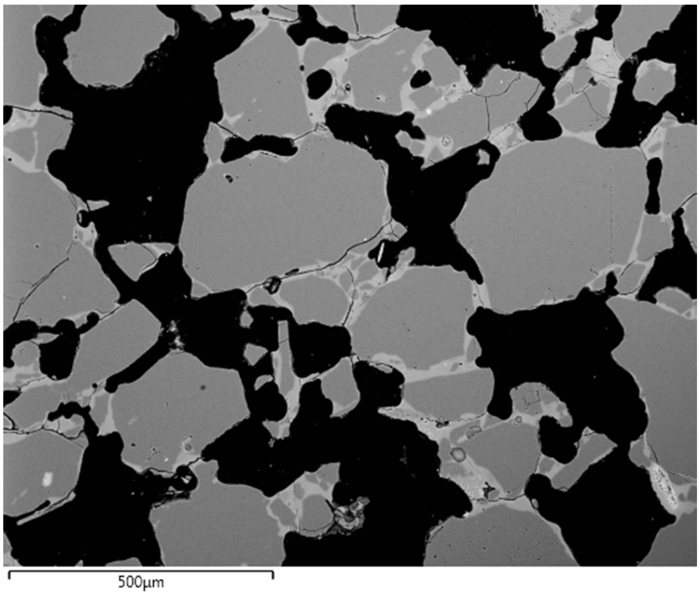

Figure 6.31 SEM photomicrograph of a tile body from Bibi Taj-ka Maqbara (BT/02) illustrating the relatively well-formed interparticle glass associated with the Punjab body type.

In addition to the quartz particles, individual grains of potash feldspars, distinguished by their relatively brighter appearance in BSE imaging, are determined in all the tile bodies. These are few in the SG tile samples, but appear with greater regularity in the bodies of the BT and HM specimens, albeit in overall limited numbers (Figure 6.32). The feldspathic content of the bodies is apparently not limited to the isolated feldspar grains in all cases, as small patches of potash-alumina-rich phases are frequently encountered on many of the quartz particles in the BT and HM bodies, appearing rather like a localised glassy phase on the grains. No such phases are determined in the SG bodies. Few bright small particles of iron and titanium minerals, and the occasional zircon grain, are also randomly dispersed in all the body matrices, these again being more frequent in the BT and HM bodies as compared to the SG bodies (Figure 6.33). Some small interparticle areas in the bodies are at times found to contain what appear to be unfused clay minerals, occasionally with undissolved lime-rich particles bound in their mass (Figure 6.34). No slips are determined employed in any of the tiles, although there are instances in some of the SG samples in which the interaction layer in the glazes gives the appearance of being a slip.

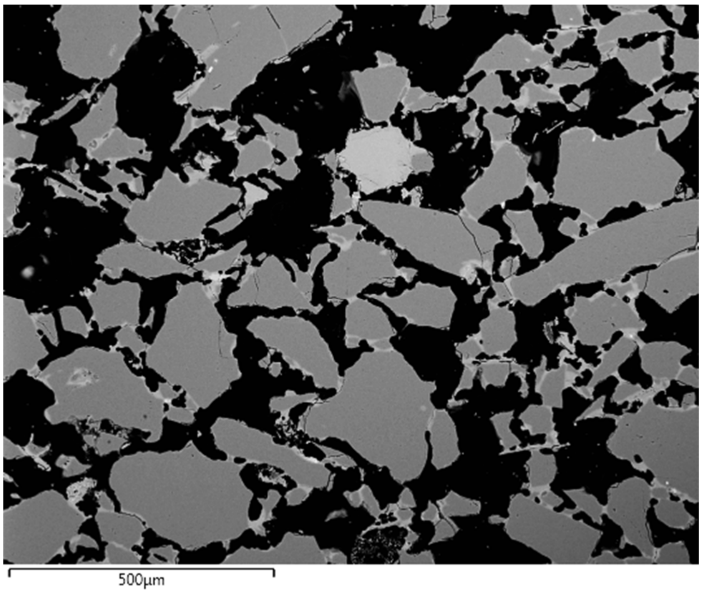

Figure 6.32 SEM photomicrograph of a tile body from Bibi Taj-ka Maqbara (BT/01). The bright particle in the upper-middle is a potash feldspar. Bright phases noticeable on some of the larger quartz particles are also determined rich in potash-alumina content.

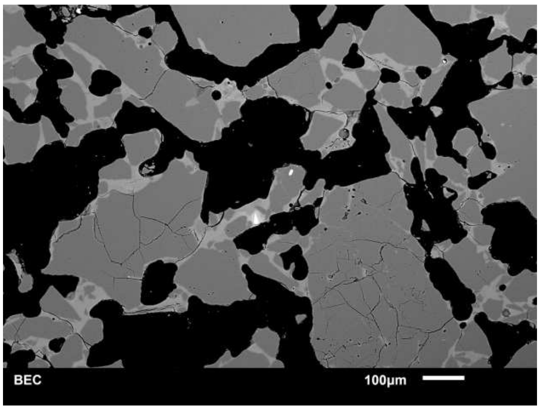

Figure 6.33 SEM photomicrograph of a tile body from Bibi Taj-ka Maqbara (BT/03) illustrating the presence of small mineral particles in its body. The relatively brighter teardrop shaped particle in the centre is a zircon grain.

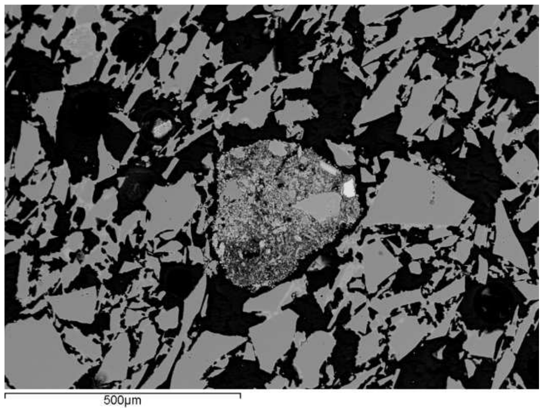

Figure 6.34 SEM photomicrograph of a tile body from Sheesh Gumbad (SG/05). The area in the centre, between the quartz particles, is occupied by a small patch of unfused clay minerals. The bright particle in the clay mass is a lime-rich grain.

HM/03 and HM/04, the two glazed terracotta samples, differ expectedly from the tile body specimens, exhibiting a microstructure typical of clay-based fired ceramics. These are found to comprise a body mass of fine silt-sand clay minerals, interspersed with randomly distributed larger non-plastic inclusions and voids of varying shape and size (Figure 6.35). No slip is determined present here as well.

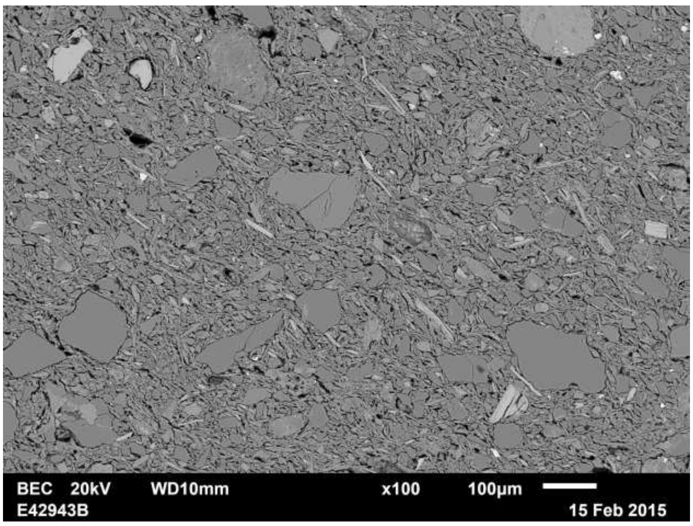

Figure 6.35 SEM photomicrograph of a glazed terracotta tile (HM/03) from Hathi-ka Maqbara illustrating the microstructure associated with their bodies.

Chemistry of the tile bodies

The bulk chemical compositions of the stonepaste tile bodies reflect their unusually high quartz content, while also being an indicator of the nature and extent of formation of interparticle glass in each (Tables 6.3 and 6.4, Appendices 6.2 and 6.3). Silica is overall very high, ranging over 95-99 wt% for the SG specimens which contain little other than quartz particles, and is only slightly lower, between 93-95 wt%, for the BT and HM samples, where some phases other than the dominating quartz particles can also be discerned. Soda is consistent in the BT and HM samples, varying over 1.3-1.5 wt%, while its values attained for the SG samples are lower and more erratic, lying below the detection limit of the instrument for some, and varying over 0.5-1.1 wt% for most of the others. The higher soda values in all cases are notably associated with tile bodies in which the interparticle glass is found better developed.

Alumina is either absent or close to the instrument detection limit of 0.3 wt% for the SG samples, barring SG/04, where it is found to be 0.9 wt%. It is clearly detected in all the BT and HM samples, in concentrations close to that of soda, except for BT/04, where it is relatively higher at 2.7 wt%. Lime is consistently found in low concentrations in all the samples from both regions, at an average of 0.6 wt%. Magnesia is also low in all the samples, not exceeding 0.4 wt% where found. Potash and iron, like alumina and soda, are consistent across the BT and HM samples, in concentrations of around 0.7 wt% and 0.4 wt% on an average respectively. Higher values for the two are only recorded in BT/04, where alumina is also correspondingly higher than otherwise measured. A similar relationship is noticeable in the SG samples, potash and iron being in low or negligible concentrations where alumina is low, enhanced values only being recorded for SG/04, where alumina is also present in appreciable concentration.

The samples are otherwise largely similar in chemical composition across their individual buildings, the close resemblance in the compositional profiles of the BT and HM samples indicating that they can be discriminated regionally as a unit as well.

Table 6.3 Chemical compositions of the Lodhi stonepaste tile bodies from Delhi determined through SEM-EDS analyses. All results are in wt%, and normalised to100 %. Results below the detection limit of the instrument are provided for comparative purposes only. '-' indicates 'not detected'.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3
1	SG/01	Dark-Blue	Sheesh Gumbad	98.0	0.6	0.6	0.2	0.2	0.1	0.2
2	SG/02	Dark-Blue	Sheesh Gumbad	97.5	1.1	0.4	0.3	0.3	0.1	0.3
3	SG/03	Turquoise	Sheesh Gumbad	99.0	0.2	0.3	0.2	0.1	-	0.2
4	SG/04	Turquoise	Sheesh Gumbad	95.4	1.3	0.8	0.6	0.4	0.9	0.7
5	SG/05	Dark-Blue	Sheesh Gumbad	98.4	0.5	0.6	0.3	-	-	0.2
6	SG/06	Dark-Blue	Sheesh Gumbad	98.4	0.4	0.5	0.1	0.3	-	0.3
7	SG/07	Dark-Blue	Sheesh Gumbad	97.6	0.5	0.8	0.1	0.4	0.3	0.1
8	SG/08	Dark-Blue	Sheesh Gumbad	98.9	0.2	0.5	0.2	0.2	-	-
9	SG/09	Dark-Blue	Sheesh Gumbad	97.6	0.5	0.8	0.2	0.4	0.3	0.1
10	SG/10	Dark-Blue	Sheesh Gumbad	98.3	0.2	0.4	0.3	0.3	0.4	0.1
			Average	**97.9**	**0.6**	**0.6**	**0.2**	**0.3**	**0.2**	**0.2**

Table 6.4 Chemical compositions of the Lodhi stonepaste tile bodies from Punjab determined through SEM-EDS analyses. All results are in wt%, and normalised to100 %. Results below the detection limit of the instrument are provided for comparative purposes only.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3
1	BT/01	Turquoise	Bibi Taj-ka Maqbara	95.2	1.5	0.4	0.7	0.2	1.8	0.3
2	BT/02	Turquoise	Bibi Taj-ka Maqbara	95.1	1.4	0.6	0.8	0.3	1.4	0.4
3	BT/03	Turquoise	Bibi Taj-ka Maqbara	95.4	1.4	0.6	0.7	0.3	1.2	0.4
4	BT/04	Turquoise	Bibi Taj-ka Maqbara	93.2	1.3	0.6	1.1	0.4	2.7	0.7
5	HM/01	Turquoise	Hathi-ka Maqbara	95.2	1.5	0.6	0.6	0.3	1.6	0.3
6	HM/02	Turquoise	Hathi-ka Maqbara	95.2	1.4	0.6	0.5	0.3	1.7	0.2
			Average	**94.9**	**1.4**	**0.6**	**0.7**	**0.3**	**1.7**	**0.4**

Interparticle glass, analysed in a representative numbers of samples, is likewise determined consistent in chemical composition across bodies from individual buildings (Table 6.5, Appendix 6.4). Significant variations from the building averages are only found to occur for samples (SG/03 and SG/08) in which the phase is poorly formed, difficulties associated with its measurement affecting readings accordingly. Although a closer match is once again evident in the case of the BT and HM samples, a general overall similarity in composition is also observed for samples from all the three buildings. A key difference however is that alumina is present in significantly higher concentrations in the interparticle glass of the BT and HM bodies as compared to its presences the SG bodies, an additional alumina-rich material apparently influencing the formation of the glassy phase in the Punjab specimens.

Table 6.5 Average chemical composition of interparticle glass in the Lodhi Delhi and Punjab stonepaste tile bodies determined through SEM-EDS analyses. All results are in wt%, and normalised to100 %.

Building (Region)/ Nos. of analyses	Composition	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3
SG (Delhi) (n=5)	Average	76.3	9.3	2.9	4.1	2.3	**2.2**	2.9
	Standard Deviation	3.0	3.8	0.9	0.5	1.1	0.9	3.2
BT & HM (Punjab) (n=5)	Average	72.9	9.9	3.2	4.4	1.8	**6.7**	1.2
	Standard Deviation	0.7	0.9	0.2	0.6	0.2	1.0	0.4

Analyses of the two terracotta tile body samples reveal the character of the clay employed in their making, attained values being consistent with compositions known to be associated with ordinary non-calcareous clay (Table 6.6, Appendix 6.5). Silica is around 70 wt%, while alumina and iron oxide are in concentrations of 16 wt% and 6 wt% respectively. Lime is noticeably low, measuring only between 1-1.5 wt%, while magnesia is marginally higher at an average 2 wt%. Potash and soda concentrations, an indicator of the feldspathic content of the clay, average 3.5 wt% and 1.2 wt% respectively.

Table 6.6 Chemical compositions of the Lodhi terracotta tile bodies from Punjab determined through SEM-EDS analyses. All results are in wt%, and normalised to100 %.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3
1	HM/03	Turquoise	Hathi-ka Maqbara	70.2	1.2	1.1	3.5	1.9	16.2	6.0
2	HM/04	Turquoise	Hathi-ka Maqbara	69.1	1.3	1.4	3.5	2.1	16.4	6.1
			Average	**69.6**	**1.2**	**1.3**	**3.5**	**2.0**	**16.3**	**6.0**

Summary and comments

Investigations reveal that the samples are analytically better discriminated through their microstructural characteristics, the chemical compositions of the bodies being less informative for the purpose of sample grouping, disadvantaged as it is by the absence of body samples for some of the buildings. The prime discriminator in determining sample groups is undoubtedly the textural character of the quartz grains, other noted microstructural features such as body colour or degree of interparticle glass formation aiding in further qualifying the groupings. The two broad typologies that emerge utilizing this criteria follow the regional groupings associated with the tile-work, all the Delhi samples being one type or group while all the Punjab samples are encompassed in the other.

The Delhi group is characterised by white or whitish coloured bodies that comprise majorly of angular and elongated quartz particles from 25-450 µm across, those of a size 250 µm or less dominating in presence, have less or little interparticle glass in their matrices, and have no discernible slip. While all samples from SG would certainly fall in this category, samples from BAG, MM, SL, and JM may be considered a sub-category of this group, having largely similar microstructural characteristics. These however remain distinguished from the SG samples through their relatively higher coarse quartz grains content, as noticed in their glazes. The average chemical composition of the SG bodies (given in Table 6.3) can tentatively be considered associated with this group, pending further clarity on the composition of the bodies of the BAG, MM, SL, and JM tiles.

The Punjab group is characterised by greyish-white coloured bodies that comprise mainly of rounded and equant quartz particles from 25-450 µm across, those of a size 100-350 µm dominating in presence, exhibit fairly well-developed interparticle glass in their matrices, and have no discernible slip. All the stonepaste samples of BT and HM are of this group type, the average chemical composition of their bodies (given in Table 6.4) being a group characteristic.

The two terracotta tiles from HM are clearly a class of their own on account of their noted peculiar characteristics and composition (given in Table 6.6). These are characterised by brick-red coloured bodies that comprise a densely packed matrix of fine clay minerals interspersed with non-plastic inclusions, and have no slip.

6.3.3 Glazes and colorants

The glaze layers are found to vary moderately in thickness across the samples, being otherwise generally uniform for specimens taken from the same building. Among the Delhi group, the two MM glazes that are 650-700 µm across are slightly thicker than the others, while those of BAG, which are c. 500 µm across, are probably the thinnest of the lot (Figure 6.36). Glazes from the other Delhi buildings, SG, SL, and JM are mostly of an intermediate thickness of 550-650 µm. The Punjab BT and HM glazes are more or less of a similar thickness as the Delhi glazes, but exhibit a lesser overall variation, being usually in the range of 500-600 µm through their sections (Figure 6.37). A notable feature of these glazes, across samples from both regions, is their high degree of penetration into the tile bodies, several having quartz particles from the bodies spread across their entire thickness. In general, all the glaze layers are found to comprise a lower glaze-body interaction zone containing quartz particles from the body below, followed by a clearer upper zone. Bubbles of varying size and at times small bright mineral inclusions are often found randomly dispersed within. Bright particles are particularly noticeable in the BT and HM glaze samples, these being few overall but equitably distributed across the glaze layers. The bright inclusions in all glazes are usually identified as being undissolved particles of iron-rich minerals, and occasionally a rare earth grain (Figure 6.38). In very few instances are these determined as being undissolved particles of the pigment or colorant employed in the colouring of the glazes.

The glaze layers of the two terracotta tile samples (HM/03 and HM/04), as macroscopically determined, are significantly thinner than the others, being about 200 µm or so thick each (Figure 6.39). No distinct glaze-slip interaction layer of particles is found present in their case.

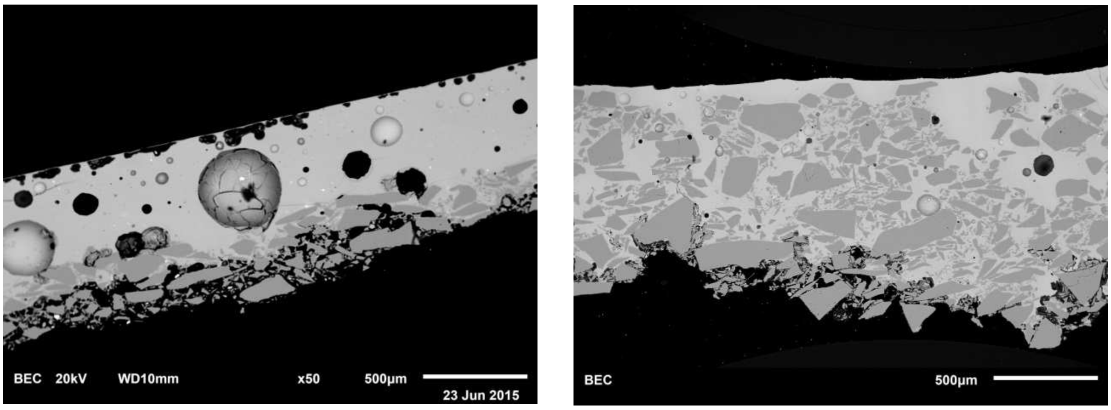

Figure 6.36 SEM photomicrographs of samples from (left) Bagh-e Alam-ka Gumbad (BAG/01) and (right) Madhi Masjid (MM/01) illustrating the size range associated with the Lodhi tile glazes. Note the extent of the interaction layer in the case of the MM glaze.

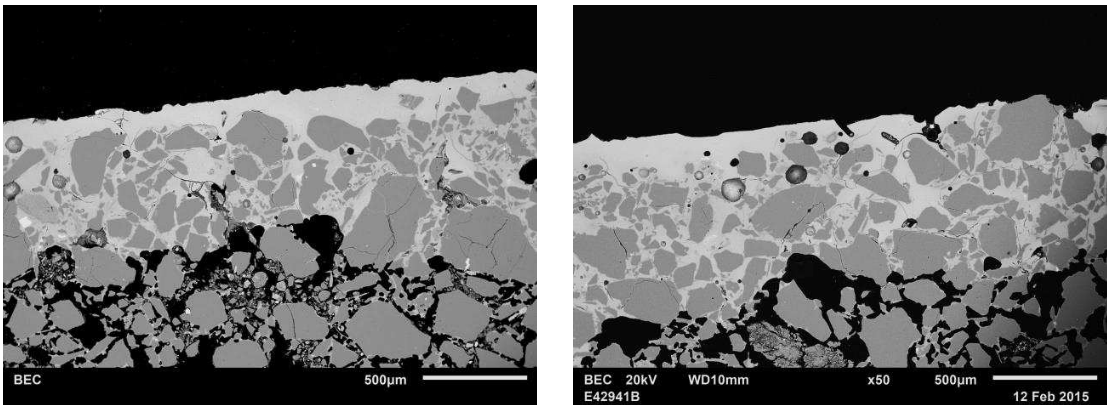

Figure 6.37 SEM photomicrographs of samples from (left) Bibi Taj-ka Maqbara (BT/04) and (right) Hathi-ka Maqbara (HM/02) illustrating their glaze thicknesses.

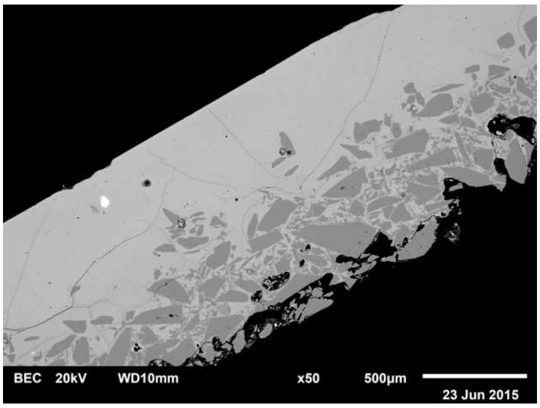

Figure 6.38 SEM photomicrograph of a glaze sample (JM/04) from Jahaz Mahal. The bright particle in the glaze is a zircon grain.

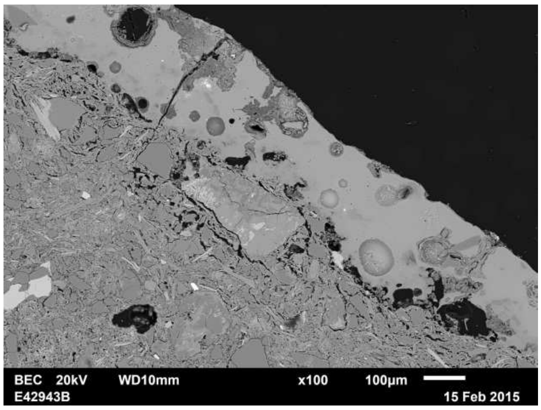

Figure 6.39 SEM photomicrograph of a terracotta tile (HM/03) from Hathi-ka Maqbara. Note the relative thinness of its glaze layer.

Chemistry of the glazes

All the glazes are determined to be of the silica-soda type, and of a generally similar compositional character for samples from the same building. Variations in composition are however apparent across the different buildings of the two groups (Appendices 6.6 to 6.9, average reduced compositions given in Tables 6.7 and 6.8). Of the base glass forming oxides, only soda and silica are found to be in comparable concentrations in samples across the buildings of the Delhi group, inconsistencies being noticed in the values of the other minor oxides. Alumina for instance is found to be in low concentrations of 1.1-1.7 wt% in the BAG, SG, and MM samples, but is significantly higher in the SL and JM samples, where it lies in the range of 4.5-5 wt%. Lime similarly, which is also seen to vary inversely with alumina, is low in the SL and JM samples at an average of around 1.5 wt%, but is present in two to three times higher concentrations in the BAG, SG, and MM samples. Iron oxide concentrations follow an even less clear pattern in this group, varying noticeably even in samples from the same building.

Little variation is found across the two Punjab buildings on the other hand, all the BT and HM glazes, including those of the terracotta tiles, being largely united in their compositional profiles. Interestingly, the BT and HM glazes are also noticed as sharing a remarkable similarity in their chemical compositions with the BAG, SG, and MM samples, the regional disparity determined associated with the bodies clearly not extending to the glazes.

On plotting the measured alumina and lime values of all the samples, the glazes are seen divided over two distinct groups or types (Figure 6.40). One group, the Type I variety, is low in alumina but high in lime content, and found to encompass all the samples from the two Punjab buildings (BT and HM), as well as all samples from three of the five Delhi buildings (BAG, SG, and MM). The Type II group of glazes are conversely those that are higher in alumina and lower in lime than the Type I glazes, and comprise all the samples of SL as well as three of the five samples from JM. Two samples from JM

(JM/04 and JM/05) exhibit intermediary characteristics between the two groups, being low in both alumina and lime.

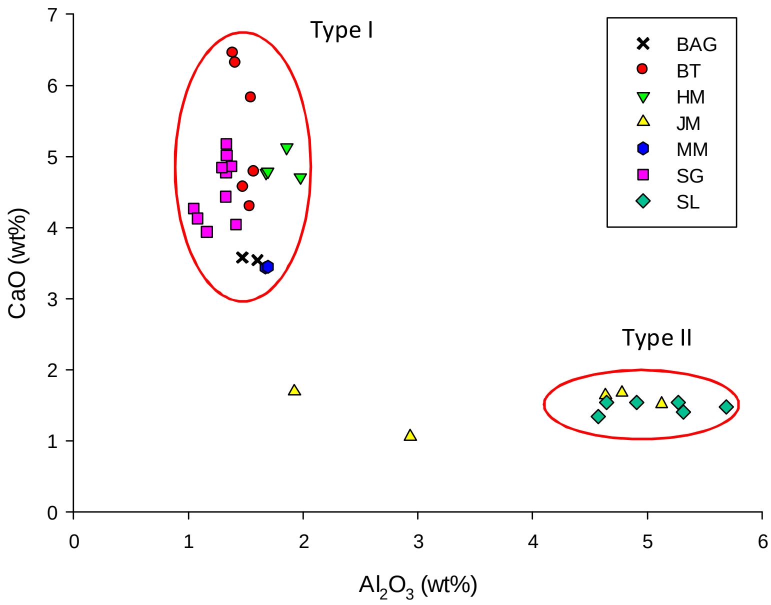

Figure 6.40 Scatter plot of alumina versus lime contents of the Lodhi tile glazes illustrating the existence of two distinct glaze groups. The two outliers to the groupings are the samples JM/04 and JM/05.

A similar grouping of the samples is noticeable on plotting potash versus magnesia, the Type I glazes in this case being distinguished from the Type II variety through their comparatively enhanced magnesia and potash contents (Figure 6.41). Magnesia is in fact determined as being an effective means of discriminating between the glaze types by itself, a clear separation between the two groups noticeable in the plot on the basis of its values only. Potash is less reliable comparatively; the range of its values, as noticed in the plot, overlapping to an extent for the two glaze types. The high values of potash and magnesia otherwise associated with the Type I glazes, typically more than 2.5 wt% for each, signify that these glazes are most likely to have been produced using alkali fluxes derived from a plant ash source (Sayre and Smith 1961). The Type II glazes on the other hand, with their low magnesia content, have the characteristics of being manufactured using a mineral soda flux. JM/04 and JM/05, the two outliers in the previous plot, are notably found to merge into the Type II group in this grouping.

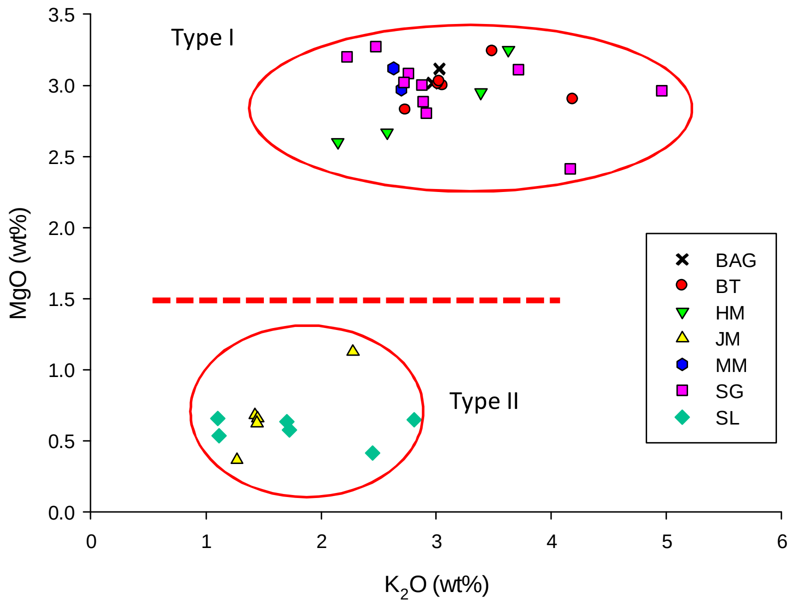

Figure 6.41 Scatter plot of potash versus magnesia contents of the Lodhi tile glazes. Note the clear separation between the two groups based on the magnesia content.

Reduced and recalculated compositions of the samples indicate that soda content is typically 18 wt% in the Type I (plant ash) glazes (Table 6.7). It is notably higher in the Type II (mineral soda) glazes at an average of 21 wt% (Table 6.8). Lime is conversely lower in the mineral soda glazes, averaging 1.6 wt%, but is much higher in the plant ash glazes where it ranges over 3.8-5.8 wt%, values at the higher end being associated with the BT and HM samples. Potash and magnesia concentrations follow those of lime, relatively enhanced values for both being recorded in the plant ash glazes, averaging around 3.2 wt% for each. Magnesia, as noted earlier, is characteristically low in the mineral soda glazes, at an average of around 0.7 wt%, Potash is also generally lower in the Type II glazes, mostly below 2 wt%, but is also often in concentrations between 2-3 wt%, more in line with those expected for the Type I variety. Alumina, a useful secondary means of discriminating between the two glaze types, is present in low concentrations of c. 1.5-2 wt% in the plant ash glazes, but is significantly higher in the mineral soda variety, where it is typically c. 5 wt%. Iron and titanium oxides vary over 0.5-1.5 wt% and 0.1-0.3 wt% respectively, the latter being in more consistent concentrations across the two glaze types. Binary plots indicate that both these oxides are mostly positively correlated with alumina in the two glaze types (Appendix 6.10). A positive correlation is also noticeable between lime and magnesia in the mineral soda glazes, but none evidenced between either of these with alumina, or between alumina and silica in both the glaze types. No clear relationship is similarly determined on plotting soda against lime, potash, magnesia, or alumina for both the glaze types (Appendix 6.11). The two glaze groups however remain consistently distinguished in most of the plots. The soda to potash ratios (Na_2O/K_2O), and normalised lime-plus-magnesia contents [$(CaO+MgO)/(Na_2O+K_2O)$] of the Type I samples, a means of identifying the plant species used as the flux source (Tite *et al.* 2006), are calculated to be 5.5 and 0.4 on an average respectively (given in Table 6.7).

On relating the glaze groups to the buildings, it is seen that a regional character that was found associated with the tile bodies does not fully apply in the case of the glazes. While regional uniformity is maintained in the case of the Punjab tiles, with Type I plant ash glazes being determined on all the samples of both BT and HM, the same is not true for the Delhi tile-work, both the glaze varieties being found on the samples from buildings in this region. It is further interesting to note that the Type II mineral soda glaze variety is found only associated with the Delhi buildings that are ascribed to a period close to the end of Lodhi rule, while at least two of the three Delhi buildings with plant ash glazes are ascribed to a period that coincides with the commencement of the Lodhi tiling industry in the region. The technology of the Lodhi glazes may therefore be read as varying both regionally and chronologically, and not just regionally, as demonstrated in the case of the bodies.

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Table 6.7 Average chemical compositions of the Type I (plant ash) variety of Lodhi glazes in terms of their base glass forming oxides. All results are in wt% from EPMA-WDS analyses and normalised to100 %.

No.	Building	Region	Date/Period	Nos. of samples	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Na_2O/K_2O	CaO + MgO /Na_2O +K_2O
1	Bagh-e Alam-ka Gumbad (BAG)	Delhi	1501 CE	2	67.2	20.3	3.78	3.19	3.26	1.63	0.57	0.08	6.4	0.3
2	Sheesh Gumbad (SG)	Delhi	c. 1500 CE	10	67.9	18.2	4.78	3.33	3.13	1.33	1.21	0.07	5.5	0.4
3	Madhi Masjid (MM)	Delhi	16th century	2	69.1	18.5	3.71	2.87	3.28	1.81	0.63	0.10	6.5	0.3
4	Bibi Taj-ka Maqbara (BT)	Punjab	15th/16th century	6	69.1	16.1	5.77	3.49	3.22	1.60	0.59	0.07	4.6	0.5
5	Hathi-ka Maqbara (HT)	Punjab	15th/16th century	4	69.3	16.6	5.19	3.15	3.07	1.93	0.61	0.10	5.3	0.4
				Average	**68.5**	**18.0**	**4.65**	**3.20**	**3.19**	**1.66**	**0.72**	**0.09**	**5.6**	**0.4**

Table 6.8 Average chemical compositions of the Type II (mineral soda) variety of Lodhi glazes in terms of their base glass forming oxides. All results are in wt% from EPMA-WDS analyses and normalised to100 %.

No.	Building	Region	Date/Period	Nos. of samples	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2
1	Tomb of Sikandar Lodhi (SL)	Delhi	c. 1518 CE	6	67.3	21.4	1.58	1.95	0.62	5.43	1.44	0.27
2	Jahaz Mahal (JM)	Delhi	16th century	5	69.1	21.4	1.63	1.70	0.75	4.17	1.04	0.21
				Average	**68.2**	**21.4**	**1.60**	**1.83**	**0.68**	**4.80**	**1.24**	**0.24**

Colorants

Copper oxide is found in all the turquoise coloured glazes, in concentrations that range over 2.2-5.5 wt% for individual samples, but otherwise generally in near similar values for samples from the same building (Table 6.9, Appendices 6.6 to 6.9). Values on the higher end among the Delhi samples are notably associated with the buildings on which tiles *in situ* are identified as being of a darker than usual tone, higher concentrations of the colorant apparently imparting a deeper turquoise-blue colour to the glazes. Small amounts of copper oxide, in the range of 0.1-0.3 wt%, are also consistently detected in all the dark-blue glazes of SG.

Table 6.9 Average copper oxide contents in the turquoise coloured glazes from Lodhi buildings at Delhi and Punjab. All results are in wt% from EPMA-WDS analyses.

Building	Region	Glaze Type	Nos. of samples	CuO
Bagh-e Alam-ka Gumbad (BAG)	Delhi	Type I	2	2.50
Sheesh Gumbad (SG)	Delhi	Type I	2	2.07
Madhi Masjid (MM)	Delhi	Type I	2	4.56
Tomb of Sikandar Lodhi (SL)	Delhi	Type II	5	4.18
Jahaz Mahal (JM)	Delhi	Type II	5	4.39
Bibi Taj-ka Maqbara (BT)	Punjab	Type I	6	3.67
Hathi-ka Maqbara (HT)	Punjab	Type I	4	3.95

Very few undissolved copper-containing particles are found in the glaze layers of the turquoise coloured samples. Spot analyses undertaken on the few such identified particles report these as essentially corresponding to copper oxide in their constitution, although some associated elements, mostly contaminants from the glass matrix, are also determined alongwith (Figure 6.42, Appendix 6.12). Small amounts of associated tin are found in only one particle in a BAG glaze (BAG/02). One particle in an SL glaze (SL/05) is found to contain significant quantities of associated zinc. The numbers of such copper-containing particles are however overall too few and too variable in composition for any definitive statement to be made on their possible original makeup in any of the cases.

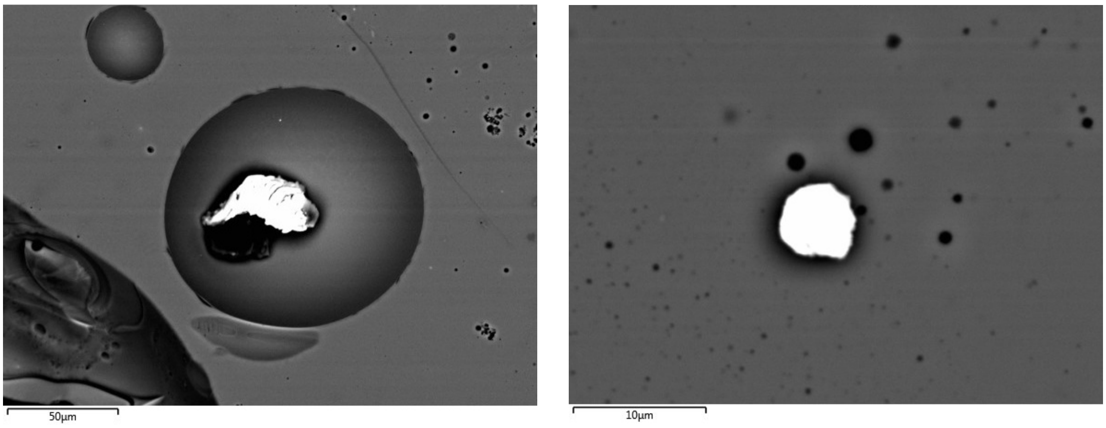

Figure 6.42 SEM photomicrographs of individual copper-containing particles in the glaze layer of a sample from (left) Bagh-e Alam-ka Gumbad (BAG/02) and (right) Tomb of Sikandar Lodhi (SL/05).

The bright particles noted as being uniformly dispersed in all the BT and HM glazes are determined through spot analyses to be particles of tin oxide (Figure 6.43). Their limited numbers, and the low tin oxide contents reported in the bulk compositions of these glazes, suggests that they are more likely to be remnants of colorant particles than being independently added opacifiers. The absence of tin oxide in the glaze compositions of HM/03 and HM/04 may be attributed to the lesser presence of such particles in their glaze layers.

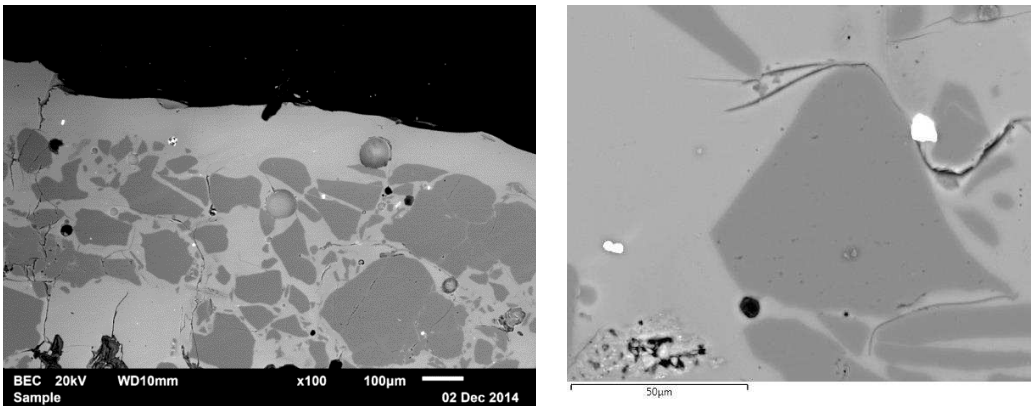

Figure 6.43 SEM photomicrographs of a glaze sample (BT/01) from Bibi Taj-ka Maqbara illustrating (left) the distribution of bright particles of tin oxide in its glaze layer and (right) close up detail of the particles.

All the SG dark-blue glazes contain cobalt oxide in concentrations of 0.2-0.3 wt%. Spot analyses undertaken on small rare bright grains detected in some of these glazes identify them as being cobalt-containing particles with significant associated nickel and iron content (Appendix 6.13). The association of nickel with the colorant is confirmed through the consistent reported presence of nickel oxide in the bulk composition of the dark-blue glazes only, in concentrations approximately equal to that of cobalt oxide (Table 6.10, Appendices 6.6 and 6.8). Iron oxide likewise is confirmed associated with the cobalt colorant on examining its reported values across all the SG glazes, an enhanced content noticed for the dark-blue glazes over those recorded for turquoise specimens from the same building. The same is also determined on re-examining the alumina versus iron oxide plot of all the sampled glazes, the group distinguished from the others on account of their unusual higher iron oxide content being found to consist of the dark-blue SG glazes only (Figure 6.44). Copper oxide, reported present in small quantities in all the dark-blue glazes, is undetected in the spot analyses conducted on the colorant particles. Its original association with the mineral colorant cannot however be ruled out, given that most of the particles analysed are found to be in a partially dissolved state. Small amounts of arsenic oxide are also reported present in the dark-blue SG glazes only. Its concentrations in the glaze bulk are however very low in most cases, being generally around or below the detection limit of the instrument.

Cobalt content is relatively higher in SL/03, the sole dark-blue SL glaze, where it stands at 0.5 wt%. Nickel is low in this case, at 0.07 wt%, while arsenic content is significantly higher at 0.95 wt%, almost twice the cobalt value for this sample. The colorant employed here clearly differs from the one used in the dark-blue SG glazes.

Table 6.10 Values of oxides associated with the cobalt colorant extracted from the bulk chemical composition of the dark-blue glazes. All results are in wt% from EPMA-WDS analyses. Results below the detection limit of the instrument are provided for comparative purposes only. '-' indicates 'not detected'.

Sample	CoO	NiO	Fe_2O_3	CuO	As_2O_5	As_2O_5/ CoO
SG/01	0.31	0.31	1.34	0.23	0.08	0.3
SG/02	0.24	0.27	1.42	0.33	-	-
SG/05	0.29	0.28	1.43	0.29	0.13	0.4
SG/06	0.27	0.24	1.33	0.31	0.10	0.4
SG/07	0.22	0.20	1.25	0.15	0.03	0.1
SG/08	0.22	0.16	1.30	0.19	0.01	0.1
SG/09	0.24	0.19	1.22	0.14	0.02	0.1
SG/10	0.24	0.15	1.18	0.12	0.01	0.1
SG (Average)	**0.25**	**0.23**	**1.31**	**0.22**	**0.05**	**0.2**
SL/03	0.51	0.07	1.56	0.04	0.95	1.9

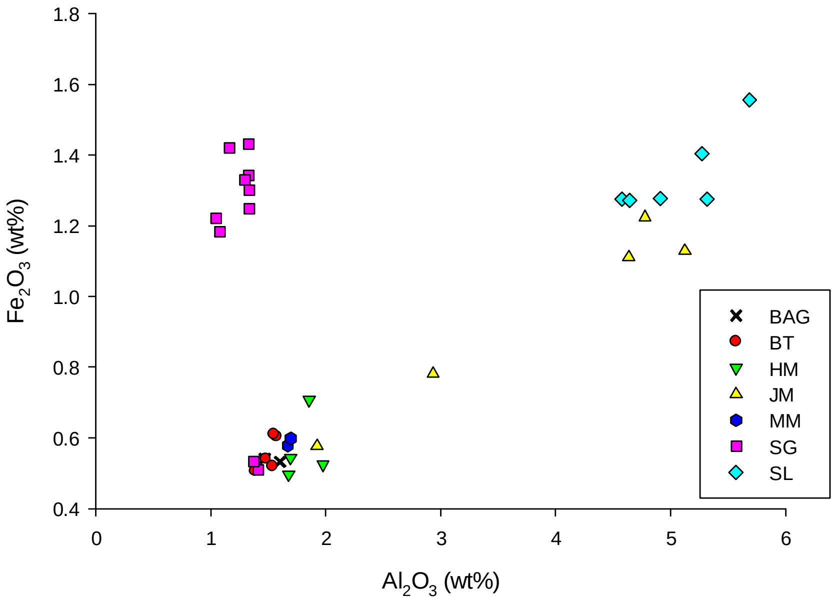

Figure 6.44 Scatter plot of alumina versus iron oxide contents of the Lodhi tile glazes. The SG dark-blue glazes, which otherwise belong to the low-alumina low-iron group of Type I samples, are seen to form a separate group of their own on account of their unusually high iron content.

The other oxides present in minor and trace concentrations in the glaze bulk composition are impurities arriving with the raw material used. Oxides determined present include those of manganese, barium and zinc, their values however seldom exceeding 0.15 wt% where measured. Phosphate levels in the glazes are higher comparatively, varying generally over 0.3-0.5 wt%, except for the SL glazes where they are lower, averaging around 0.15 wt%. Sulphates are mostly in the range of 0.2-0.3 wt%.

Summary and comments

The Lodhi glazes, determined as varying in character and composition across the Delhi and Punjab buildings, are divided over two broad typologies (Type I and Type II), distinguished mainly through their chemical compositions. All samples from individual buildings are of just one of the types. Noted differences between the two types, unlike in the case of the bodies, are independent of regional affiliations of the buildings.

All samples from three of the Delhi buildings (BAG, SG and MM), and those from both the Punjab buildings (BT and HM) are of one typology (Type I). These are alkali glazes that exhibit characteristics of being fluxed using a plant ash source. The samples from the remainder two Delhi buildings (SL and JM) are of the second typology (Type II). These are also alkali glazes, but exhibit characteristics instead of being fluxed using a mineral soda source. The two glaze types are discriminated chemically mainly through their magnesia and alumina contents, their individual associated chemical compositions being given in Tables 6.7 and 6.8. A chronological discrimination can also be made out in the case of the Delhi samples, those of an earlier period being of the Type I variety, while the later glazes are of the Type II kind.

The glazes, across the two types, are similar in their coloration and to an extent in their micro-characteristics. The turquoise glazes are all coloured using copper oxide, while cobalt oxide, of more than one variety, is determined as the colorant used in all the dark-blue glazes. The glazes are largely similar in their thicknesses, particularly for samples from the same building. Some variations in thickness are however determined for samples from different buildings and between the two regions. Except for the terracotta tile samples, a distinct glaze-slip interaction layer of quartz particles exists in all the glazes, often spanning the entire thickness of the glaze layer in individual samples.

The analytical findings are further discussed in Chapter 8, following the presentation of data on Mughal tile-work, and on examining the variances and consistencies determined between Lodhi and Mughal tiling.

7. MUGHAL TILE-WORK: SURVEY AND ANALYSES

This chapter, structured like the previous, is divided over three sections and describes findings of field and laboratory investigations carried out on Mughal tile-work in northern India, as a prelude to discussions on their history and technology. The first section provides a broad appraisal of Mughal architecture and tiling determined through a generic survey of the region of study. The next section expounds findings of a more detailed assessment carried out on tile-work embellishing the buildings specific to the study. The third section provides the results of laboratory analyses and investigations carried out on tile samples sourced for the study.

7.1 Mughal architecture and its tiling

Unlike Lodhi architecture that was restricted in variety and numbers as seen in the preceding chapter, a great many buildings of diverse typologies, sizes, and styles were erected during the reign of the Mughals, particularly as mentioned earlier, in the sixteenth and seventeenth century era of the Great Mughals (1526-1707 CE). The buildings of this period that are otherwise an inestimable figure, become finite in numbers, when reduced to those embellished with tile-work. Even so, in the absence of any known list of recent times, identifying such buildings and according a precise figure to those existing or known to have existed was a difficulty posed for the research. An inventory of such buildings could only be prepared on the compilation of information from several different sources, and its corroboration to the utmost possible through a physical survey of standing monuments in the region taken up for the study. A list of Mughal tiled buildings determined in this manner is provided in Appendix 7.1. Although probably not absolute as in the case of the Lodhi monuments, the list effectively covers all Mughal tiled buildings that are mentioned in published literature, while adding on several lesser known examples as well. The buildings are further noted as existing in two broad geographical zones (Figure 7.1), the tile-work and architecture generally differing in each.

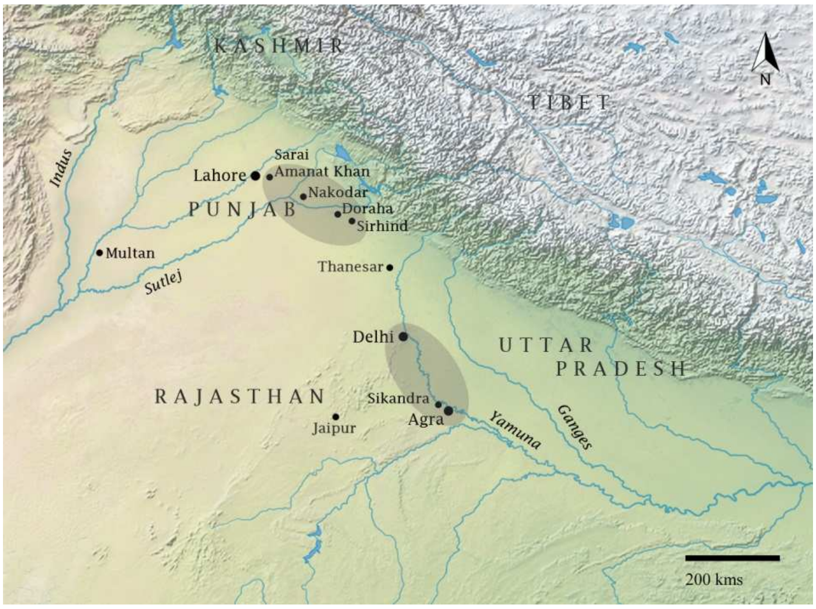

Figure 7.1 Map of northern India. Boundaries of the two zones considered for the study of Mughal tile-work are shaded in grey.

Delhi and Agra

Delhi and Agra, which together make up the first of the two zones, the other being the Punjab, are laden with buildings that exemplify Mughal architecture as widely known. Two phases of architectural development are acknowledged to have taken place here, the sixteenth century showcasing a transition from a Lodhi building style of dressed-stone exteriors to a characteristic Mughal one marked by the large-scale employment of red sandstone, while in the seventeenth century architecture is found to transform to exhibit an increasing use of marble over sandstone before entering a phase of decline. Glazed tile embellishment in the region seems to chart a similar graph, its mode and scale of employment on the buildings apparently following the changing tastes in architecture across time.

Of the tiled buildings in this region, only two can be conclusively identified as being from the early period of Mughal rule, both of which exhibit characteristics typical of Lodhi architecture. Notable of these is the Tomb of Jamali-Kamali (1528-1529 CE) located at Mehrauli in Delhi, the tile-work of which is found to be similar to that of Sikandar Lodhi's tomb in range of colours employed, and to an extent in application technique as well (Figure 7.2). The other building, the Tomb of Yusuf Qattal (d. 1527 CE) in south Delhi, like most Lodhi specimens, is adorned with turquoise coloured tiles only.

Figure 7.2 Detail of the tile-work embellishment in the Tomb of Jamali-Kamali. Although completed in the early Mughal period, the tiles are of a colour scheme similar to that found in Sikandar Lodhi's tomb, employed similarly in the interiors as well.

The use of tiles after the advent of the Mughals is better determined on the monuments of the Sur's (r. 1540-1555 CE), whose buildings are seen to exhibit intermediary characteristics in both architecture and tile-work between Mughal and Lodhi times. The Tomb of Isa Khan at Delhi for instance, is similar in shape and form to the Sikandar Lodhi's tomb (of the Lodhi period), similarities also evident in the tile-ornamentation of the two. The Lal Darwaza (literally Red Gate) likewise, attributed to Sher Shah Sur (1540-1545 CE), is named for the innovative use of red sandstone as a visual offset to its stone masonry construction, the ornamental value of the sandstone enhanced by the placement of panels of geometric mosaic compositions of glazed tiles on the surfaces.

Akbar's (r. 1556-1605 CE) buildings at Delhi and Agra go a step further. Increased building activity and an unencumbered use of sandstone is matched by a rise in tile-work application, although mutual dependence was apparently not necessary as tiles are found employed on plastered buildings as well. The complete palette of colours used at this time comprises turquoise, dark-blue, yellow, green, and white, the tiles remaining individually monochrome as before. The employment of tiles as a single row or band as noticed for Lodhi tile-work is less seen, most tiling now comprising mosaic compositions of geometric patterns. Edges of adjacent tiles in the mosaic compositions are generally straight with the intention of forming geometric shapes and designs. Well-known specimens for the period include the Khairul Manzil Masjid (1561-1562 CE) and Tomb of Atgah Khan (1566-1567 CE) at Delhi (Figure 7.3), and the Amar Singh Gate at Agra Fort, all of which exemplify the above-defined features. Epigraphy executed in tile-work is extremely rare, the only determined examples being a pair of tiled panels located on the walls of the Naubat Khana at Agra Fort, these perhaps also being of a later date. Although a comparative increase from Lodhi times is apparent, an overall general restraint is still visible, the purpose of tiling being clearly only to ornament and not overshadow building form or design.

Tiled buildings at Delhi and Agra from the era of Jahangir (r. 1605-1627 CE) are relatively fewer in numbers, two known structures of this period being the Kanch Mahal and the Tomb of Akbar, both at Sikandra on the outskirts of Agra city. While tiles on the Kanch Mahal are no different from those used earlier, a set of *chhatris* used to ornament the upper pavilion of Akbar's tomb exhibit a hitherto unseen medley of multifarious tile-work techniques (Figure 7.4). Here mosaic compositions, which notably include the use of the orange tiles, can be found alongside polychrome *haft rang* tiles, as well as what appear to be remnants of underglaze-painted blue-and-white specimens. It is interesting to also note that this building is one of the first in which marble cladding is used at places independently of sandstone, transformations quite apparent both in architecture and its tiling.

Figure 7.3 A detail from the wall- mosque at Atgah Khan's tomb (1566-1567 CE). Note the colour palette and geometry of the tiles used.

Figure 7.4 A general view of the tiling employed on a *chhatri* at the Tomb of Akbar. The unusual use of individual polychrome *haft rang* tiles in addition to monochrome tiles set in mosaic compositions is evidenced here.

Fresh influences are noticeable in the buildings at Delhi too. The Nila Gumbad (c. 1625 CE), which is one of the few structures of Jahangir's period here, is unusual in having a dome completely encased with monochrome turquoise coloured tiles. An overall decline and perhaps cessation in the regional tradition and style of tiling seems to have now been reached. If the Naubat Khana at Agra Fort is indeed considered attributable to either the period of Akbar or Jahangir as generally believed, then no buildings from the period of Shah Jahan or Aurangzeb embellished with tiles in the style made popular by Akbar are found to exist. A new style with origins in the Punjab is instead found introduced.

The Punjab

In contrast to the activity noted for Delhi and Agra in the sixteenth century, a perceptible lack of tiling is evident in Punjab in the aftermath of the erection of the Lodhi buildings at Sirhind. In fact but for the Tomb of Shaikh Musa Ahangar at Lahore that is thought to date to a period between 1519 CE and 1560 CE or so (Vogel 1920, 57), no buildings with tile-work can be found in the region that date to the sixteenth century period of Mughal or Sur rule. The earliest tiled buildings here are of the seventeenth century, and ascribed to the reign of Jahangir, the Fatehabad Sarai and the Tomb of Ustad at Nakodar being two such known specimens. While the repertory of five colours employed on these buildings is the same as that used at Delhi and Agra, differences are noticeable in the technique of tiling, as brought forth by Parihar (2008, 264). The tiles in this case are found to be inlaid in strapwork compositions of unglazed bricks, a hitherto unused technique, of unknown origin, which curiously remained in vogue for only a very short while, and was employed only on very few buildings.

It is by far to the period of Shah Jahan (r. 1628-1658 CE) that most tiling in Indian Punjab can be attributed, the majority of tiled structures across the province being from the time of his rule. Many more such buildings are known to exist in Lahore, all featuring yet another new style, characteristic of this period and region. The distinguishing features of this new style of tile-work are not only in its rather lavish employment, covering larger surface areas on structures, but also in its technique of preparation and application. The tiles in all instances in this case are found assembled only in mosaic compositions, and laid in a manner to form a variety of intricate geometric and stylized floral patterns (Figure 7.5). To fashion such patterns, individual monochrome tiles of different colours have been cut and shaped to have curvilinear edges, their curved outlines allowing more complex designs to be created on their assembling. An increase in the number of glaze colours is also apparent, purple and orange coloured tiles being now found in addition to the five colours that mark the Delhi and Agra style. Buildings that exhibit such tile-work include the Tomb of Shagird (1657 CE) and Dakhini Sarai at Nakodar, to name a few. The gates of Sarai Amanat Khan (1640-1641 CE), another such building, are adorned with highly ornate calligraphic inscriptions executed in tiles (Figure 7.6), their use for epigraphy also not so uncommon now.

Figure 7.5 A tile-mosaic panel depicting a stylized floral pattern, typical of seventeenth century tiling in the Punjab.

Figure 7.6 Detail of a calligraphic inscription in tiles at Sarai Amanat Khan (1640-1641 CE).

The style made popular by Shah Jahan was apparently sustained for a while by his successor Aurangzeb (r. 1658-1707 CE) as well, as buildings with similar tile-work continued to be erected up to c. 1670 CE, but a decline is noticed in their numbers, fewer tiled structures from this period being known or found. It is interesting to note that no decline in the quality of work is seen, the Jami Masjid at Mathura near Agra, dating to this period, exhibiting remnants of tile-work of the finest workmanship, comparable to that produced in the first half of the seventeenth century. Tile-work of a high standard is also noted existing on some other contemporary buildings elsewhere along the road to Delhi, suggestive of the spread of the craft beyond the boundaries of Punjab at this time. The continued proficiency of the artisans could apparently not ensure the longevity of the craft, no tile-work being yet found or reported on Mughal buildings in northern India that date to the last quarter of the seventeenth century or thereafter. No *haft rang* tiles dating to the period of Shah Jahan or Aurangzeb's rule can also be found, those reported by Porter (Degeorge and Porter 2002, 271) for the *dargah* of Qutb al-Din Bakhtiyar Kaki at Delhi no longer extant, being either removed or painted over sometime in the recent past.

As regards their current general condition, deterioration that was noticeable for Lodhi tiles is found repeated here, separation of glaze layers from tile bodies and complete loss of tiles from buildings being the most apparent forms of decay. No consistent pattern in the loss of glazing can be determined, sun-facing areas embellished with tiles being equally susceptible as those in the shade. The degree of exposure to the environment does however seemingly matter, tiles in building interiors clearly being in a far better state of preservation than those found on the exteriors. Some monuments, such as the Sheesh Mahal in Aam Khas Bagh at Sirhind, are also apparently more severely affected than others, very few complete tiles surviving on this building. Discolouration is very rare, an exception being the tiling on the *chhatris* of the Tomb of Akbar, one of which exhibits tiles of a peculiar faded green-yellow colour on account of some kind of deterioration. Some decay, as in the case of the Lodhi tile-work, is evidently due to inadequacies in the care and maintenance procedures being followed.

7.2 The buildings and their tile-work

Seventeen tiled buildings from the Mughal period, eight of which are located at Delhi (Figure 7.7), three at Agra, and six distributed over the region of Indian Punjab, were taken up for study. Of these, the Delhi and Agra group of buildings consist of Humayun Darwaza, Tomb of Isa Khan, Arab-ki Sarai, Khairul Manzil Masjid, Tomb of Atgah Khan, Sabz Burj, Nila Gumbad, Tomb of Quli Khan, Kanch Mahal, Naubat Khana, and Chini-ka Rauza. One of the buildings of this group, the Tomb of Isa Khan, is of the Sur period, of a date after the establishment of Mughal rule, but while the Mughals had temporarily lost control of Delhi. The six buildings that make up the Punjab group consist of Doraha Sarai, Fatehabad Sarai, Tomb of Ustad, Sheesh Mahal, Dakhini Sarai, and Tomb of Shagird. A brief description of each of these buildings and observations on their tile-work decoration, as determined through field work, is given as follows:

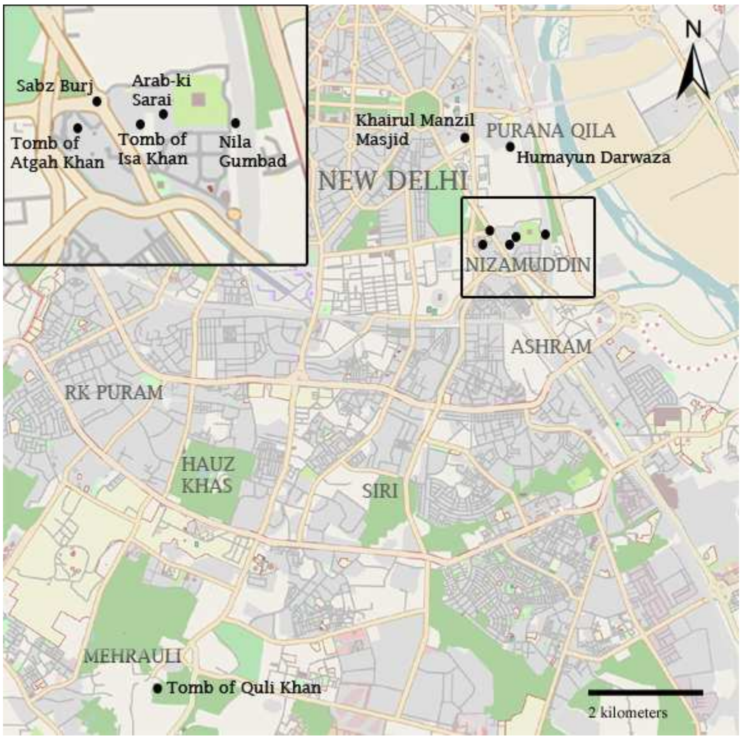

Figure 7.7 Map showing the locations of the eight Delhi buildings taken up for study. Five of these buildings are in close proximity of each other in the locality of Nizamuddin (given in inset).

7.2.1 The Delhi buildings

i) Humayun Darwaza

Humayun Darwaza is one of three similarly styled gateways that pierce the fortified walls of the citadel complex of Purana Qila (Old Fort) at Delhi. Like the others, this gateway is a narrow double-storeyed sandstone-clad structure with a high arched entranceway, flanked on its sides by two prominent semi-circular bastions (Figure 7.8). A pair of *jharokhas* (covered projecting balconies), one on either side of the large central arch, are found to adorn its outer facade. The roof of the structure is flat, but has a pair of stately *chhatris* added on for ornamentation. While the outer portion of the building is in a fairly sound state, part of the rear or inner portion has collapsed, giving the whole gateway a sort of ruinous appearance when viewed from the grounds within. No precise date can be assigned to the building, but it is generally considered to have been built either during the reign of Humayun, in whose name it stands, or in the times of Sher Shah Sur, who is credited with having the fort rebuilt during his reign.

Figure 7.8 A general view of Humayun Darwaza from within the complex.

Both the *jharokhas* and the *chhatris* on the building bear evidence of tiled ornamentation on their roof-bases and canopies (Figure 7.9), a narrow frieze of individually laid tiles also noticed employed above the main archway of the outer facade. From the scant remnants of complete tiles that are *in situ*, it appears that only turquoise coloured tiles were employed. No evidence of the use of any other colour or the employment of any elaborate application technique can be determined. Some tiles on the square roof-bases of the *jharokhas* appear to be of a darker tone than the others, but like the Lodhi tiles these are apparently a variation of the same turquoise colour and are not a distinct separate shade. Of the surviving tiles, as in the case of extant specimens on Lodhi buildings, only about half exhibit evidence of their original glazes, the glaze layers being lost in the remainder.

Figure 7.9 Detail of the tile-work on one of the *jharokhas* on the external facade of the gateway.

ii) Tomb of Isa Khan (Isa Khan's Tomb)

The Tomb of Isa Khan[1] is located adjacent to Humayun's tomb at Nizamuddin in Delhi, and is part of a larger walled enclosure that also contains a garden and a mosque. This tomb-structure bears a strong resemblance in form to the Tomb of Sikandar Lodhi, having a similar central octagonal chamber enclosed by a verandah, and three arched-openings on each side (Figure 7.10). On the roof is a large plastered dome, surrounded

[1] Isa Khan is identified as being a noble of high rank in the Sur courts.

by a series of *chhatris*, one being positioned at the centre of each side. All the roof corners, and those on the drum of the dome, have a shaft-like decorative pinnacle-feature placed thereon, while the parapet is just a row of ornamental merlons. The interiors of the building are plastered, with a *mihrab* provided on the western wall. The building is dated to 1547-1548 CE from an inscription given on a stone slab over the *mihrab*.

Figure 7.10 A general view of the Tomb of Isa Khan.

As opposed to findings at Sikandar Lodhi's tomb, no glazed tiles are found in the interiors, the exteriors conversely bearing a fair degree of tiled ornamentation, most of which is in a deteriorated state. Tiles are found to have been used to outline the profile and frames of the outer arched openings of the verandah, as a frieze over the *chhajjas* (dripstone-eaves) on the building sides, on the merlons that make up the parapet, on the *chhatris* on the roof, and on the drum of the dome. While all the tiles are individually monochrome and mostly used as a band or course of a single colour, the employment of simplistic mosaic compositions can also be seen. The narrow frieze above the *chhajjas* and the band outlining the verandah arches notably have tiles of different colours laid in polychromatic compositions (Figure 7.11). Interestingly, the colour scheme is found to comprise five colours, possibly for the first time in the chronology of development. White glazes are now found in addition to the turquoise, dark-blue, yellow and green coloured ones reported earlier in the case of Sikandar Lodhi's tomb. Remains of tiles of similar colours and application style are also evidenced on the mosque located within the same complex.

Figure 7.11 Detail of the tile-work on one of the verandah arches. The use of white coloured tiles can be evidenced here, employed in a mosaic composition with the two blues.

iii) Arab-ki Sarai

Arab-ki Sarai, as known, is the name given to an extended walled enclosure that lies sandwiched between the Tomb of Isa Khan on one side, and the perimeter wall of the Tomb of Humayun on the other. The *sarai*-enclosure is generally believed to have been built to house Arab workmen brought in by the widow of the emperor Humayun to aid in the construction of the tomb erected in the memory of her husband. On the north and east of the enclosure are two lofty gateways, the north facing one being the source of samples taken for this study. Clad in contrasting tones of red and grey sandstone, this gateway is an elongated structure comprising a projecting central portion having a large arched entranceway, flanked on its sides by bays of a lower height. The only architectural feature of merit on the building is a pair of *jharokhas*, provided on the upper portions of the outer facade. A plaque placed by the Archaeological Survey of

India ascribes a date of 1560-1561 CE to the *sarai*, the source for which is not clear as no inscription is known to exist on the structure.

The ornamental value of the two *jharokhas* was originally enhanced by the application of glazed tiles to almost completely cover their canopied roofs, remains of which can still be evidenced on their square roof-bases (Figure 7.12). Tiles of a turquoise, dark-blue, yellow, and green colour are found here, assembled in mosaic compositions on more than one level. A lower frieze, above the dripstones, is noticed as comprising square-shaped yellow tiles placed on their edges, alternating with dark-blue coloured tiles in use. Fragmentary remains of an inverted lotus motif executed in glazed tiles are also noticeable on the next frieze directly above, but overall few tiles are found in place on both the *jharokhas*, almost all of those on the curved roofs that lie further above having detached and fallen off some time in the past.

Figure 7.12 Detail of the tile-work on one of the *jharokhas* on the north gateway.

iv) Khairul Manzil Masjid

The Khairul Manzil Masjid is a walled mosque complex of significant extent, located close to the northern entrance of Purana Qila. This complex consists of an entrance gateway positioned on the eastern side, a spacious courtyard flanked by a row of colonnaded-cells in the middle, and a large plastered domed-building reserved for praying at its western end (Figure 7.13). Within the main mosque-building is a prayer chamber with three *mihrab*-features, one in the centre, and one on either side in two adjoining bays. On its exteriors, the loftier projecting central bay that carries the dome is provided with a large arched entranceway, the flanking bays having similar openings but of a smaller size. The parapet, as in most other buildings of this time, is a kind of a faux-battlement having a row of ornamental merlons executed on a low wall. The building is dated to 1561-1562 CE on the basis of a chronogram given thereon.

The tile-work on this building is notable for its relatively extravagant use as compared to other contemporary tile-decorated structures. From extant remnants it appears that a substantial portion of the exteriors of the large central bay was once decorated with tiles exhibiting the full repertory of colours associated with the times. Remains of a multi-coloured tile-mosaic of individual turquoise, dark-blue, yellow, green, and white coloured tiles can be evidenced here (Figure 7.14), as can a prominent calligraphic inscription in stucco having turquoise coloured tiles embedded within. Tiles are also be found elsewhere on the building exteriors, on medallions of varying size located on spandrels of the arches of the side bays, inset once again to highlight the stucco carvings. Significant numbers of tiles are found used in the interiors as well, outlining the profile of the arches in the *mihrab*s and on their protruding rectangular frames (Figure 7.15). Impressions of tiles are also found on patches of plaster on the inner side of the entrance gateway, possibly originally employed on the entire arched vestibule here. Notably, of the extant tiles, all those in the interiors of the mosque-structure are complete tiles with their glaze layers in place, while of those on its exteriors, only about half have their glaze layers intact, the other half being tile bodies only.

Figure 7.13 A general view of the mosque-structure in Khairul Manzil Masjid.

Figure 7.14 Detail of the tile-work affixed in mosaic compositions on the exteriors of the central arch of the mosque-structure.

Figure 7.15 Tile-work decorating the interiors, as on the *mihrab* frame in the detail seen here, is in a much better state than that on the exteriors, very little separation of the glaze from the body noticeable.

v) Tomb of Atgah Khan (Atgah Khan's Tomb)

Located near Humayun's tomb, in the crowded quarter of what is now Nizamuddin Basti, the Tomb of Atgah Khan is an exquisite square-shaped structure of marble and red sandstone erected in memory of an influential noble who served in the court of the emperor Akbar (Figure 7.16). The building, in construction, is provided with a marble-bordered high archway in the middle of each side, with blind arches and panels of smaller dimensions distributed on the rest of the wall surfaces. On the top is a large dome clad in marble. The chief attractiveness of the structure lies in the effective utilization of marble as a counterpoise to red sandstone, the former drawing attention to features of importance as well as acting as a source of ornamentation itself. On the western side, a part of the boundary wall of the enclosure is found fashioned as a wall-mosque, elevated in height from the rest of the wall, and provided with three recessed arches outlined with bricks in front. An inscription above the southern door on the main building indicates that it was completed in 1566-1567 CE.

Figure 7.16 A general view of the Tomb of Atgah Khan.

On the tomb-building, in a departure from the usual, glazed tiles are found employed as insets in some parts of the marble cladding, notably in the spandrels of all the central arches and in rectangular panels located above the smaller side arches. Dark-blue and green coloured tiles have been thus utilized to enliven the marble surfaces, forming decorative geometric patterns, and providing an alternative to the use of stone inlay. The wall-mosque is relatively more liberally decorated with tiles; the application technique used here also more in keeping with contemporary trends. All the recessed portions of this small brick structure are filled with mosaic compositions of monochrome turquoise, dark-blue, yellow, green, and white coloured tiles. Some turquoise tiles are also noticed used as separators between successive bricks on the frames of the recesses. A great deal of the tile-work on both the building and wall-mosque has however unfortunately been lost, with plaster being often seen applied in place. The glazes of the majority of the extant tiles have also been lost, surviving numbers of complete tiles being overall few but sufficient to appreciate the fine quality of their original application.

vi) Sabz Burj

Sabz Burj, meaning 'Green Tower', is an isolated octagonal-shaped tomb-building located to the west of Humayun’s tomb in Nizamuddin. Styled with an unusually long drum for its dome, this building is distinct for its lack of indigenous features like *chhatris* and *chhajjas* that are typical of Mughal architecture for the region (Figure 7.17). Little else is notable in the architecture besides the elongated drum-dome, the four cardinal sides of the structure being taller and provided with larger archways as compared to the other four sides. A parapet wall, elevated on the four taller sides, runs around the roof. No merlons are found executed on the parapet. Both the drum and dome are circular in shape, the latter of a slightly larger girth jutting out above a cornice like feature that separates them. The whole building, except where ornamented with tiles, bears a plastered finish. The building is undated, but is ascribed by some to the early Mughal era based on its architectural features.

No tiles can be found on any of the sides of the building. Monochrome tiles have instead been used to good effect on the drum and the dome, the drum being embellished with turquoise, dark-blue, yellow, and green specimens, while the dome carries tiles of a dark-blue colour only. The patterns formed by different coloured tiles on the drum are noticeably simpler than those seen on any of the other buildings, an overwhelming use of square-shaped tiles also most apparent. The dark-blue tiles that cover the dome are known to be of recent origin, having been applied in a documented restoration effort a few decades back. The tiles on the drum on the other hand, are accepted as matching the building in age, and exhibit signs of deterioration in keeping with their antiquity. Some tiling was also probably carried out at places on the wall surfaces below, as impressions of what appear to be tiles can be discerned on patches of plaster present on the parapet walls. No tiles with intact glazes can however be determined here.

Figure 7.17 A general view of Sabz Burj and its tile-work decoration.

vii) Nila Gumbad

The tomb-structure that goes by the name of Nila Gumbad also lies in close proximity of Humayun's tomb, and like Sabz Burj is noted for its unique form; its shape, characteristic tile-work decoration, and lack of local architectural features lending it a Central Asian or Iranian character. The building itself is a double-storeyed octagonal-shaped structure of rubble masonry that rises from a high platform and is crowned by a dome embellished with turquoise tiles wherein it derives its name, Nila Gumbad literally meaning 'Blue Dome' (Figure 7.18). The four sides or facades of the building that are oriented in the cardinal directions are each provided with a large central arch, flanked by a pair of shallow blind arched recesses in two levels. The other four faces only have a central arch of relatively smaller size in each. Patches of extant plaster visible on all the sides indicate that the building, excluding the tiled areas, was originally provided with a plastered finish. The building is not dated but is assigned to the early seventeenth century (c. 1625 CE), built purportedly to house the remains of Fahim Khan, an attendant to a high noble of that time.

Besides their unusual application on the dome, glazed tiles have been used to notably cover the entire north facade of the building, and embellish a part of the drum of the dome as well. No tiles are found in the interiors. The tiles on the walls and parapet of the north facade, and on the drum of the dome, are all laid in the style of a multi-coloured mosaic, assembled in geometric patterns utilizing individual monochrome tiles of different colours (Figure 7.19). Glaze colours found employed are the usual palette of five, comprising turquoise, dark-blue, yellow, green, and white. The dome is adorned with relatively larger sized rectangular-shaped tiles of a turquoise colour only (Figure 7.20). From the existing remnants at the site, it is clear that principal forms of deterioration follow those noticed on other contemporary tiled structures, tiles being either entirely lost and where extant, many exhibiting losses of their glaze layers. Islands of glazes of varying size that can be seen remaining on many of the extant tiles indicate that the separation of the glaze layer from the body is apparently taking place in more than one stage, and seems related to the glaze-fit.

Figure 7.18 A general view of Nila Gumbad.

Figure 7.19 Detail of a portion of the tile-mosaic on the north facade. Note the apparent stage-wise loss of glazes on their separation from the bodies.

Figure 7.20 Close-up of the tile-work employed on the dome and drum. The dome carries tiles of a turquoise colour only, while the drum has a band of tiles of different colours laid in the mosaic fashion.

viii) Tomb of Quli Khan (Quli Khan's Tomb)

The tomb of Quli Khan, said to be the son of a wet nurse of Akbar, is located in the quarter of Mehrauli in south Delhi. A rubble construction of octagonal form, the building is situated on a high arcaded plinth (Figure 7.21), and surrounded by an extensive garden that was laid out at the time of its conversion to a private residence in the nineteenth century. Each side or face of the building is provided with high archways, with openings given in alternating sides. Bands of stucco carvings and calligraphic inscriptions outline the profile of the arches and their rectangular frames. The arches are further embellished through the placement of carved stucco medallions on their spandrels. The roof carries a dome rising from a low drum, while the parapet wall has merlons carved on the outside for ornamentation. The interior chamber has blind arches at two levels which are profusely decorated with stucco work painted in a dominant blue shade. No clear date is assigned to the building, but is believed to have been erected in the early seventeenth century.

Figure 7.21 A general view of the Tomb of Quli Khan.

On the eastern facade, glazed tiles are found employed on the band that surrounds the rectangular frame bordering the archway. The same band on the other building sides is found to be embellished with carved stucco-work only. Glaze colours determined include dark-blue, yellow, green, and white, the tiles as elsewhere being individually monochrome and employed to form geometric mosaic compositions. The absence of turquoise coloured tiles on the building does not necessarily indicate their exclusion from the original employed colour scheme, as only a few of the surviving tiles are found to have their glaze layers in place. It is remnants of the tile bodies in fact that largely inform the nature and extent of tiling originally employed. Some evidence of tiling can also be found on the two small niches that flank the eastern entrance into the interiors, but very little survives here as well to indicate the original pattern and palette.

7.2.2 The Agra buildings

i) Kanch Mahal

The Kanch Mahal, or 'Glass Palace', is believed to have been built by Jahangir, and used first as a royal resort and then later as a hunting lodge by him. Square in plan, this elegant building is located at Sikandra, on the outskirts of Agra, close to the main entrance gateway of the Tomb of Akbar (Figure 7.22). The original exteriors of this restored two-storeyed building can be appreciated from its northern facade, the only side clad in sandstone, which has a prominent centrally positioned arched entrance to its interiors. On the ground floor, on either side of the entrance archway, is a relatively smaller arched vestibule, above which on the first floor is a *jharokha* styled in the form of a bay window, its sides being covered by perforated stone screens. *Jharokhas* were apparently provided on the east and west facades as well, one surviving example visible on the upper storey on each of these sides. The interiors comprise a series of small and large rooms at both levels, the roof curiously designed not to have a dome but be flat instead, and provided with a low parapet wall.

The name by which the building is now known is thought to originate from its tiled ornamentation, the word *kanch* or 'glass' referring to the brilliant glazes of the tiles employed. The parapet on the north and parts of the east and west facade is in effect a frieze of monochrome yellow and turquoise coloured tiles inlaid in a battlemented pattern of alternating inverted and upright lotus motifs, bordered by a narrow band of green tiles below. A similar pattern of tile-work can also be evidenced on the roof-bases of all the *jharokhas*, the pair on the northern facade having tiles on the canopied parts of their roofs as well. Here dark-blue tiles are found employed along with green and yellow to form a mosaic composition of geometric patterns. A similar scheme may have existed on the canopied portions of the roofs of the other extant *jharokhas* as well, but no trace of this is now evident, these now being plastered over. No orange coloured tiles reported by Smith (1901, 23) are found *in situ*, yellow tiles being noticed instead in the locations where they are mentioned as existing.

Figure 7.22 A general view of Kanch Mahal and its tile-work decoration.

ii) Naubat Khana

The Naubat Khana or ‘Drum House’ stands between Amar Singh Gate, the current entrance to Agra Fort, and the vast expanse of the fort complex within. Pierced by an entrance that provides passage to the inner grounds, and flanked by a pair of bastions terminating in cupolas[2] (Figure 7.23), this high building was originally utilized by royal musicians to announce the arrival or departure of the emperor through the playing of instruments. While the upper part of the outer facade of this building is clad with red sandstone, the lower is plastered and provided with three horizontal rows of blind arched recesses set in rectangular frames, separated from each other by relatively smaller rectangular panels. Openings above the gateway notify the presence of two distinct floors or levels in the building, the top being the usual battlemented parapet. The building in all likelihood is contemporaneous to the date of the fort, constructed during the reign of Akbar in the sixteenth century. The tile-work is however said to be of later date, most probably from the period of Jahangir.

All the plastered recesses in the lower part of the outer facade were apparently once embellished with tiles, remains of which can be seen in some of them. Monochrome tiles of turquoise, dark-blue, yellow, green, and white glaze colours are observed on the upper two rows of arched recesses, on the rectangular panels between them, and on a broad band that runs uninterrupted across the length of the bastions and the gateway above the uppermost row. Notably, while the tiles here have also been applied in geometric mosaic compositions, a fair number of individual tiles have been cut and shaped to have curvilinear edges to form patterns that now include vines and arabesque motifs in addition to the usual geometric repertory (Figure 7.24). Calligraphic inscriptions executed in tiles, unusual for the period, can also be made out on a pair of rectangular panels that flank the arched entrance passage (Figure 7.25). Surprisingly, almost all the extant tiles on the building have their glaze layers in place, those that lack glazes seemingly plastered over during the course of repairs.

[2] Distinguished from *chhatris* by having side walls instead of pillars, supporting the canopy or roof.

Figure 7.23 A general view of Naubat Khana.

Figure 7.24 A series of tile-mosaic panels on the one of the bastions. The patterns exhibited notably include arabesque and floral designs, a feature not seen on the Mughal tile-work at Delhi.

Figure 7.25 Detail of a panel with epigraphy executed in tiles, a rarity for tile-work associated with the region of Delhi and Agra.

iii) Chini-ka Rauza

An unparalleled specimen of tiled architecture, the Chini-ka Rauza or 'Porcelaneous Tomb' is located on the left bank of the river Yamuna at Agra, not far from the famed Taj Mahal. Square in plan, this tomb-structure seems to have been purposefully constructed to allow unhindered tiling (Figure 7.26), the exterior surfaces being largely flat and bereft of features, except for elaborate large arched portals provided at the centre of each side. On the four corners of the building are slender shafts that start from the ground, appear to pierce the parapet, and terminate in *guldastas* (a kind of ornamental pinnacle) some distance above the roof. Similar but narrower shafts border the abutments of the central arches as well. On top and at the centre of the roof is a dome of modest size, resting on a sixteen-sided drum. A parapet wall, elevated above the portals, runs along the upper perimeter of the wall surfaces. The interiors comprise a large octagonal-shaped chamber that contains two cenotaphs, the crypt being located in a chamber below. No clear date is given to the building, but it is ascribed to the early period to Shah Jahan's rule (c. 1639 CE), and is said to house the remains of Shukrullah Khan Shirazi, a courtier of his times.

The exceptional feature of this building is undoubtedly its profuse tile-work decoration, countless numbers of tiles having been used been to cover the entire building facade in an extraordinary variety of patterns. Seven colours of monochrome tiles are found used here, assembled in mosaic compositions of stylized floral and geometric patterns. Floral patterns dominate in employment, being exhibited on the wall surfaces in a series of panels or frames (Figure 7.27). The colour scheme utilized includes purple and orange coloured tiles, in addition to the usual palette of turquoise, dark-blue, yellow, green, and white found elsewhere on buildings at Delhi and Agra. Notable is the dexterity and manipulation involved in the cutting and assembling of tiles, the work necessitating the skilful shaping of small individual pieces to create irregular forms in an otherwise overall geometry of design. The shafts that carry the *guldastas* are additionally adorned with some underglaze-painted polychrome tiles (Figure 7.28), the painted designs of which are not of any remarkable quality.

Figure 7.26 A general view of Chini-ka Rauza.

Figure 7.27 An intricate tile-mosaic panel on a wall surface. Highly ornate floral depictions, such as this one, dominate the tile-work compositions employed on this building.

Figure 7.28 Remains of polychrome tiles on one of the corner shafts.

The drum and dome of the building were apparently also once tiled but less evidence of their use is available here, much having been lost with the ravages of time. A substantial portion of the tile-work all over has in fact been lost, less than half of that originally employed in place on the building. Even among the surviving tiles, those with and without glazes are probably equivalent in numbers, many being just tile bodies shorn of their glaze layers.

7.2.3 The Punjab buildings

i) Doraha Sarai

In its construction and plan, Doraha Sarai exemplifies the *caravansarais* (roadside inns) of its time, constructed for the lodging of merchants and travellers along the old highway connecting Agra and Delhi with Lahore. Located at Doraha, close to the modern city of Ludhiana, the *sarai* essentially comprises a large square-shaped open camping enclosure bounded by battlemented brick walls, with some cells or rooms built along its inner perimeter. Octagonal-shaped bastions mark the four corners of the compound. The north and south walls of the complex are pierced by imposing gateways, while a small mosque is located near the centre of the grounds within. Each of the gateways is a double-storeyed rectangular-shaped brick structure having a large central arched entranceway, flanked by a pair of smaller arches at each storey (Figure 7.29). A bastion surmounted with a cupola marks either end on the sides. Although no inscription is found in the *sarai*, Parihar (1999, 118-119) identifies it as being Sarai Itimad al-Daulah based on a historical reference, and suggests a date of c. 1611-1620 CE for its construction.

As in other notable *sarais* in the Punjab, glazed tiles have been judiciously used to enhance the importance of prominent architectural features. Monochrome tiles of turquoise, dark-blue, yellow, green, and white colours are determined employed on the outer facades of both the gateways, in a band framing the central arches of each, and on the spandrels of the smaller arches on the sides (Figure 7.30). The technique of application employed here is distinct from that used in contemporary or earlier buildings at Delhi and Agra. The tiles in this case are found to be embedded between raised unglazed bricks laid in geometric strapwork compositions, but whether the tiles were employed as insets subsequent to the laying of bricks or installed together with them as large composite panels cannot be clearly determined.

Figure 7.29 A general view of the southern gateway of Doraha Sarai.

Figure 7.30 Tile-work on the spandrel of one of the smaller arches on the gateway. Note the use of unglazed bricks to separate individual tiles in the composition.

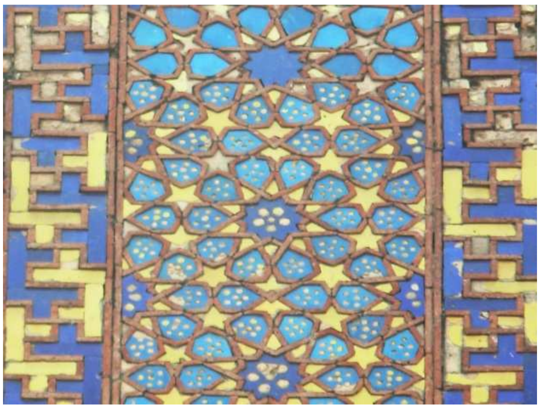

Figure 7.31 Detail of a portion of the tiled band that frames the central arch. Dot-patterns that can be evidenced on some of the tiles here, have been attained through the inlaying of small round yellow tiles in the glaze layers of larger specimens.

Some pentagonal and star-shaped turquoise and dark-blue tiles used on the border framing the archway appear to be 'enamelled', on account of being further inlaid with 'buttons' of smaller yellow-coloured tiles (Figure 7.31). Some evidence of the use of tiles can also be discerned on the domes of the cupolas over the bastions at the gateway and on the corners of the enclosure, but the surviving numbers are too scanty to make any conjecture on the extent of their use. Forms of deterioration are consistent with those noticed on tile-work elsewhere in the region, being mostly either loss of individual tiles, or separation of glazes from the tile bodies. Vandalism has apparently played a key role in the observed decay, as the lower easily accessible areas are the ones most affected, tiles on the upper reaches of the building being better preserved.

ii) Fatehabad Sarai

Like the Doraha Sarai, the *sarai* at Fatehabad, a small town to the south-east of Amritsar, would have originally been a large spacious enclosure with lodgings for travellers and fortified for protection, but little remains of all this now. All that is extant are its two gateways that face east and west, and a small mosque. Of the two gateways, the western is probably closer to the original in shape and size, having bastions at either side that terminate in small domes above the battlemented parapet at the centre (Figure 7.32). The two gateways are otherwise similar, being double-storeyed brick constructions having a large central archway, and two smaller arches positioned at two levels on the flanks. The grounds that would have originally made up the inner enclosure are now crowded with modern buildings. No clear date is assigned to the *sarai*. Parihar (1999, 111-112), based on a historical account, attributes the founding of the town and *sarai* to Jahangir, and using the same source suggests a date of 1606 CE for the commencement of its construction.

Both the gateways are decorated with glazed tiles on their outer facades. The better-preserved western gateway has tiles decorating the spandrels of all the arches, the central arch being further decorated through a tiled band that frames it on three sides. All the tiles here are applied in the same technique witnessed at Doraha Sarai, being inset in patterns of raised brickwork that form geometric compositions. No white coloured tiles are found, the palette seemingly limited to the use of monochrome tiles of turquoise, dark-blue, yellow, and green colours. Interestingly the 'enamelling' of tiles noticeable at Doraha is repeated here but in a reverse scheme, yellow coloured tiles having blue 'button' inlays instead.

Figure 7.32 A general view of the western gateway of Fatehabad Sarai.

Comparatively fewer tiles are found on the eastern gateway, only the band framing the large central arch remaining here, the technique of application and colours used otherwise being the same. Surprisingly, the extant tile-work on both the gateways is found to be in a fairly good state of preservation, significant numbers being complete tiles.

iii) Tomb of Ustad

One of a pair of exquisite tombs located within a small complex, the Tomb of Ustad is situated at Nakodar, a town that lies on the old highway to the south-west of Jalandhar. Octagonal in shape, this brick-constructed tomb rests on a high plinth that follows its ground plan, comprising four long and short sides (Figure 7.33). In elevation, the four larger sides, which face the cardinal directions, are each provided with a large archway that has openings within, the other four alternating sides each having a pair of smaller arches at two levels. A series of rectangular framed niches are distributed on the wall surfaces on all sides. The interior is primarily composed of a large central square chamber that can be accessed from the southern side, openings on the other cardinal sides being trellised. A low parapet wall marks the boundary of the roof, while cupolas are found provided on four of the eight corners of the roof for ornamentation. At the centre of the roof is a large plastered hemispherical dome that springs from a cylindrical base. An inscription given on the tomb indicates that it was erected for a certain 'Muhammad Mumin Hussaini'[3] in 1612 CE.

Figure 7.33 A general view of the Tomb of Ustad.

Matching the elegance of the building is its tile-work ornamentation, applied in the spandrels of all the arches and arched features, in the smaller rectangular niches on the wall surfaces, and on the entire length of the parapet wall. Monochrome turquoise, dark-blue, yellow, and green tiles are found employed, as well as a few specimens of underglaze-painted blue-and-white tiles (Figure 7.34). The technique of application is

[3] Parihar (1985, 34-35) identifies him as a musician of repute, in the service of a high official of that time.

similar to that witnessed on the *sarais* at Doraha and Fatehabad, individual tiles being inset in patterns of raised brickwork, the variety of designs seen here perhaps being greater than those found at the two other sites.

Figure 7.34 A tiled panel on one of the wall surfaces exhibiting the use of blue-and-white tiles in addition to monochrome specimens.

Figure 7.35 Tile-work on the spandrel of an arch. Note the floral patterns realised through the tile-in-tile inlay technique.

The tile-in-tile inlay that is seen at Doraha and Fatehabad is also found here, once again in greater diversity and detail, motifs of stylized floral patterns being realised through this technique in addition to the 'button' patterns recorded earlier (Figure 7.35). Besides the above-described methods of application, a single band of individually laid tiles is also found to circumvent the building below the parapet, a similar band finding use on the bases of the roof cupolas as well. As at Fatehabad Sarai, the tiles here are found to be in a comparatively better condition than those on other Mughal buildings of a contemporary period, the ones in the rectangular panels being in a particularly good state.

iv) Sheesh Mahal

Located within the garden complex of Aam Khas Bagh at Sirhind, the Sheesh Mahal, or 'Palace of Mirrors', is believed to have been built for royal use, either for the emperor to grant audience to his subjects, or to serve as a private royal apartment. Although much altered by civil restoration works carried out in the recent past, the building can be determined to have been originally a double-storeyed structure constructed on a rectangular plan, surmounted on its middle by a trio of domes, all of which are still largely in an original state. The only other original features on the exteriors are four additional domes of a smaller size that are placed on the corners on the roof, and a portion of the parapet wall. No inscription is found on the current structure. Parihar (2008, 193), based on a historical reference, attributes its construction to having been ordered by Shah Jahan in 1634 CE.

Figure 7.36 Detail of the tile-mosaic employed on one of the corner domes. The use of purple and orange coloured tiles can be determined here, in addition to the common repertory of five colours.

Figure 7.37 Fragment of an underglaze-painted tile employed on a dome. The grey coloured material on its sides is cement mortar from repair work.

From fragmentary remains *in situ*, it is evident that all the domes and the parapet of the building were once decorated with tiles, only few of which now survive. The remnants however suffice to indicate that all the tile-work employed was in the mosaic fashion, highly intricate motifs and patterns being formed through the assembling of monochrome tiles of different colours (Figure 7.36). Glaze colours determined include purple, orange, turquoise, dark-blue, yellow, green, and white. Evidence of the use of underglaze-painted tiles is also found on the centrally placed domes (Figure 7.37). The tile-work itself is in an overall extremely poor state of preservation, a significant proportion of the tiles having been lost and most of those surviving being devoid of their glazes. Extant tile bodies too are found to have undergone some degree of deterioration, those on the rib of the large central dome being in a highly eroded state whereas the ones on its curvatures are in relatively better condition. A substantial portion of the parapet appears to have been reconstructed in cement mortar at the cost of tile-work that once adorned it. Repair work in cement or lime mortar has also been carried out on the domes, covering the original tile-work at places.

v) Dakhini Sarai

The Dakhini Sarai, located at Mahlian Kalan near Nakodar, follows the layout of the *sarai* at Doraha and others of its time, being a large open complex enclosed by high battlemented walls, the corners of which are provided with octagonal bastions. Two grand gateways, one each at the centre of the eastern and western flanks, permit entry into the complex. The outer facades of the gateways are bordered by an octagonal bastion on each side, topped in the case of the western gateway by a *chhatri*, the eastern side being currently devoid of this feature. At the centre of both gateways is a large arch having an entrance passage within. Like the other *sarais*, all the structures in the complex are brick constructions. The *sarai* carries no inscription but is generally believed to have been erected during the reign of Shah Jahan from its architectural features and tile-work decoration.

Glazed tiles at this *sarai* are found on the external facades of both the gateways and on the mosque in the complex. The tiles used here are notably different from those employed at the *sarais* at Doraha and Fatehabad in their technique of application and in the palette of colours that they exhibit. The repertory of glazed colours found here and the method of application is in fact similar to that evidenced on the Sheesh Mahal at Sirhind. Purple, orange, turquoise, dark-blue, yellow, green, and white monochrome tiles are found laid in elaborate mosaic compositions, forming intricate geometric, floral, and arabesque patterns (Figure 7.38). These have been employed as a band to frame all the arches on the facade, and on the domes of the *chhatris* that lie above the gateway bastions (Figure 7.39). Some tiles can be made out on the front facade of the mosque as well, in a band framing the arches, but very little of the original remains here to determine the exact extent of their application.

Figure 7.38 Detail of a portion of the tile-work on the western gateway. The use of seven distinct glaze colours can be evidenced in the mosaic composition depicted here.

Figure 7.39 Close-up of the dome of a *chhatri* on the western gateway illustrating the use of tiles for its embellishment.

vi) Tomb of Shagird

The second of the two notable tomb-structures at Nakodar, the Tomb of Shagird is located in close vicinity of the Tomb of Ustad, in the same garden enclosure. Built on a high platform, the building reverses the plan of its neighbour, being square on the outside and octagonal within (Figure 7.40). Each of its four facades has a prominent archway at the centre, the four comers being occupied by octagonal-shaped turrets covered by *chhatris*. Recesses bounded by rectangular frames are distributed across all the external surfaces, some of which have shallower arched niches set within. On the roof is a low parapet, the whole structure being topped by a pear-shaped dome. An inscription on the northern facade of the tomb identifies the person interred within as Haji Jamal and assigns its date of construction or completion to 1657 CE. Haji Jamal's identity is not known, but would have probably been a man of influence and title in his times judging from the size of his mausoleum.

The exceptional feature of this building is the prolific use of glazed tiles in the decoration of its exteriors. The recesses in the walls and turrets, the entire parapet, the neck of the central dome, and the domes of the *chhatris* are all embellished with tiles that form a variety of colourful patterns and designs. The highlights are perhaps the wall panels exhibiting bouquets of flowers springing from elegant vases, and the unique depictions of bowls of fruit (Figure 7.41). All the tiles are monochrome specimens, assembled in the tile-mosaic fashion, and bearing the same seven colours as found at Dakhini Sarai and Sheesh Mahal. What is notable however is the relatively larger numbers of extant tiles of this kind found here, many having their glaze layers intact. Not all the tile-work in place is however original, newer tiles having being provided in recorded repairs, which can be macroscopically distinguished through the comparatively rougher texture of their glaze layers. Repairs, thus distinguished, appear to be largely confined to replicating simpler geometric patterns as the intricate flower and fruit panels apparently bear original tile-work. A small inscription on the southern and northern facades indicates that the tile-work was restored in 1902-1903 CE by a tile-artisan, namely Mohammed Sharif, who hailed from Jalandhar city (Figure 7.42).

Figure 7.40 A general view of the Tomb of Shagird.

On the extant original tiles the primary noted deterioration once again is the delamination of glaze layers, most apparent on the band on the neck of the dome. Recent repairs, provided where entire tiles have been lost, are found to cover and conceal the original design, as in the case of the parapet. Increased loss of complete tiles at the dado level is seemingly linked to rising damp and the related decay of lime plaster in which the tiles are embedded. The tiles that appear to be from the recorded restoration are in a significantly better state than the remainder on the building.

Figure 7.41 An unusual representation of a bowl of fruit, executed in tiles, on one of the wall surfaces.

Figure 7.42 An inscription recording a past restoration event. Tiles in the vicinity of the inscription can be seen to be relatively inferior in make and in their laying technique.

7.2.4 Summary of observations

The examined buildings showcase the entire range of techniques and styles of tiling known to be associated with Mughal tile-work. The Delhi and Agra buildings of the sixteenth and first quarter of the seventeenth century have tiles principally employed in mosaic compositions of geometric patterns. The full palette of glaze colours used includes turquoise, dark-blue, yellow, green, and white, the tiles being individually monochrome. All the buildings have at least four of the five noted colours for the time, Humayun Darwaza, an early Mughal building, is an exception, having tiles of a turquoise colour only. The use of white coloured tiles is detected for the first time on the Tomb of Isa Khan. The Tomb of Atgah Khan is distinct from the others in having tiles being applied as insets in marble, a technique not used elsewhere. The tile-work on the Naubat Khana comprises arabesque motifs and calligraphic inscriptions in addition to the usual geometric arrangement.

The tile-work on the three Punjab buildings of the first quarter of the seventeenth century is distinct from that of Delhi and Agra in application technique, the repertory of five glaze colours however remaining the same. The technique used here, of tiles inset between unglazed bricks, is of unknown origin and has no known parallel elsewhere in the country. This technique was utilized for a short while only, and applied on very few buildings. The Punjab buildings of the second quarter of the seventeenth century and thereafter have tiles applied differently, in elaborate and intricate mosaic compositions of geometric and stylized vegetal and floral patterns. The range of colours associated with this technique includes purple and orange in addition to the five earlier known colours. All the buildings of this period are found to carry the entire range of glaze colours. The Chini-ka Rauza at Agra, which is of a contemporary period, is similarly tiled, as opposed to being of the general Delhi/Agra type. Some of the tile-work on the Tomb of Ustad appears to be from a documented restoration effort.

A summary of the principal features of tile-work employed at each of the surveyed sites is given in Tables 7.1 and 7.2 that follow:

Table 7.1 Summary of the tile-work decoration on the Delhi and Agra buildings.

No.	Building	Typology	Date/Period	Glaze colours	Application
1	Humayun Darwaza	Fort gateway	16^{th} century	i) Monochrome: Turquoise.	(i) As individual tiles - band below parapet, on roofs/domes of *chhatris* and *jharokhas*.
2	Tomb of Isa Khan	Tomb	1547-1548 CE	i) Monochrome: Turquoise, dark-blue, yellow, green, white.	(i) As individual tiles - band framing arches, in merlons, on *chhatris*. (ii) As tile-mosaic - on arch profiles, above *chajjas*.
3	Arab-ki Sarai	Sarai gateway	c. 1560 CE	i) Monochrome: Turquoise, dark-blue, yellow, green.	(i) As individual tiles - bands on facade of east gateway. (ii) As tile-mosaic - roofs of *jharokhas* on north gateway.
4	Khairul Manzil Masjid	Mosque	1561-1562 CE	i) Monochrome: Turquoise, dark-blue, yellow, green, white.	(i) As inlay - in stucco medallions and stucco inscription. (ii) As tile-mosaic - exteriors of central bay of mosque-structure, arch profiles, arch frames.
5	Tomb of Atgah Khan	Tomb	1566-1567 CE	i) Monochrome: Turquoise, dark-blue, yellow, green, white	(i) As inlay - in marble cladding on arches. (ii) As tile-mosaic - almost entire wall-mosque.
6	Sabz Burj	Tomb	16^{th} century	i) Monochrome: Turquoise, dark-blue, yellow, green.	(i) As individual tiles - entire dome. (ii) As tile-mosaic - drum of the dome.
7	Nila Gumbad	Tomb	c. 1625 CE	i) Monochrome: Turquoise, dark-blue, yellow, green, white.	(i) As individual tiles - entire dome. (ii) As tile-mosaic - entire north facade, band on drum of dome.
8	Tomb of Quli Khan	Tomb	17^{th} century	i) Monochrome: Turquoise, dark-blue, yellow, green.	(i) As tile-mosaic - band on east facade.
9	Kanch Mahal	Royal apartment	17^{th} century (1^{st} Qtr.)	i) Monochrome: Turquoise, dark-blue, yellow, green.	(i) As individual tiles - parapet, roof-bases of *jharokhas*. (ii) As tile mosaic - roofs of *jharokhas* on north facade.
10	Naubat Khana	Fort gateway	17^{th} century (1^{st} Qtr.)	i) Monochrome: Turquoise, dark-blue, yellow, green, white.	(i) As tile-mosaic - recessed panels distributed over facade.
11	Chini-ka Rauza	Tomb	c. 1639 CE	i) Monochrome: Turquoise, dark-blue, yellow, green, white, purple, orange. ii) Polychrome: Turquoise, dark-blue, white.	(i) As tile-mosaic - entire facade, dome, part of drum of dome, *guldastas*. Polychrome tiles present on corner shafts above roof level.

Table 7.2 Summary of the tile-work decoration on the Punjab buildings.

No.	Building	Typology	Date/Period	Glaze colours	Application
1	Doraha Sarai	Sarai gateway	17th century (1st Qtr.)	i) Monochrome: Turquoise, dark-blue, yellow, green, white.	(i) As individual tiles or inlay - inset in raised bricks compositions on arches and arch frames. Domes of cupolas on gateway bastions and enclosure corners.
2	Fatehabad Sarai	Sarai gateway	c. 1606 CE	i) Monochrome: Turquoise, dark-blue, yellow, green.	(i) As individual tiles or inlay - inset in raised bricks compositions on arches and arch frames.
3	Tomb of Ustad	Tomb	1612 CE	i) Monochrome: Turquoise, dark-blue, yellow, green, white. ii) Polychrome: Blue-and-white.	(i) As individual tiles or inlay - inset in raised bricks compositions on arches, recessed panels on facade, parapet wall. Band below parapet and on bases of roof cupolas.
4	Sheesh Mahal	Royal apartment	c. 1634 CE	i) Monochrome: Turquoise, dark-blue, yellow, green, white, purple, orange. ii) Polychrome: Blue-and-white.	(i) As tile-mosaic - all domes on roof, parapet. Polychrome tiles present on centrally placed domes.
5	Dakhini Sarai	Sarai gateway	17th century (2nd Qtr.)	i) Monochrome: Turquoise, dark-blue, yellow, green, white, purple, orange.	(i) As tile-mosaic - on arches, arch frames, domes of *chhatris* on gateway bastions.
6	Tomb of Shagird	Tomb	1657 CE	i) Monochrome: Turquoise, dark-blue, yellow, green, white, purple, orange.	(i) As tile-mosaic – in recessed panels distributed over facade, parapet, neck of central dome, domes of *chhatris* on corner turrets.

7.3 Results of analyses

A total of 126 samples from the Mughal era buildings under study were subject to analysis. Seventy four of these samples were complete tile fragments, consisting of both the body and glaze layer, while 52 samples were just tile glazes. Although sampling limitations resulted in several tiled buildings being represented by samples of their glazes only, an adequate number of complete fragments could be sourced from the two broad geographical zones under study, ensuring that the tile bodies were fairly well represented as well. Results of the investigations and analyses carried out on the individual samples are detailed as below:

7.3.1 Macroscopic examination

Like the Lodhi samples, each of the Mughal period tile fragments essentially consists of a visibly porous tile body with an overlying coloured glaze layer, the samples together appearing to be outwardly similar at first glance. Distinguishing features are however noticeable on a more careful macroscopic examination. The bodies of the Delhi tiles are found to be relatively thicker, usually 1.5 cm or more across their original thickness, and are of a creamy-red colour, the redness being most apparent in the Tomb of Quli Khan (QK) and Nila Gumbad (NG) samples (Figure 7.43). The Punjab specimens are thinner in comparison, seldom exceeding 1.3 cm in complete thickness, and are of an overall off-white colour although a slight reddish tinge can be determined here as well (Figure 7.44). Between the Punjab body samples, those from Doraha Sarai (DS), Fatehabad Sarai (FS) and Tomb of Ustad (TU) differ in texture and colour from the others, appearing to have grains of a coarser size in their matrices (Figure 7.45). Their bodies are apparently more brittle than the others as well, crumbling comparatively easily with pressure, those from TU being especially most fragile. Samples from Chini-ka Rauza (CR) at Agra are found to match the Punjab type that are of a contemporary date and style, forming a group along with those of Sheesh Mahal (SM), Dakhini Sarai (DKS), and Tomb of Shagird (TS). The Punjab samples in general are also of a smaller size than those of the Delhi type, reflecting the differences in the sizes of individual tiles employed at the two regions.

Figure 7.43 Cross-section of a tile sample (NG/04) from Nila Gumbad. Note the reddish colour tone of the body.

Figure 7.44 Cross-section of a tile sample (TS/01) from Tomb of Shagird. Note the off-white colour tone of the body, and the thinness of the glaze layer.

Figure 7.45 Cross-section of a tile sample (DS/02) from Doraha Sarai. Note the relatively coarser texture of the body as compared to that of TS/01 (previous figure).

Differences in the samples are apparent in the thickness, colour, and texture of the glaze layers too. Glazes of the SM, DKS, TS, and CR samples are clearly the thinnest and most refined of the lot, these being thin, smooth, and without blemishes, akin to a fine coloured slip (Figure 7.46). The Delhi and Agra glazes (excluding those of CR) are considerably thicker in comparison, and have a more uneven surface finish. No major weathering of the glazes is noticeable for any of the samples. Micro-pores, appearing as pinholes, are however found evenly spread over the glaze surfaces of the Delhi and Agra samples, but being of a generally fine size they do not mar the overall surface presentation in any way (Figure 7.47). The DS, FS, and TU glazes are of an intermediate thickness and surface texture between the two described types. Three samples from TS (TS/05, TS/07, and TS/12) are distinctively different from others taken from the same building, having comparatively thicker glaze layers and a rougher surface texture. These appear to correspond to the tiles identified as being later additions on the building.

Figure 7.46 Close-up of a tile sample (TS/04) from Tomb of Shagird. Note the fine quality of the glaze.

Figure 7.47 Close-up of a tile sample (NG/04) from Nila Gumbad. Note the fine pores on the glaze surface.

The glaze colours of the samples correspond to findings of the field survey. Individually turquoise, dark-blue, green, yellow, white, orange, and purple glaze colours are determined in samples sourced from SM, DKS, TS, and CR (Figure 7.48), while samples from the remainder buildings comprise monochrome glazes of a range of five colours only, these being turquoise, dark-blue, green, yellow, and white (Figure 7.49). No polychrome glazes are found on any of the samples. It is worth noting that samples from different buildings determined macroscopically similar are virtually indistinguishable from each other but for their glaze colours. Those of the same colour, from the same or different buildings of their group, cannot be told apart.

Figure 7.48 A set of tile samples illustrating the colour range associated with the later Punjab style of tile-work.

Figure 7.49 A set of tile samples illustrating the colour range associated with the Delhi and early Punjab style of tile-work.

7.3.2 Tile bodies: Microstructure and chemical composition

All the samples, on analysis, are found to exhibit features of stonepaste technology, the bodies consisting mainly of quartz grains or particles bound together by a network of glass, while the glazes appear as a distinct separate layer (Figure 7.50). A fair but variable degree of porosity is noticeable in the microstructure of all the tile bodies, voids at times making up nearly half of the sectioned-areas examined. The Punjab (and CR) samples are distinguished from the others by the existence of a slip in their bodies, a distinct additional layer of relatively finer particles visible at the interface between the body and glaze layer in their case.

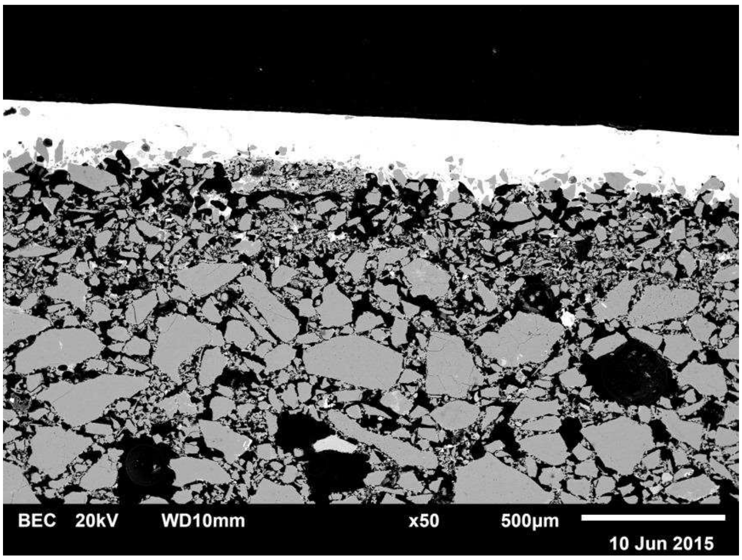

Figure 7.50 SEM photomicrograph through the section of a tile sample (TS/02) from Tomb of Shagird, the body of which can be seen to comprise almost entirely of quartz particles. A slip layer of finer sized particles is noticeable between the coarser particles in the main body, and the bright glaze layer on top.

Dissimilarities are also evident in the textural character of the quartz particles between samples from different buildings or determined groups, and in the extent of formation of the glassy phase that connects the particles. In line with macroscopic observations, the bodies of the Delhi samples are found to be microstructurally similar and form one group. These are characterised by quartz particles that are mainly elongated in shape, and angular or sub-angular along their boundaries or edges (Figure 7.51). In size, the particles generally vary over c. 25-500 µm along their longer axis, significant numbers of those present being coarser ones, of a size 300-500 µm across. Some particles of an even larger size are found as well, extending at times up to 1 mm across, but such instances are unusual and random rather than a characteristic. Medium-sized particles, from 100-250 µm across, are present in approximately equal abundance as the coarse ones, finer ones being less conspicuous. The interparticle glass in these bodies is found to be fairly well-developed in most specimens, particularly in samples from Arab-ki Sarai (AS) and NG where it completely surrounds the finer quartz particles present in the matrices (Figure 7.52). Extended bonding of the medium and coarser particles is otherwise noticed for almost all samples of this group, the particles together with interparticle glass appearing as one coherent mass in individual bodies.

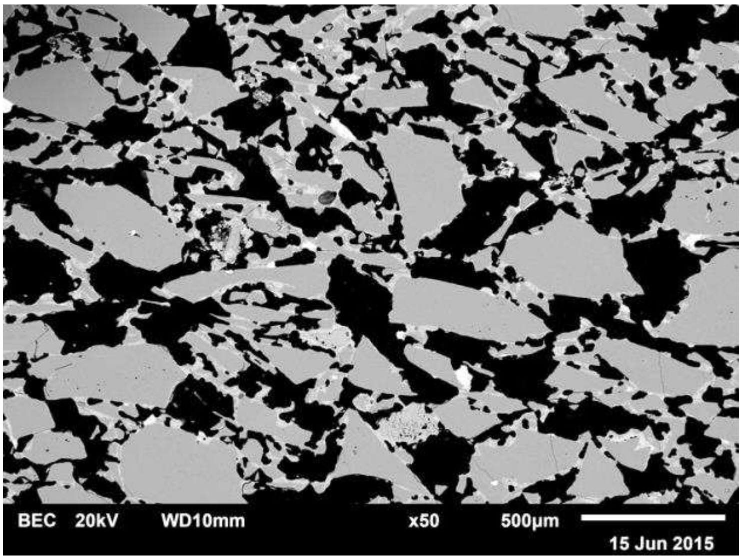

Figure 7.51 SEM photomicrographs of tile bodies from Nila Gumbad (NG/15) illustrating the general elongated shape and angularity of the quartz particles associated with the Delhi/Agra body type.

Tiles on the Delhi and Agra buildings that are represented by their glazes only appear to have been similarly constructed, particles of a similar shape, size, and angularity being noted present in their respective glaze-body interaction layers. The CR tiles/glazes differ from the others of the Delhi/Agra region, having characteristics common with those of the Punjab group instead.

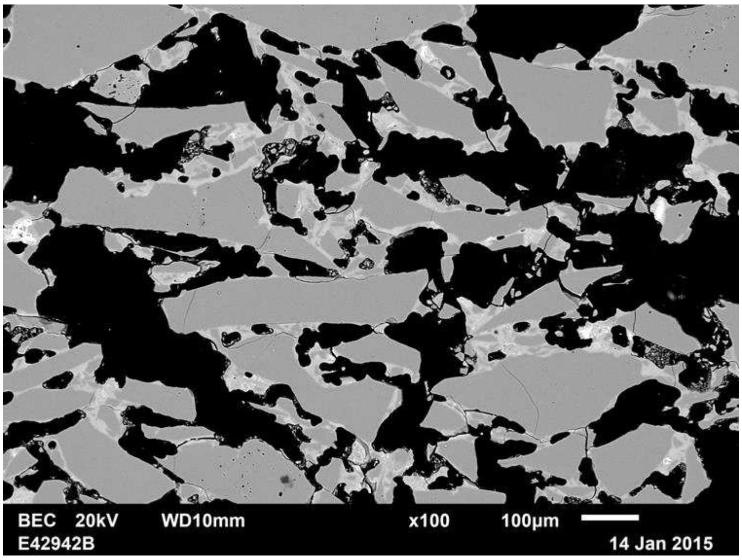

Figure 7.52 SEM photomicrograph of a tile body (AS/02) from Arab-ki Sarai. Note the well-formed interparticle glass.

The bodies of tiles from all the Punjab buildings (and CR) on the other hand, which form a second group, have quartz particles that tend to be more equant in shape, and are noticeably more rounded (Figure 7.53). Some variations are however apparent between samples of the earlier and later buildings. The majority of the particles in the body matrices of SM, DKS, TS, and CR are of a fine to medium size, in the range 25-250 µm across. Relatively coarser particles, generally of a size range 250-400 µm across but extending up to 500 µm or more in some cases, are also consistently present but in overall lesser proportions. Coarser particles are notably more frequent in samples of the earlier Punjab buildings (DS, FS, and TU), often in roughly equal proportions as the fine-medium sized particles in their bodies. Interparticle glass, in all the bodies of this group, is found less-formed than that noted for the Delhi tiles. The glassy phase in most cases suffices to only fuse adjacent particles, those of a fine to medium size being relatively better bonded, while the coarser ones are only sintered at places on their boundaries. Although an overall bonding of all the particles is achieved in this manner, they do not exhibit the appearance of a unified mass, the coarser particles particularly appearing disconnected from each other. The slip layer, found in almost all samples of this body group, is generally 400-500 µm thick and made up of fine quartz particles of a size 25-75 µm across.

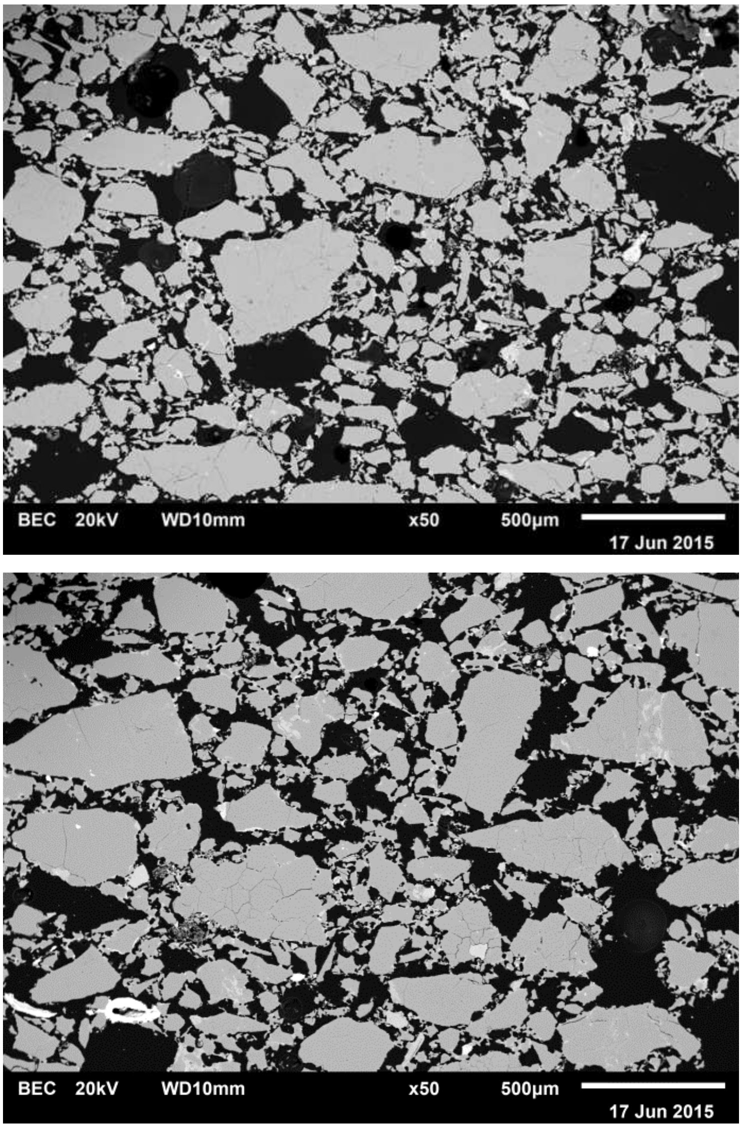

Figure 7.53 SEM photomicrographs of tile bodies from (above) Sheesh Mahal (SM/06) and (below) Fatehabad Sarai (FS/02) illustrating the general shape, size, and roundedness of the quartz particles associated with samples of their type. Note the overall little formation of interparticle glass.

The Punjab (and CR) group of samples is further distinguished from the Delhi type through the consistent presence of fairly large (up to 350 µm across) composite particles of quartz and alkali (potash) feldspars in their bodies, and of the existence of potash-alumina rich phases on significant numbers of the coarser quartz particles in the matrices (Figure 7.54). These are especially more frequent in the DS, FS and TU bodies. Although alkali feldspars are occasionally also detected in the Delhi group of bodies, they are always found as individual grains, and are of a size that rarely exceeds 100 µm.

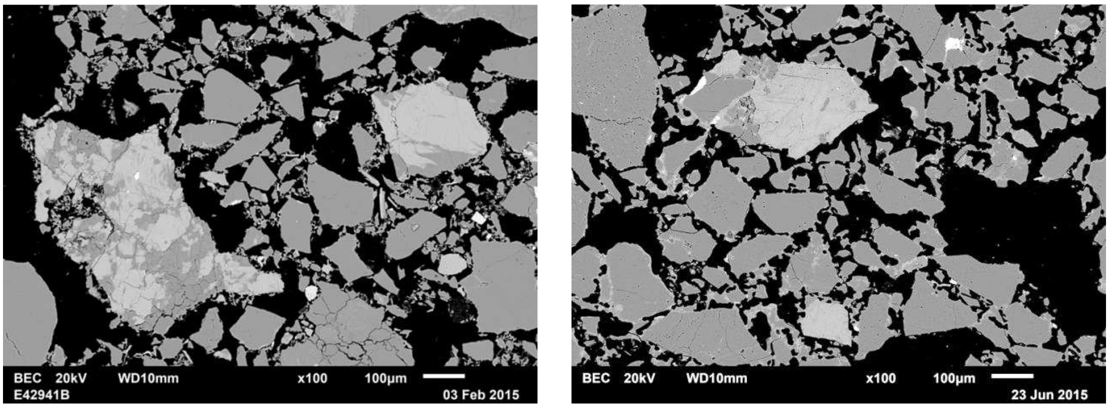

Figure 7.54 SEM photomicrographs of tile bodies from (left) Doraha Sarai (DS/04) and (right) Chini-ka Rauza (CR/16). The bright phases on the quartz particles and the small individual bright grains are all rich in potash-alumina content.

Other minor inclusions include particles of iron and iron-titanium minerals that are randomly dispersed in the body matrices, these being noticeably frequent in the Delhi group, a high concentration being particularly detected in the NG samples. Such particles are often found enveloped by the glassy phase in this body group, especially in samples where the interparticle glass is well-formed. Some particles of zirconium-rich minerals are also occasionally detected, but these are much rarer comparatively, occurring only in isolated instances in both the body groups.

Although some variations in the body characteristics are found to exist in the Delhi/Agra group of samples, these are mostly related to modest differences in the degree of development of interparticle glass and in the relative abundance of particles of different sizes. In no case is the basic textural character of the quartz grains or the overall microstructure found to differ. A few samples in the Punjab group on the other hand vary from the typical in this respect. One body each from DS (DS/10) and SM (SM/02) contain quartz particles that are noticeably angular and well-bonded with interparticle glass (Figure 7.55), quite unlike the others of their group. Two bodies from CR (CR/07 and CR/14) are likewise determined atypical, one (CR/07) exhibiting a highly vitrified matrix (Figure 7.56), while the other (CR/14) has no slip and a distinctly thicker glaze than usual. Some variances are also observed for the three TS samples (TS/05, TS/07, and TS/12) that were determined differing macroscopically. These appear to have more interparticle glass, and particles that are better sorted in their body matrices (Figure 7.57), as compared to other samples from the same building.

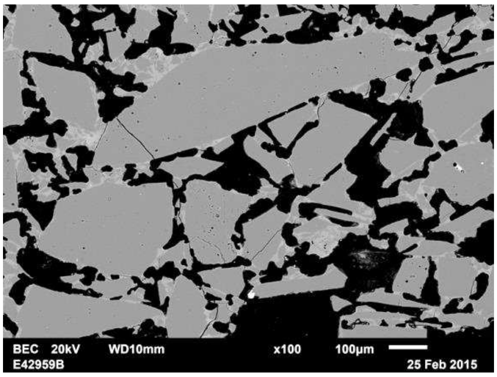

Figure 7.55 SEM photomicrograph of sample DS/10. Note well-formed interparticle glass and angularity of the quartz grains.

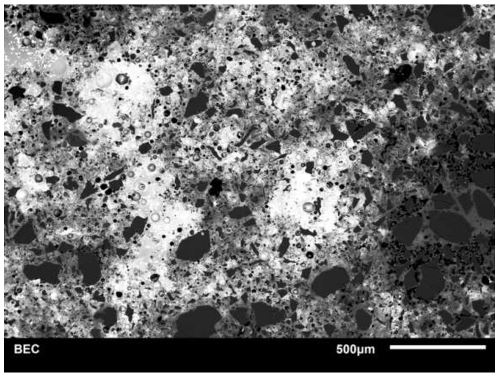

Figure 7.56 SEM photomicrograph of sample CR/07 illustrating its unusual glassy body matrix.

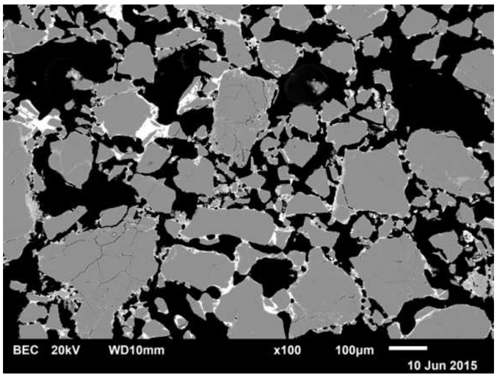

Figure 7.57 SEM photomicrograph of sample TS/12 illustrating its body characteristics.

Chemistry of the tile bodies

Discrepancies that are quite evident in the microstructure of the tile bodies are less apparent on their chemical analyses. Compositional profiles of the samples across the two broad regions or tile-work styles indicate a general similarity in proportion of constituents, although some variations are found to exist (Tables 7.3 and 7.4, Appendices 7.2 to 7.7). Silica, as expected for these quartz-enriches bodies, is high and mostly in the narrow range of 95-96 wt% across all. Soda content is higher in the Delhi tile bodies as compared to those of the Punjab type, commensurate with the relatively enhanced interparticle glass content in the former, averaging 1.5 wt% and 1.1 wt% respectively. Alumina is present in slightly lower concentrations than soda in the Delhi samples, averaging 1.3 wt%. It is higher in the Punjab body type, particularly in the samples from the earlier Punjab buildings (DS, FS, and TU) where it stands at around 2 wt%, but otherwise averages 1.6 wt% for this group.

Lime, potash, and magnesia values are fairly consistent across the Delhi group, averaging 0.4 wt%, 0.5 wt%, and 0.3 wt% respectively. Lime is slightly higher in the Punjab group but consistent here as well, averaging 0.6 wt%, SM/02 being a rare exception with lime content of 2.8 wt%. Potash contents, which average 0.7 wt% for this body group, are slightly higher in samples from the earlier seventeenth century buildings as compared to those of a later date, varying like alumina in this respect. Magnesia values, like in the Delhi samples, are notably low, particularly for samples from the later buildings (SM, DKS, CR, and TS) where they are seldom found to exceed the detection limit of the instrument. Iron oxide concentrations are generally consistent and comparable across the two body types at an average of around 0.5 wt%.

Lead oxide content detected in TS/05, TS/07 and TS/12, ranging from 0.2-0.5 wt%, appears to be on account of its presence in the interparticle glass in these bodies. The slips, of the Punjab group samples, are determined to be of a generally similar chemical composition as the tile bodies (Appendix 7.8).

Table 7.3 Chemical compositions of the Mughal Delhi group of tile bodies determined through SEM-EDS analyses. All results are in wt%, and normalised to100 %. Results below the detection limit of the instrument are provided for comparative purposes only.

No.	Building	Region	Date/Period	Nos. of samples	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3
1	Tomb of Isa Khan (IK)	Delhi	1547-1548 CE	3	95.8	1.6	0.4	0.4	0.2	1.1	0.6
2	Arab-ki Sarai (AS)	Delhi	c. 1560 CE	4	94.9	1.9	0.6	0.5	0.3	1.3	0.5
3	Tomb of Atgah Khan (AK)	Delhi	1566-1567 CE	3	94.8	1.8	0.5	0.5	0.3	1.6	0.6
4	Sabz Burj (SB)	Delhi	16^{th}. cent.	1	96.6	1.0	0.3	0.4	0.3	1.1	0.4
5	Nila Gumbad (NG)	Delhi	c. 1625 CE	12	95.3	1.7	0.5	0.5	0.3	1.2	0.5
6	Tomb of Quli Khan (QK)	Delhi	17^{th} cent. (1^{st} Qtr.)	1	95.2	1.3	0.4	0.5	0.4	1.6	0.6
				Average	**95.4**	**1.5**	**0.4**	**0.5**	**0.3**	**1.3**	**0.6**

Table 7.4 Chemical compositions of the Mughal Punjab group of tile bodies determined through SEM-EDS analyses. All results are in wt%, and normalised to100 %. Results below the detection limit of the instrument are provided for comparative purposes only. Samples from Chini-ka Rauza at Agra are included in this group on account of their bodies being of a similar type.

No.	Building	Region	Date/Period	Nos. of samples	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3
1	Doraha Sarai (DS)	Punjab	17^{th} cent. (1^{st} Qtr.)	6	94.5	1.1	0.6	0.8	0.3	2.1	0.6
2	Fatehabad Sarai (FS)	Punjab	c. 1606 CE	2	94.6	1.2	0.8	0.8	0.4	1.7	0.5
3	Tomb of Ustad (TU)	Punjab	1612 CE	3	94.5	1.3	0.6	0.8	0.5	1.9	0.6
4	Sheesh Mahal (SM)	Punjab	c. 1634 CE	8	96.1	0.9	0.8	0.6	0.2	1.1	0.4
5	Dakhini Sarai (DKS)	Punjab	17^{th} cent. (2^{nd} Qtr.)	4	95.8	1.0	0.4	0.6	0.2	1.5	0.4
6	Chini-ka Rauza (CR)	Agra	c. 1639 CE	14	95.7	1.2	0.4	0.6	0.2	1.5	0.4
7	Tomb of Shagird (TS)	Punjab	1657 CE	13	96.0	1.0	0.4	0.7	0.2	1.2	0.4
				Average	**95.3**	**1.1**	**0.6**	**0.7**	**0.3**	**1.6**	**0.5**

Variations are also determined in the composition of the interparticle glass across the two body types (Tables 7.5 and 7.6, Appendices 7.9 to 7.11). Soda is in the range of 11-13 wt% in the Delhi samples, but is lower in the majority of the Punjab group, averaging around 8 wt%. The relatively depleted values associated with the Punjab group are apparently on account of measurement anomalies, the overall poor formation of the phase in most of these samples providing little area for analyses. Silica is accordingly correspondingly higher in this group, at around 77 wt% on an average, and generally about 5-6 wt% lower in the interparticle glass of the Delhi samples.

Table 7.5 Average chemical composition of interparticle glass in the Mughal Delhi group of tile bodies determined through SEM-EDS analyses. All results are in wt%, and normalised to100 %.

No.	Building	Region	Date/Period	Nos. of samples	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3
1	Tomb of Isa Khan (IK)	Delhi	1547-1548 CE	3	72.5	13.0	2.2	3.0	1.1	6.0	2.3
2	Arab-ki Sarai (AS)	Delhi	c. 1560 CE	4	72.3	12.8	2.1	3.0	1.7	5.7	2.3
3	Tomb of Atgah Khan (AK)	Delhi	1566-1567 CE	3	70.3	11.3	2.0	2.9	1.4	9.4	2.6
4	Sabz Burj (SB)	Delhi	16th. cent.	1	71.5	12.6	2.7	3.6	1.7	4.4	3.5
5	Nila Gumbad (NG)	Delhi	c. 1625 CE	8	71.7	12.3	2.1	3.7	1.8	6.4	2.2
6	Tomb of Quli Khan (QK)	Delhi	17th cent. (1st Qtr.)	1	69.7	12.3	1.6	4.2	1.8	7.7	2.8
				Average	**71.3**	**12.4**	**2.1**	**3.4**	**1.6**	**6.6**	**2.6**

Table 7.6 Average chemical composition of interparticle glass in the Mughal Punjab group of tile bodies determined through SEM-EDS analyses. All results are in wt%, and normalised to100 %. Samples from Chini-ka Rauza at Agra are included in this group on account of their bodies being of a similar type. Samples DS/10, CR/14, TS/05, TS/07, and TS/12 are excluded in the calculated averages.

No.	Building	Region	Date/Period	Nos. of samples	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3
1	Doraha Sarai (DS)	Punjab	17th cent. (1st Qtr.)	3	81.6	5.6	1.5	3.3	1.2	4.0	2.8
2	Fatehabad Sarai (FS)	Punjab	c. 1606 CE	2	71.7	13.0	3.7	4.5	2.4	3.7	1.2
3	Tomb of Ustad (TU)	Punjab	1612 CE	3	75.1	8.9	3.5	4.7	2.2	3.7	1.8
4	Sheesh Mahal (SM)	Punjab	c. 1634 CE	4	77.5	6.6	2.1	3.5	1.3	6.6	2.4
5	Dakhini Sarai (DKS)	Punjab	17th cent. (2nd Qtr.)	3	76.9	8.7	2.2	3.9	1.3	3.6	3.4
6	Chini-ka Rauza (CR)	Agra	c. 1639 CE	6	77.5	8.0	2.2	3.6	1.4	4.5	2.7
7	Tomb of Ustad (TU)	Punjab	1657 CE	4	78.1	6.2	2.0	4.2	1.8	5.0	2.7
				Average	**76.9**	**8.1**	**2.5**	**4.0**	**1.7**	**4.4**	**2.4**

Lime contents in the glass are generally comparable across the samples from the two groups, ranging over 2-2.5 wt% for the most part, but are notably higher in the FS and TU samples where they average around 3.5 wt%. The same (FS and TU) samples are determined higher in their potash and magnesia contents as well as compared to the others of their group. Alumina is in roughly equal proportions as potash in the Punjab group, around 4-4.5 wt%, but is significantly higher and about twice the potash values in the Delhi samples, where it stands at about 6.5 wt% on an average. Magnesia is generally measured as being between 1-2 wt%. Iron oxide is mostly in the range of 2-3 wt% for both groups, except in the FS and TU samples where it is moderately lower.

Summary and comments

The Mughal tile bodies, as in the case of the Lodhi specimens, are determined divided over two broad groups or types, distinguished mainly through the textural character of the quartz grains present in their matrices. Interparticle glass content and other microstructural characteristics typically associated with each of these body types aid in further qualifying the groupings. The first of the body groups encompasses all the samples from the Delhi (and likely Agra) buildings of the sixteenth and first quarter of the seventeenth century, while the second group is associated with all the Punjab samples from the seventeenth century. One set of samples from a building (CR) at Agra are included in the latter group, being similar in body macro and micro-characteristics.

The Delhi group is characterised by creamy-red coloured bodies that comprise mainly of angular and elongated quartz particles from 25-500 µm across, those of a medium-coarse size from 100-500 µm predominating, have fairly well-developed interparticle glass in their matrices, and have no discernible slip. While the examined available body samples from IK, AS, AK, SB, NG, and QK clearly fall in this category, samples from Humayun Darwaza (HD), Khairul Manzil Masjid (KM), Kanch Mahal (KMA), and Naubat Khana (NK) may also be considered in this group, having particles of a similar nature in their glazes. The average chemical composition associated with this body type is given in Table 7.3.

The Punjab group is characterised by off-white coloured bodies that comprise mainly of rounded and equant quartz particles from 25-400 µm across, have little interparticle glass in their matrices, and have a clearly defined slip. The samples of DS, FS, TU, SM, DKS, CR, and TS are of this group type, the average chemical composition of their bodies (given in Table 7.4) being a group characteristic. Samples DS/10, SM/02, CR/07, CR/14, TS/05, TS/07, and TS/12 are anomalies to this grouping, these having microstructural features of a different kind than the others of the group.

7.3.3 Glazes and colorants

As determined macroscopically, the glaze layers are found to differ considerably in thickness between the samples of the various identified groups (Figure 7.58). The Delhi and Agra samples, except those from CR, have glazes that typically vary over 500-800 µm in thickness. Glazes of the majority of samples from the later Punjab buildings (SM, DKS, and TS), and those of CR, are of a distinctly different category, being much thinner, usually of the order 175-250 µm across. Samples from the earlier Punjab buildings (DS, FS, and TU), have glazes of an intermediate thickness, these being mostly 400-500 µm across through their sections. The few samples from DS, SM, TS, and CR, determined differing from the typical in their body characteristics, are noted to exhibit variances in glaze thicknesses too, being c. 200-300 µm or so thicker than the group average.

The glazes otherwise, like the Lodhi specimens, are of a uniform thickness for samples taken from the same building, and consist similarly of a lower interaction zone containing quartz particles from the body followed by an upper core zone. An overall lesser degree of penetration is noticed for the Delhi and Agra glazes, the interaction zone or layer of particles seldom exceeding a third of their thickness in most cases. Greater depth seems to have been achieved in the Punjab samples, the interaction layer being more clearly defined and often extending to cover half the thickness of the glaze layers. Rarely, in both cases, is the interaction layer found to be spread across the entire thickness of the glazes, a feature that was common for the Lodhi tiles. All the yellow, green, and orange glazes have small bright particles of what appears to be a colorant or opacifier dispersed throughout (Figure 7.59). The glaze layers of all samples are otherwise clear, barring the random occurrence of bubbles of varying sizes and the odd mineral inclusion grain.

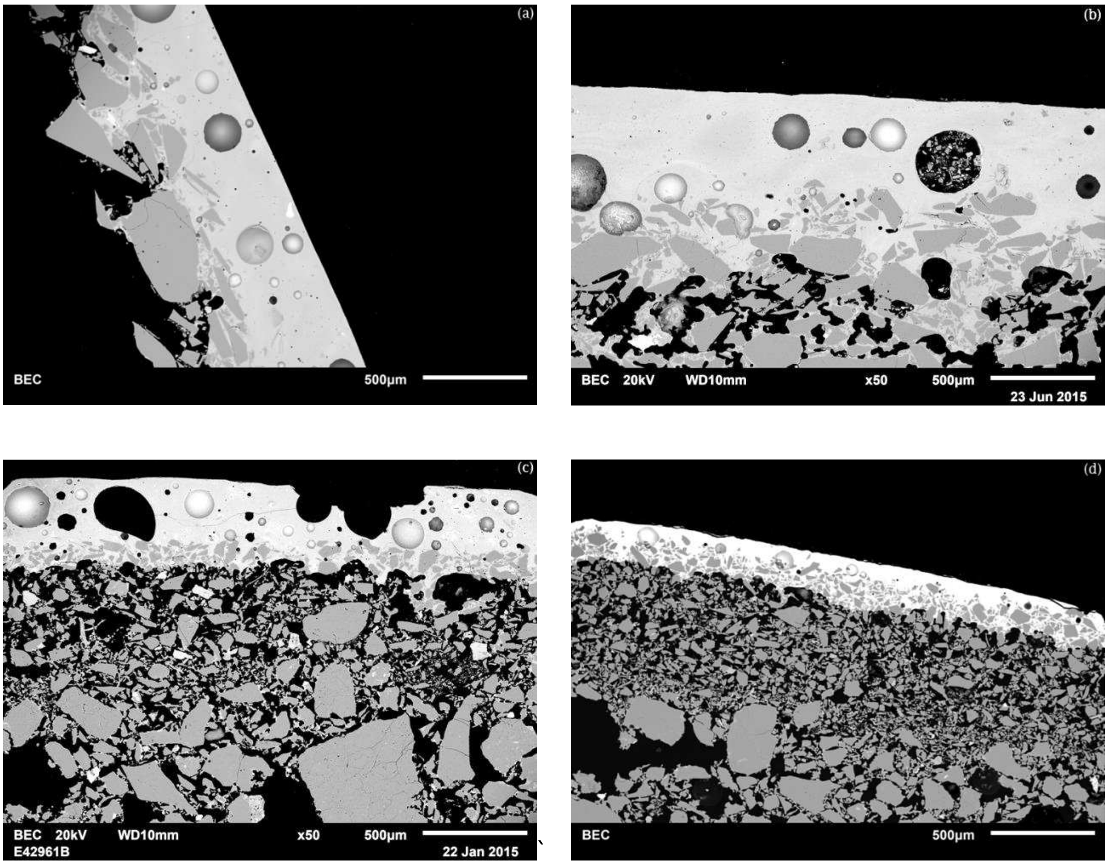

Figure 7.58 SEM photomicrographs of samples from (a) Sabz Burj (SB/05), (b) Nila Gumbad (NG/14), (c) Fatehabad Sarai (FS/02), and (d) Chini-ka Rauza illustrating the size range associated with the Mughal tile glazes. Note the thinness of the glaze layer of the CR sample as compared to the others.

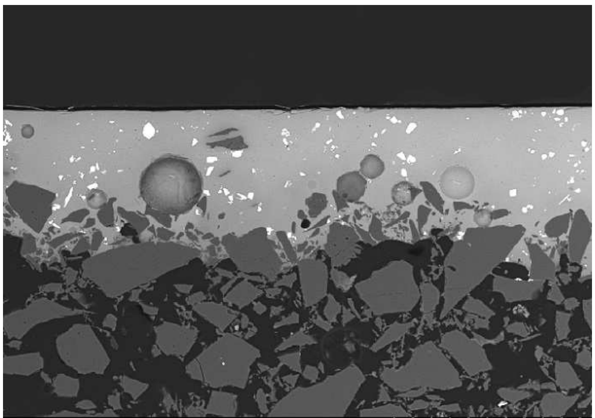

Figure 7.59 SEM photomicrograph of an orange tile sample from Tomb of Shagird (TS/04). The bright particles spread across its glaze layer are determined present in all the yellow, green, and orange glazes.

Chemistry of the glazes

All the glazes, except TS/07 and TS/12, are of the alkali type containing soda in concentrations of 11-22 wt% (Appendices 7.12 to 7.19, average reduced compositions given in Tables 7.7 and 7.8). Lead and tin oxide, in significant proportions, are additionally detected in the yellow, green, and orange glazes, the glaze layers of which are noted to have bright particles distributed uniformly within. Preliminary analyses of these particles identify them as being the pigment/opacifier lead stannate, the lead and tin oxide content recorded for these glazes thus apparently related to their coloration. A comparison of the ratios and concentrations of various oxides in the lead stannate-coloured and other glazes indicates that the pigment was added to the same base alkali glaze as used for the other colours, its addition apparently resulting in the dilution of all other oxides by around 15 wt% on average. Significant tin oxide content is also noted for one dark-blue glaze from TS (TS/11) but this is clearly an aberration limited to this specimen only. TS/07 and TS/12, the two exceptions, differ from all other glazes in composition, their abnormally high lead oxide and low soda contents, of c. 60 wt% and c. 3 wt% respectively, suggesting that they are lead glazes and not of the alkali type.

On subtracting the colorants from the analytical results and normalizing the totals of the base glass forming oxides to 100 wt%, the two broad compositional groups noticed existing for the Lodhi glazes are determined present for the Mughal glazes as well (see Tables 7.7 and 7.8). All the glaze samples (except TS/07 and TS/12) belong to just one of the groups. The two groups or types, as in the case of the Lodhi tiles, are distinguished mainly through their magnesia and alumina contents, although the value ranges for the two oxides differ somewhat for the glazes of this period. The first variety (Type I) of glazes accordingly are those that are low in alumina and high in magnesia, in concentrations that vary over c. 1.5-4 wt% and 2-3.5 wt% respectively. The second type (Type II) have distinctly higher alumina and lower magnesia contents, in the range of c. 5-9 wt% and 0.5-2 wt% respectively. An appreciation of the distribution of the two glaze types across the Mughal period and their buildings can be gained through a plot of the recast alumina and magnesia values (Figure 7.60).

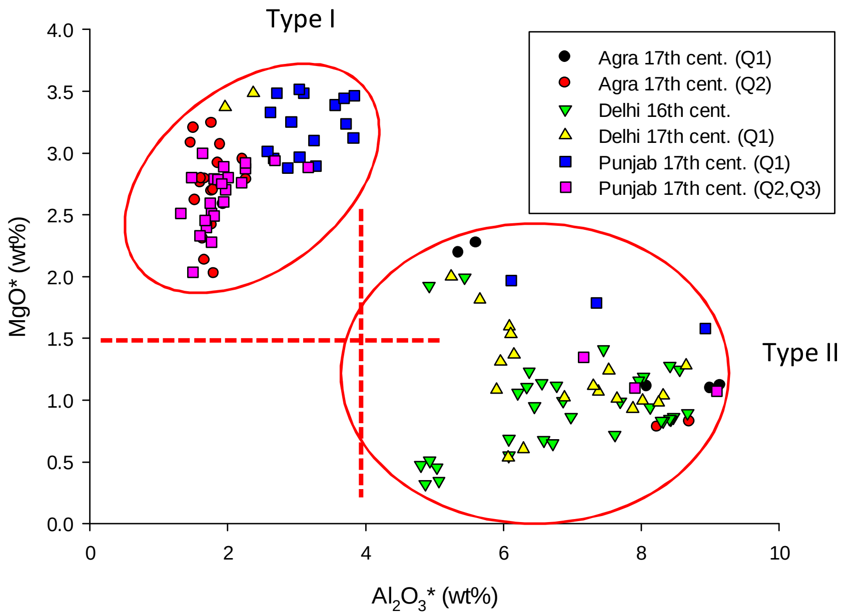

Figure 7.60 Scatter plot of alumina versus magnesia contents of the Mughal tile glazes illustrating the existence of two distinct glaze groups, and their chronological and regional spread. '*' indicates reduced composition. 'Q' signifies 'Qtr.', Q1 implying 1st Qtr. and so on. Samples TS/07 and TS/12 are excluded from the plot.

The two groups are clearly distinguishable in the plot, samples conforming to the specifications of the Type I glazes being a relatively more compact cluster, distinct from the Type II glazes, which are spread out over a relatively larger area. But for two exceptions, NG/01 and NG/16, all the glaze samples from the Delhi buildings of the sixteenth and seventeenth century (HD, IK, AS, KM, AK, SB, NG, and QK), and both from Agra from the first quarter of the seventeenth century (KMA and NK), are of the Type II variety. Almost all the samples across the seventeenth century Punjab buildings (DS, FS, TU, SM, DKS, and TS) in contrast have glazes of the Type I variety. The majority of the Agra CR glazes samples, which date to the second quarter of the seventeenth century, are also of this category. Three glaze samples from DS, (DS/09, DS/10, and DS/13), two from SM (SM/02 and SM/09), and one from TS (TS/05) differ from their Type I Punjab brethren, having characteristics of the Type II Delhi/ Agra variety instead. Two samples from CR (CR/07 and CR/14) similarly are of the general

Delhi/Agra type, as opposed to being of the Punjab kind like the rest from their building. TS/07 and TS/12 are excluded from the plot, and the two groupings, on account of their compositions being entirely different. Besides the obvious regional connotations, a relationship between glaze types and tile-work styles is evident, the Type I glazes being generally associated with the two Punjab styles, and the Type II glazes with the Delhi/Agra style. The Agra CR glazes are of the Type I category on account of the tile-work on this building being of one of the Punjab styles, the same relationship also earlier apparent in the investigations on their bodies. It is worth noting that all the individual tile bodies considered atypical, are determined differing from the usual in their glaze characteristics as well. The two NG samples (NG/01 and NG/16) are however not distinguished similarly, these being similar to the others of their building in their body characteristics, but having glazes of a different type.

Recalculated values of the samples for the individual buildings, excluding the outliers, indicate that soda concentrations in the Type I glazes typically fall in the range of 16-18 wt%, while silica for them ranges over 66-72 wt% (Table 7.7). Lime, potash, and magnesia contents are fairly consistent across these glazes, averaging 3.9 wt%, 3.8 wt%, and 2.9 wt% respectively. Alumina varies more comparatively, being in a higher range of 3-3.5 wt% in samples from the earlier seventeenth century buildings, but notably lower, in the range of 1.7-2.1 wt%, in those of a later date. Iron and titanium oxide concentrations that range over 0.7-1.5 wt% and 0.1-0.2 wt% respectively are clearly interrelated, and follow a parallel relationship with alumina contents. Higher values for the two are noted for the glazes that are relatively higher in alumina content, while lower values for both are recorded for the glazes that are low in alumina. No clear relationship can be determined between any of the other base glass forming oxides, other than for lime and magnesia (Appendices 7.20 and 7.21). The noted potash and magnesia contents indicate that these glazes, like the Lodhi Type I variety, are most likely to have been manufactured using a plant ash alkali flux. Their soda to potash ratios (Na_2O/K_2O), and normalised lime-plus-magnesia contents [$(CaO+MgO)/(Na_2O+K_2O)$] are found to range over 3.3-5.4 and 0.3-0.4 respectively.

Table 7.7 Average chemical compositions of the Type I (plant ash) variety of Mughal glazes in terms of their base glass forming oxides. All results are in wt% from EPMA-WDS analyses and normalised to100 %. Outliers to the groupings in individual buildings are excluded in the calculation of averages.

No.	Building	Region	Date/Period	Nos. of samples	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Na_2O/K_2O	CaO + MgO /Na_2O +K_2O
1	Doraha Sarai (DS)	Punjab	17th cent. (1st Qtr.)	10	67.4	17.7	4.16	3.31	3.17	3.00	1.11	0.12	5.3	0.3
2	Fatehabad Sarai (FS)	Punjab	c. 1606 CE	2	65.6	17.5	4.44	3.92	3.49	3.44	1.42	0.16	4.5	0.4
3	Tomb of Ustad (TU)	Punjab	1612 CE	4	66.7	15.9	4.22	4.87	3.20	3.45	1.51	0.17	3.3	0.4
4	Sheesh Mahal (SM)	Punjab	c. 1634 CE	9	72.5	15.5	3.30	3.73	2.41	1.72	0.77	0.08	4.2	0.3
5	Dakhini Sarai (DKS)	Punjab	17th cent. (2nd Qtr.)	4	70.3	17.3	3.93	3.24	2.75	1.76	0.68	0.06	5.3	0.3
6	Chini-ka Rauza (CR)	Agra	c. 1639 CE	18	71.9	15.7	3.28	3.61	2.73	1.77	0.89	0.07	4.4	0.3
7	Tomb of Shagird (TS)	Punjab	1657 CE	10	69.0	17.3	3.74	3.95	2.84	2.14	1.03	0.08	4.4	0.3
				Average	**69.1**	**16.7**	**3.87**	**3.80**	**2.94**	**2.47**	**1.06**	**0.10**	**4.5**	**0.3**

Table 7.8 Average chemical compositions of the Type II (mineral soda) variety of Mughal glazes in terms of their base glass forming oxides. All results are in wt% from EPMA-WDS analyses and normalised to100 %. Outliers to the groupings in individual buildings are excluded in the calculation of averages.

No.	Building	Region	Date/Period	Nos. of samples	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2
1	Humayun Darwaza (HT)	Delhi	16th cent.	5	67.9	22.3	1.34	1.43	0.42	4.94	1.38	0.29
2	Tomb of Isa Khan (IK)	Delhi	1547-1548 CE	5	67.8	19.1	1.91	1.90	0.79	6.58	1.54	0.33
3	Arab-ki Sarai (AS)	Delhi	c. 1560 CE	4	67.3	17.1	2.63	2.04	1.43	7.61	1.50	0.35
4	Khairul Manzil Masjid (KM)	Delhi	1561-1562 CE	4	64.5	18.8	2.42	2.63	0.90	8.12	2.23	0.43
5	Tomb of Atgah Khan (AK)	Delhi	1566-1567 CE	5	65.8	18.9	1.65	2.30	0.88	8.28	1.86	0.40
6	Sabz Burj (SB)	Delhi	16th/17th cent.	10	68.8	17.2	2.16	2.24	1.13	6.56	1.55	0.38
7	Nila Gumbad (NG)	Delhi	c. 1625 CE	15	67.0	18.8	2.25	2.18	1.22	6.59	1.66	0.35
8	Tomb of Quli Khan (QK)	Delhi	17th cent. (1st Qtr.)	4	64.4	19.2	2.26	2.63	1.07	8.14	1.95	0.37
9	Kanch Mahal (KMA)	Agra	17th cent. (1st Qtr.)	3	65.9	18.8	3.16	1.92	1.86	6.35	1.66	0.33
10	Naubat Khana (NK)	Agra	17th cent. (1st Qtr.)	2	66.5	17.1	1.69	1.75	1.11	9.08	2.31	0.42
				Average	**66.6**	**18.7**	**2.15**	**2.10**	**1.08**	**7.22**	**1.76**	**0.36**

Soda is comparatively higher in the Type II glazes, in concentrations of 17-22 wt%, with values in excess of 19 wt% not being unusual (Table 7.8). Such high soda levels seem to be a feature typical of Delhi glazes, similar results being recorded for most Lodhi glazes from this region as well. Lime and potash concentrations are lower than in the Type I variety, at an average of around 2 wt% for both. Magnesia is typically low, mostly in the range of 0.5-1.5 wt%, its low values indicating that these glazes are of the mineral soda type, just like the Lodhi glazes of this category. Magnesia is however also present in higher than expected concentrations for mineral soda glazes, with values in the range of 1.5-2.3 wt% being recorded for several samples. Alumina, which is more consistent as a discriminator between the two types in the case of Mughal glazes, is present in significant characteristic concentrations of 6-8 wt% in most of the specimens. Iron and titanium oxide values are higher than those recorded for the Type I glazes, varying over 1.4-2.2 wt% and 0.3-0.4 wt% respectively. These are clearly interrelated, and found to vary positively with alumina as well (see Appendix 7.20). A relationship between lime and magnesia values for these samples is also evident. Silica is determined as being typically in the range of 64-69 wt%.

The outliers generally match the glaze compositions of their ascribed type, although some variances are apparent. The two Delhi samples (NG/01 and NG/16) that have Type I glazes for instance, are generally higher in soda and lower in potash than the Punjab Type I glazes. The few Type II Punjab glazes that exist likewise are all marked by potash values that are higher than those recorded for the Delhi samples of their kind. The variations are however all of a minor nature, and not indicative of any technological differences of note.

Turquoise glazes

All the turquoise glazes, across the two glaze types, contain copper oxide that varies over 1.4-4.8 wt% in concentrations, but is usually in the range of 2.5-3.5 wt% for most samples (Table 7.9). Most of the higher values recorded are associated with the HD and KMA glazes, their copper contents averaging 3.7 wt% and 4.8 wt% respectively. Lower than normal values of 1.4-2.2 wt% on the other hand are recorded consistently in the case of the AK glazes. Copper oxide is present in all the green glazes as well, in relatively lower concentrations as compared to the turquoise glazes, being mostly in the range of 1-2 wt% here. The two well-established outliers, TS/07 and TS/12, are significantly lower in copper oxide content as compared to a third sample of the same (green) colour from their building. An overall general consistency in the employment of the colorant is otherwise apparent, glazes from the same building being largely similar in their copper content. Small quantities of the colorant, c. 0.1 wt% or less, are also detected in most of the dark-blue glazes. One dark-blue glaze (DS/11) is unusual in this respect, its copper oxide content being notably high, measured at 1.4 wt%.

Very few undissolved copper-containing particles are found in the turquoise or green glaze samples, these being notably much rarer in occurrence here than in the Lodhi specimens. The few particles detected are mostly limited to the AK and DS turquoise samples, their individual analysis also revealing little other than a copper and oxygen content. Two particles in AK/02 are noted as having some associated tin content as well. Interestingly, all the AK turquoise glazes are also found to contain tiny particles of tin oxide dispersed in their glaze layers, a similar feature being noticed earlier for the Lodhi BT and HM glazes. The tin oxide particles are of a much smaller size and fewer in numbers in this case, apparently insufficient for their measurement through EPMA-WDS as no tin oxide is reported in the chemical analyses of any of the AK turquoise samples.

Table 7.9 Copper oxide contents of the Mughal turquoise and green glazes. All results are in wt% from EPMA-WDS analyses. Average values, where applicable, are given in bold. . '-' indicates 'not applicable'.

Turquoise glazes			
Sample	**Region**	**Glaze type**	**CuO**
HD/01	Delhi	Type II	3.75
HD/02	Delhi	Type II	3.77
HD/03	Delhi	Type II	3.71
HD/04	Delhi	Type II	3.66
HD/05	Delhi	Type II	3.62
HD (Avg.)	**Delhi**		**3.70**
AK/02	Delhi	Type II	2.18
AK/03	Delhi	Type II	1.53
AK/04	Delhi	Type II	1.36
AK/05	Delhi	Type II	2.02
AK (Avg.)	**Delhi**		**1.77**
SB/08	Delhi	Type II	3.56
SB/09	Delhi	Type II	2.60
SB (Avg.)	**Delhi**		**3.08**
NG/04	Delhi	Type II	3.22
NG/10	Delhi	Type II	3.22
NG/11	Delhi	Type II	3.09
NG/13	Delhi	Type II	3.11
NG/14	Delhi	Type II	2.91
NG (Avg.)	**Delhi**		**3.11**
KMA/01	Agra	Type II	4.73
KMA/02	Agra	Type II	4.84
KMA (Avg.)	**Agra**		**4.78**
DS/02	Punjab	Type I	2.88
DS/04	Punjab	Type I	3.24
DS/12	Punjab	Type I	2.84
DS/13	Punjab	Type II	2.53
DS (Avg.)	**Punjab**		**2.87**
SM/07	Punjab	Type I	3.04
DKS/01	Punjab	Type I	2.70
CR/13	Agra	Type I	3.73
CR/14	Agra	Type II	3.81
CR/15	Agra	Type I	3.59
CR/19	Agra	Type I	2.87
CR/20	Agra	Type I	2.41
CR (Avg.)	**Agra**		**3.28**

Green glazes			
Sample	**Region**	**Glaze type**	**CuO**
AS/01	Delhi	Type II	0.82
KM/03	Delhi	Type II	1.89
NG/05	Delhi	Type II	1.27
NG/17	Delhi	Type II	1.36
NG (Avg.)	**Delhi**		**1.32**
DS/09	Punjab	Type II	0.81
SM/05	Punjab	Type I	3.00
DKS/04	Punjab	Type I	3.01
CR/05	Agra	Type I	1.84
CR/06	Agra	Type I	1.62
CR/07	Agra	Type II	1.54
CR (Avg.)	**Agra**		**1.67**
TS/06	Punjab	Type I	3.04
TS/07	Punjab	-	1.37
TS/12	Punjab	-	1.08
TS (Avg.)	**Punjab**		**1.83**

Dark-blue glazes

Cobalt oxide is detected in all the dark-blue glazes, mostly in concentrations of 0.2-0.5 wt%. Values above this range are recorded only in the case of two samples, QK/01 and DS/10, where it stands at 0.6 wt% and 0.8 wt% respectively (Table 7.10). All the cobalt-containing samples, except TS/11, are found to have some associated arsenic oxide as well, in concentrations ranging from as low as 0.1 wt% to as high as 1.2 wt% in the glaze bulk. Higher concentrations of arsenic in general are noted for the Type II glazes over the Type I glazes. Small amounts of nickel and copper oxide are also determined present in the dark-blue glazes, the latter being consistently detected in measurable quantities in the Delhi SB and almost all of the Punjab glazes. Copper oxide is present in significant quantity only in the case of DS/11, as brought out earlier, where it is 1.4 wt%.

Undissolved cobalt-containing particles, like those of copper, are rare in the Mughal glazes, one particle being detected trapped in a bubble in the glaze layer of QK/04, and few others in some of the DS samples (Figure 7.61). Their analyses only suffices to confirm an associated arsenic and iron oxide content with the colorant, the values recorded being too erratic for any other determination. The grains in DS are moreover found to be in a semi-dissolved state, some of the associated oxides probably already having gone into the melt by this time.

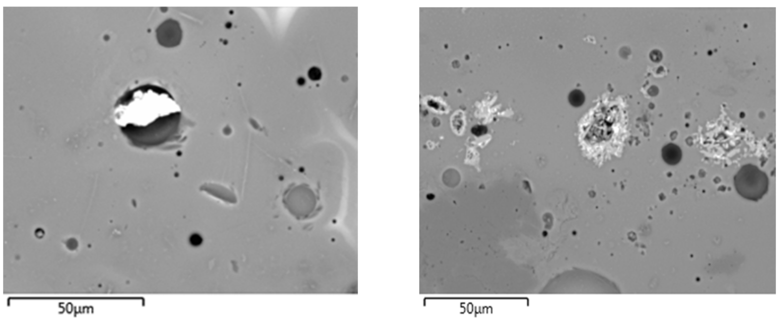

Figure 7.61 SEM photomicrographs of (left) a cobalt-rich particle trapped in a bubble in a glaze sample (QK/04) and (right) cobalt-containing grains in a partially-dissolved state in a glaze sample (DS/07).

Table 7.10 Values of oxides associated with the cobalt colorant extracted from the bulk chemical composition of the Mughal dark-blue glazes. All results are in wt% from EPMA-WDS analyses. '-' indicates 'below detection limit'.

Sample	Region	Date/Period	Glaze type	CoO	As_2O_5	NiO	CuO	As_2O_5/ CoO
IK/01	Delhi	1547-1548 CE	Type II	0.45	1.22	0.06	0.06	2.7
IK/03	Delhi	1547-1548 CE	Type II	0.44	0.92	0.05	-	2.1
IK/04	Delhi	1547-1548 CE	Type II	0.31	0.90	-	-	2.9
IK/05	Delhi	1547-1548 CE	Type II	0.44	1.06	0.09	0.06	2.4
AS/02	Delhi	c. 1560 CE	Type II	0.21	0.47	0.05	-	2.2
AS/03	Delhi	c. 1560 CE	Type II	0.18	0.37	-	-	2.0
KM/01	Delhi	1561-1562 CE	Type II	0.31	0.50	-	-	1.6
KM/02	Delhi	1561-1562 CE	Type II	0.31	0.74	-	-	2.4
KM/04	Delhi	1561-1562 CE	Type II	0.48	0.53	0.06	0.08	1.1
SB/01	Delhi	16th/17th cent.	Type II	0.18	0.60	-	0.06	3.3
SB/02	Delhi	16th/17th cent.	Type II	0.16	0.46	0.05	0.05	2.8
SB/03	Delhi	16th/17th cent.	Type II	0.21	0.65	-	0.06	3.1
SB/04	Delhi	16th/17th cent.	Type II	0.20	0.54	-	0.05	2.7
SB/05	Delhi	16th/17th cent.	Type II	0.20	0.46	-	0.05	2.3
SB/10	Delhi	16th/17th cent.	Type II	0.17	0.43	-	0.08	2.6
NG/03	Delhi	c. 1625 CE	Type II	0.24	0.60	0.05	-	2.5
NG/08	Delhi	c. 1625 CE	Type II	0.29	0.63	-	-	2.2
NG/09	Delhi	c. 1625 CE	Type II	0.29	0.63	-	-	2.1
NG/12	Delhi	c. 1625 CE	Type II	0.30	0.63	-	-	2.1
NG/15	Delhi	c. 1625 CE	Type II	0.34	0.70	-	-	2.1
QK/01	Delhi	17th cent. (1st Qtr.)	Type II	0.62	1.25	0.06	-	2.0
QK/02	Delhi	17th cent. (1st Qtr.)	Type II	0.23	0.46	-	0.05	2.0
QK/03	Delhi	17th cent. (1st Qtr.)	Type II	0.31	0.53	-	-	1.7
QK/04	Delhi	17th cent. (1st Qtr.)	Type II	0.31	0.82	-	-	2.7
DS/06	Punjab	17th cent. (1st Qtr.)	Type I	0.20	0.30	-	-	1.5
DS/07	Punjab	17th cent. (1st Qtr.)	Type I	0.33	0.46	-	0.11	1.4
DS/10	Punjab	17th cent. (1st Qtr.)	Type II	0.79	0.11	-	0.25	0.1
DS/11	Punjab	17th cent. (1st Qtr.)	Type I	0.26	0.07	-	1.43	0.3
FS/02	Punjab	c. 1606 CE	Type I	0.25	0.62	-	0.10	2.4
TU/01	Punjab	1612 CE	Type I	0.34	0.51	-	0.15	1.5
TU/02	Punjab	1612 CE	Type I	0.34	0.67	0.06	0.10	2.0
TU/03	Punjab	1612 CE	Type I	0.29	0.63	0.05	0.11	2.2
SM/03	Punjab	c. 1634 CE	Type I	0.40	0.16	0.07	0.06	0.4
SM/10	Punjab	c. 1634 CE	Type I	0.29	0.40	-	0.09	1.4
CR/08	Agra	c. 1639 CE	Type I	0.49	0.47	0.05	0.18	1.0
CR/09	Agra	c. 1639 CE	Type I	0.49	0.31	0.07	0.21	0.6
CR/10	Agra	c. 1639 CE	Type I	0.43	0.29	0.06	0.06	0.7
CR/11	Agra	c. 1639 CE	Type I	0.34	0.39	-	0.14	1.2
CR/12	Agra	c. 1639 CE	Type I	0.42	0.20	-	0.10	0.5
CR/18	Agra	c. 1639 CE	Type I	0.45	0.42	0.07	0.06	0.9
TS/03	Punjab	1657 CE	Type I	0.27	0.10	-	0.09	0.4
TS/10	Punjab	1657 CE	Type I	0.21	0.12	0.05	0.09	0.6
TS/11	Punjab	1657 CE	Type I	0.33	-	-	0.05	-

Calculated arsenic to cobalt ratios (As_2O_5/CoO) show that more than one variety of a cobalt colorant was probably utilized, the oxide concentrations of arsenic being around double that of cobalt in one group of glazes, while cobalt values invariably exceed those of arsenic in the other. The high-arsenic variety is found used across all the Delhi Type II dark-blue glazes of the sixteenth and first quarter of the seventeenth century, and interestingly in almost all the Punjab Type I glazes of the first quarter of the seventeenth century as well. The second variety of cobalt, with relatively lower arsenic content, was seemingly employed in the later seventeenth century Type I glazes only. Two very apparent exceptions to this categorization are DS/10 and DS/11, their cobalt and arsenic values being consistent with the second variety of the colorant, while the other samples from their building and their period in general correspond to the first variety.

Some further discrimination between the two varieties can be made out on plotting reduced and normalised alumina against iron oxide values for all the sampled dark-blue glazes (Figure 7.62). All the low-alumina Type I dark-blue glazes are found to separate from the other colours of their typology in the plot, highlighting an increased iron oxide content for this glaze colour. The same phenomenon is not noticed for the Type II dark-blue glazes, these merging with the other colours of their group in the plot. It is therefore apparent that the Punjab Type I dark-blue glazes of the first quarter of the seventeenth century, which otherwise share similarities with the Type II dark-blue glazes in their cobalt and arsenic contents, differ from the latter by having an increased iron oxide content associated with their group. These may therefore be considered a sub-category in the high-arsenic variety of cobalt employed.

The two prominent outliers among the high-alumina Type II glazes are the samples DS/10 and KM/04. The sample TS/11, which is distinguished from all the other dark-blue glazes in not having any arsenic content, is singular for other reasons too, having numerous small bright particles dispersed in its glaze layer. Spot analyses on these particles identify them as grains of tin oxide, explaining the significant tin oxide content noted for the sample on its bulk analysis.

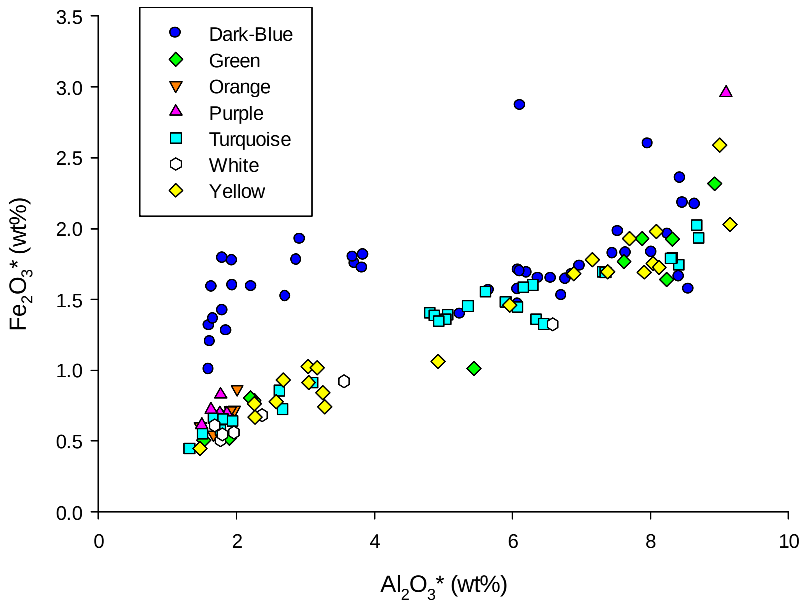

Figure 7.62 Scatter plot of alumina versus iron oxide contents of the sampled Mughal tile glazes. All the low-alumina (Type I) dark-blue glazes are seen to form a group, separate from the others, on account of their unusually high iron content. '*' indicates reduced composition.

Average arsenic to cobalt ratios (As_2O_5/CoO) of the two varieties of the colorant determined employed for the sampled dark-blue glazes, excluding the above-stated exceptions, are calculated to be 2.1 and 0.7 for the first and second variety respectively (Table 7.11).

Table 7.11 Average cobalt and arsenic oxide contents of the Mughal dark-blue glazes. All results are in wt% from EPMA-WDS analyses.

Colorant	Region	Period	Glaze type	Nos. of samples	CoO	As_2O_5	As_2O_5/CoO
Cobalt-I	Delhi	16th cent, 17th cent. (1st Qtr.)	Type II	23	0.29	0.66	2.3
	Punjab	17th cent. (1st Qtr.)	Type I	6	0.28	0.53	1.9
				Average	**0.29**	**0.60**	**2.1**
Cobalt-II	Punjab/Agra	17th cent. (2nd & 3rd Qtr.)	Type I	10	**0.34**	**0.25**	**0.7**

Yellow, green, and orange glazes

Lead and tin oxide concentrations, barring a few exceptions, are comparable across the yellow, green, and orange glazes, being mostly in the range of 12-18 wt% and 2-4 wt% respectively (Table 7.12). Zinc, like lead and tin oxide, is also found to be consistently associated with the yellow, green, and orange glazes. Its values are however significantly higher in the orange glazes as compared to the yellow and green glazes, being in the range of 1.5-2.6 wt% for the former, and between 0.3-0.4 wt% for most samples of the other two colours.

Table 7.12 Lead, tin, and zinc oxide contents of the Mughal yellow, green, and orange glazes. All results are in wt% from EPMA-WDS analyses. Results below the detection limit of the instrument are provided for comparative purposes only. '-' indicates 'not applicable' or 'not detected'.

Yellow glazes					
Sample	**Region**	**Glaze Type**	**SnO_2**	**PbO**	**ZnO**
AS/04	Delhi	Type II	1.21	15.77	0.09
AK/01	Delhi	Type II	2.75	14.68	0.65
SB/06	Delhi	Type II	2.75	16.81	0.26
SB/07	Delhi	Type II	2.00	12.70	0.24
NG/02	Delhi	Type II	1.89	15.29	0.37
NG/06	Delhi	Type II	3.53	15.56	0.35
NG/07	Delhi	Type II	2.72	15.38	0.34
KMA/03	Agra	Type II	2.37	15.71	0.17
NK/01	Agra	Type II	0.29	4.99	0.13
NK/02	Agra	Type II	2.49	17.59	0.44
DS/01	Punjab	Type I	2.23	11.67	0.06
DS/03	Punjab	Type I	1.86	11.17	0.03
DS/05	Punjab	Type I	2.66	11.81	-
FS/01	Punjab	Type I	2.26	13.17	0.05
TU/04	Punjab	Type I	2.93	11.92	0.02
SM/02	Punjab	Type II	3.20	16.40	0.27
SM/09	Punjab	Type II	2.53	16.19	0.16
CR/03	Agra	Type I	1.99	12.32	0.11
CR/04	Agra	Type I	2.96	14.26	0.33
TS/02	Punjab	Type I	4.85	29.39	0.35
TS/08	Punjab	Type I	2.99	17.55	0.45
TS/09	Punjab	Type I	3.65	29.61	0.35

Green glazes					
Sample	**Region**	**Glaze Type**	**SnO_2**	**PbO**	**ZnO**
AS/01	Delhi	Type II	1.97	9.71	0.01
KM/03	Delhi	Type II	1.21	9.04	0.01
NG/05	Delhi	Type II	1.87	11.18	0.34
NG/17	Delhi	Type II	1.27	10.47	0.41
DS/09	Punjab	Type II	0.92	9.04	0.02
SM/05	Punjab	Type I	4.54	19.52	0.37
DKS/04	Punjab	Type I	2.39	16.71	0.27
CR/05	Agra	Type I	2.71	12.07	0.34
CR/06	Agra	Type I	2.98	15.77	0.25
CR/07	Agra	Type II	2.35	12.76	0.03
TS/06	Punjab	Type I	4.49	18.33	0.36
TS/07	Punjab	-	5.64	60.58	1.59
TS/12	Punjab	-	6.28	57.14	1.25

Orange glazes					
Sample	**Region**	**Glaze Type**	**SnO_2**	**PbO**	**ZnO**
SM/04	Punjab	Type I	3.63	19.39	1.78
SM/11	Punjab	Type I	4.68	20.25	1.58
DKS/02	Punjab	Type I	4.08	29.06	2.60
DKS/03	Punjab	Type I	1.92	15.34	1.56
TS/04	Punjab	Type I	4.09	18.43	1.93
TS/13	Punjab	Type I	3.37	17.61	1.54

Lead oxide contents are generally on the higher side for the orange glazes, being markedly high in the case of DKS/02, where it is measured at 29 wt%, a similar high value also being recorded for the yellow glaze TS/09. It is unusually low on the other hand in the case of the yellow glaze NK/01, where it is found to be around 5 wt%. Exceptionally high values of lead oxide, from 57-60 wt% are recorded for the two outliers, TS/07 and TS/12, both of which are green glazes. Tin oxide values to a certain degree vary correspondingly with those of lead oxide, being generally higher for glazes where the lead oxide content is more, and relatively lower where it is less. Tin oxide content also clearly varies with the concentration of particles in the area subject to analysis, increased concentrations of the particles resulting in higher recorded values for the oxide. This phenomenon is however not observed in the case of lead oxide, results for it being quite consistent across the glaze bulk irrespective of particle presence.

Analyses of a random selection of individual particles in these glazes indicates that while most of them conform to the variety of the pigment known to be employed in the colouring of glass, $Pb(Sn,Si)O_3$, and contain small amounts of silica in their composition in addition to tin and lead oxide (Rooksby 1964, Kuhn 1968, Clark *et al*. 1995), a fair number of the particles are found to have zinc oxide in their composition in place of silica (Table 7.13, Appendices 7.22 and 7.23). Interestingly, all the particles investigated in the orange glazes are exclusively those with associated zinc content, as opposed to the yellow and green glazes where most of the particles analysed are found to be the silica-containing ones. This corresponds to results determined for the glaze compositions, zinc oxide values in the orange glazes being higher than those noted for the other two colours.

From the results it is apparent that both the particles types, although individually different, are remarkably consistent in their composition across the samples. Calculated atomic ratios indicate that the two types probably differ in their atomic structure. While the sum of the atom percent of tin and silicon is nearly the same as the atom percent of lead in the case of the silica-containing particles, consistent with the generally accepted formula of the pigment, $Pb(Sn,Si)O_3$, the same is not true for the zinc-rich particles. The atom percent of tin and lead are generally similar in their case, with zinc values being a third of either extra.

Table 7.13 Compositions of lead stannate particles in select Mughal yellow, green, and orange glazes from buildings at Delhi, Agra, and Punjab. All results are in wt% from SEM-EDS analyses, and normalised to 100 %. '-' indicates 'not detected' or 'below detection limit'.

No.	Sample	Glaze colour	Region	Nos. of particles	WEIGHT PERCENT				ATOMIC PERCENT				
					SiO_2	ZnO	SnO_2	PbO	O	Si	Zn	Sn	Pb
1	AS/01	Green	Delhi	6	4.6	-	29.7	65.7	59.7	5.4	-	14.0	20.9
2	AS/04	Yellow	Delhi	4	4.6	-	29.4	66.0	59.7	5.4	-	13.9	21.0
				1	-	6.0	34.7	59.3	58.8	-	5.3	16.6	19.3
3	AK/01	Yellow	Delhi	3	5.8	-	29.2	65.0	60.1	6.6	-	13.3	20.0
				1	-	6.0	34.7	59.3	58.9	-	5.3	16.6	19.2
4	NG/06	Yellow	Delhi	4	5.3	-	29.4	65.3	59.9	6.2	-	13.6	20.4
				1	-	6.5	36.2	57.2	58.6	-	5.8	17.2	18.4
5	NG/07	Yellow	Delhi	4	6.1	-	29.7	64.2	60.1	6.9	-	13.4	19.6
				2	-	9.6	35.4	55.0	58.1	-	8.3	16.5	17.2
6	SB/06	Yellow	Delhi	2	5.0	-	28.9	66.1	59.8	5.9	-	13.5	20.9
				2	-	6.1	36.7	57.2	58.8	-	5.4	17.5	18.4
7	SB/07	Yellow	Delhi	1	5.4	-	31.3	63.3	60.2	6.2	-	14.2	19.4
				3	-	6.3	37.0	56.7	58.7	-	5.6	17.6	18.1
8	DS/01	Yellow	Punjab	5	4.5	-	30.3	65.2	59.8	5.3	-	14.2	20.7
9	DS/05	Yellow	Punjab	5	4.4	-	30.5	65.1	59.8	5.2	-	14.3	20.7
10	DS/09	Green	Punjab	5	5.7	-	28.4	65.8	59.9	6.6	-	13.1	20.5
11	FS/01	Yellow	Punjab	4	4.6	-	28.6	66.8	59.5	5.5	-	13.6	21.4
				1	-	6.1	34.7	59.2	58.5	-	5.4	16.8	19.3
12	SM/02	Yellow	Punjab	3	5.2	-	32.4	62.4	60.3	5.9	-	14.7	19.1
				3	-	6.0	37.7	56.2	58.9	-	5.3	17.8	18.0
13	SM/04	Orange	Punjab	4	-	6.6	37.3	56.0	58.8	-	5.8	17.6	17.8
14	SM/05	Green	Punjab	4	5.1	-	32.1	62.9	60.2	5.8	-	14.6	19.4
15	SM/11	Orange	Punjab	6	-	6.3	35.2	58.6	58.5	-	5.6	16.9	19.0
16	DKS/03	Orange	Punjab	5	-	4.0	35.2	60.7	58.7	-	3.7	17.4	20.2
17	DKS/04	Green	Punjab	3	6.3	-	28.6	65.1	60.0	7.1	-	13.0	20.0
				2	-	4.1	35.5	60.5	58.9	-	3.7	17.3	20.1
18	CR/03	Yellow	Agra	3	5.7	-	28.9	65.3	60.0	6.6	-	13.3	20.2
				2	-	6.1	35.3	58.6	58.9	-	5.4	16.8	18.9
19	CR/04	Yellow	Agra	2	5.6	-	29.2	65.2	60.0	6.4	-	13.4	20.2
				2	-	6.2	35.1	58.7	59.0	-	5.5	16.7	18.9
20	CR/05	Green	Agra	3	5.8	-	30.2	64.1	60.1	6.5	-	13.7	19.6
				1	-	5.5	35.3	59.2	58.8	-	4.9	17.0	19.3
21	CR/06	Green	Agra	5	5.6	-	29.1	65.4	60.0	6.4	-	13.3	20.2
				1	-	6.0	34.5	59.5	58.8	-	5.3	16.5	19.4
22	CR/07	Green	Agra	4	5.2	-	28.9	65.9	59.8	6.1	-	13.4	20.6
23	TS/02	Yellow	Punjab	5	5.4	-	30.9	63.7	60.2	6.2	-	14.1	19.6
24	TS/04	Orange	Punjab	5	-	7.1	37.5	55.3	58.7	-	6.2	17.6	17.6
25	TS/06	Green	Punjab	4	5.5	-	31.8	62.7	60.2	6.2	-	14.4	19.3
26	TS/07	Green	Punjab	4	7.2	-	28.8	64.0	60.3	7.9	-	12.7	19.1
27	TS/13	Orange	Punjab	5	-	6.2	36.1	57.7	58.6	-	5.5	17.2	18.6

The likely discrepancy in the atomic structure of the two particle types is further strengthened through the results of Raman analyses of yellow and orange particles in two sets of glazes (Yellow in SM/05 and TS/02; Orange in SM/04 and TS/04). The spectra recorded for the yellow particles, characterised by an intense band at 141 cm^{-1} and a weaker broad band at 331 cm^{-1}, are determined similar to the known spectrum given by Clark *et al.* (1995) of the variety of lead stannate employed in glass (Figure 7.63). Spectra obtained from the orange particles on the other hand, are however quite different from the given reference, very strong bands in this case being typically noted at 118 cm^{-1} and 144 cm^{-1} and weaker broad bands at 286 cm^{-1}, 335 cm^{-1}, 440 cm^{-1} and 538 cm^{-1} (Figure 7.64) It is worth noting that similar results have also been reported by Gulzar *et al*. (2013) on the spectroscopic analysis of yellow and orange particles present in some yellow seventeenth century Mughal glazes from Lahore, Pakistan.

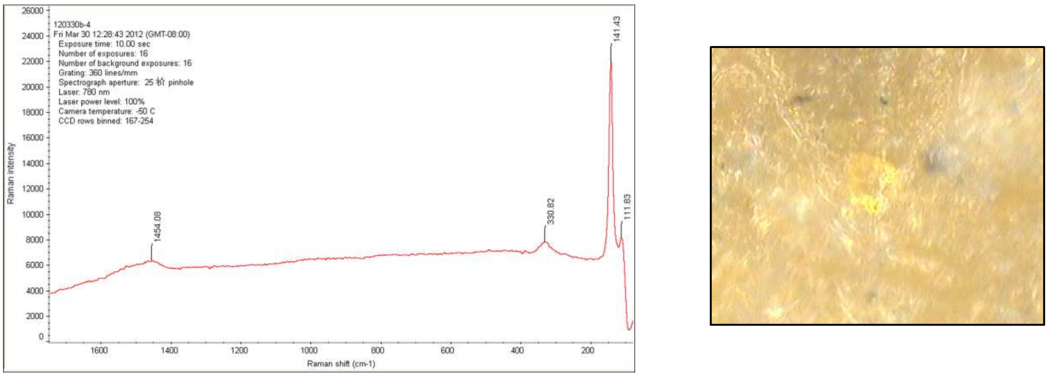

Figure 7.63 Raman spectrum (left) collected from a yellow particle (right) in a yellow glaze (TS/02).

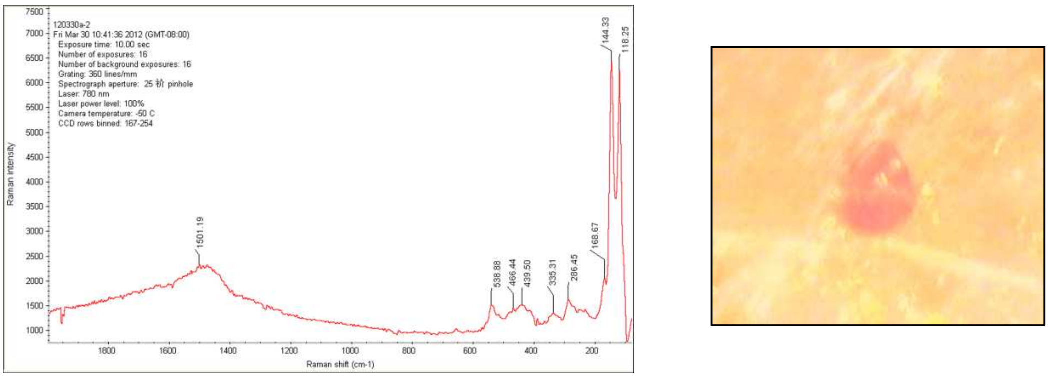

Figure 7.64 Raman spectrum (left) collected from an orange particle (right) in an orange glaze (TS/04).

Variations are also noticed in the shape, size, and distribution of the particles in the glazes. In general the particles are of an anhedral form or shape, but are marked by angular edges and often exhibit what appear to be conchoidal fractures (Figure 7.65). The smallest of these are about one micron or so across, while the largest ones, although fewer overall, are up to 15 µm across. Particles that are of an intermediate size of 5-10 µm are more likely to be equant than elongated, those of a smaller size generally having blurred or diffused boundaries. The particles that lie in the later Type I samples (SM, DKS, CR, and TS) are found to be more evenly distributed across the glaze layers, as compared to the other samples where they are less spread out individually and found to congregate in small clusters (Figure 7.66). An overall uniform distribution of the particles is however still apparent, the clusters where present being themselves spread out across the length of the glazes. Particles present in the glaze layers of TS/07 and TS/12 are found to be unusually large, some exceeding 30 µm across, and have a kind of fragmented appearance, probably on account of their partial dissolution.

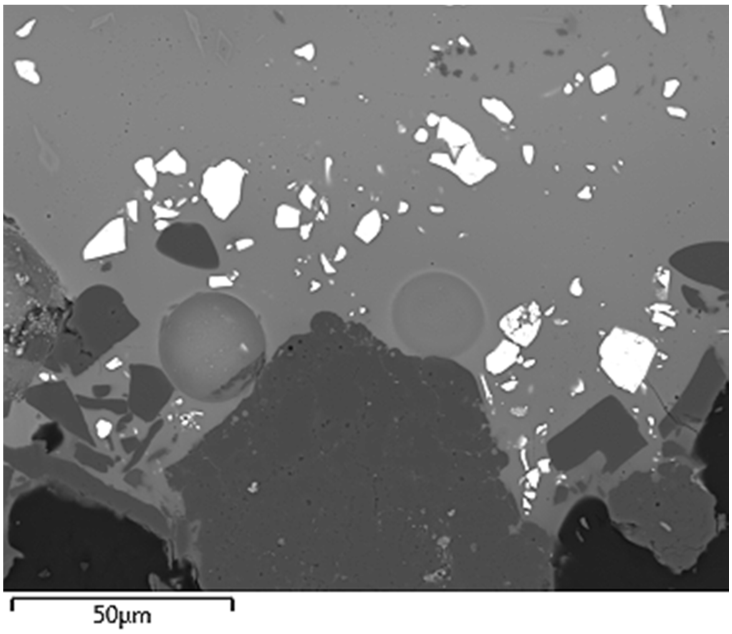

Figure 7.65 SEM photomicrograph of lead stannate particles in a green glaze from Dakhini Sarai (DKS/04) illustrating their general shape and angularity.

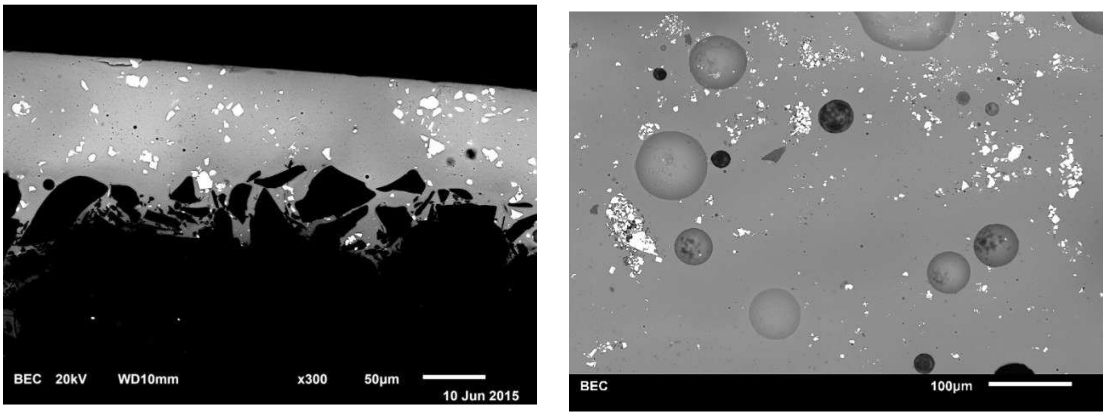

Figure 7.66 SEM microphotograph illustrating the distribution of pigment particles across the glaze layers of a sample from (left) Tomb of Shagird (TS/13) and (right) Sabz Burj (SB/06). Note the visible clustering of the particles in the case of the SB/06 glaze.

White and purple glazes

No colorant/opacifier particles are detected in the white glazes, their glaze layers being generally clear and having no extraordinary numbers of bubbles as well. It is interesting to note that both the NG white glazes, NG/01 and NG/16, are of the Type I glaze variety, whereas all other glazes from the same building are of the Type II form. These two glazes in fact are the only ones from all the Delhi/Agra buildings (excluding CR) which are of the Type I variety. The other white glazes, IK/02, DS/08, SM/06, CR/16, and CR/17, are all of a composition similar to those of the majority of samples from their respective buildings.

The six purple glazes (SM/01, SM/08, CR/01, CR/02, TS/01, and TS/05) are all found to contain manganese oxide, in concentrations that vary over the range 0.8-2 wt% but are consistent for samples from the same building. Spot analyses of some small rare bright grains present in the glaze layer of TS/05 confirm these as being particles of manganese oxide with some associated iron, explaining the unusual iron oxide values reported for this sample on its bulk analysis. No undissolved particles of the colorant are detected in the other samples of this colour. Purple glazes, as noted earlier, are only associated with the tile-work of the later Punjab type.

LA-ICP-MS results

LA-ICP-MS analyses conducted on a selection of 32 glaze samples corroborate the results and groupings determined through EPMA-WDS, the major and minor oxide compositions of the examined samples being more or less the same in both cases (Appendix 7.24). The ascribed groupings are also quite apparent in the trace element data obtained through LA-ICP-MS, as are some earlier determined peculiarities of a few individual samples (Table 7.14). The Delhi/Agra (Type II) group of samples (including two samples from the Lodhi period added for comparative purposes) are distinguished from those of the Punjab (Type I) group through their relatively higher contents of titanium (Ti), vanadium (V), chromium (Cr), zirconium (Zr), lanthanum (La), cerium (Ce), neodymium (Nd), and uranium (U). Interestingly, the diagnostic elements are in similar concentrations across almost all samples for a particular group, irrespective of the period or actual location of the buildings from where the samples were sourced. The seventeenth century Agra KMA samples are thus similar to the sixteenth century Delhi SL, IK, KM, and SB samples in their Ti, V, Cr, Zr, La, Ce, Nd, and U contents, as are the seventeenth century SM, CR, and TS samples between each other, the buildings in the latter case being distributed across a fairly wide geographical spread. It seems that the raw material, of which these trace elements are representative, was consistently drawn from the same general source across the period of proliferation of the two examined glaze groups. It is also interesting to note that the samples SM/02, SM/09, and CR/07, determined anomalies from among the Punjab sample set through EPMA-WDS analyses and related to the Delhi/Agra group instead, exhibit similar characteristics in their trace element compositions as well. Their Ti, V, Cr, Zr, La, Ce, Nd, and U values are found to match those of the Delhi/Agra sample group, although some variations are noticed in the Zr and U values for one of them (CR/07). TS/12 differs in this respect, which although being a constant outlier to the groupings on account of its unusual major and minor oxide contents, is found to share similarities with the Punjab group in its trace element composition, except perhaps for an elevated U content.

Table 7.14 Trace element compositions of select Mughal glazes determined through LA-ICP-MS analyses and reported in ppm. Samples of the Punjab (Type I) group are highlighted in grey, the remainder being of the Delhi/Agra (Type II) group. Elements that are diagnostic of the two groups are highlighted in bold. Outliers among the Punjab group are highlighted in orange. SL/01 and SL/03 are Lodhi period samples added on for comparative purposes.

No.	Sample	Colour	Li	B	Ti	V	Cr	Mn	Co	Ni	Cu	Zn	As	Rb	Sr	Y	Zr	Sn	Sb	Ba	La	Ce	Nd	Pb	Th	U
1	SL/01	Turquoise	13	228	**1505**	**35**	**20**	205	36	51	33863	33	216	12	131	10	**120**	44	76	153	**19**	**40**	**16**	92	7	**37**
2	SL/03	Dark-Blue	24	235	**1764**	**37**	**27**	228	5136	343	117	23	4833	19	126	11	**115**	2	0	152	**20**	**43**	**17**	29	8	**34**
3	IK/01	Dark-Blue	26	210	**1974**	**37**	**30**	244	4590	405	508	30	5766	21	120	14	**126**	10	0	168	**20**	**43**	**16**	121	8	**30**
4	IK/05	Dark-Blue	14	187	**1796**	**35**	**27**	506	5150	454	110	22	6185	20	98	11	**100**	6	0	142	**18**	**38**	**15**	268	7	**23**
5	KM/01	Dark-Blue	34	262	**2520**	**54**	**32**	370	3111	259	294	28	2858	33	166	16	**119**	12	0	245	**27**	**55**	**24**	172	10	**60**
6	KM/02	Dark-Blue	25	242	**2554**	**54**	**36**	356	3602	302	352	29	3590	22	164	71	**120**	5	0	226	**28**	**57**	**25**	29	11	**64**
7	KM/03	Green	12	314	**2012**	**50**	**21**	266	7	25	17205	97	114	24	134	13	**101**	13936	42	210	**23**	**47**	**20**	94892	9	**37**
8	KM/04	Dark-Blue	29	218	**2708**	**55**	**81**	358	5154	414	410	156	2505	37	197	16	**115**	123	0	230	**29**	**62**	**24**	140	11	**70**
9	SB/02	Dark-Blue	22	159	**2429**	**31**	**27**	431	2807	228	391	47	3619	44	156	20	**181**	2	0	222	**33**	**65**	**29**	40	12	**14**
10	SB/03	Dark-Blue	20	149	**2447**	**34**	**30**	432	2724	216	445	40	3609	44	149	21	**175**	2	0	214	**30**	**60**	**27**	38	12	**15**
11	SB/04	Dark-Blue	21	148	**2478**	**32**	**28**	436	2814	220	407	50	3256	43	147	21	**165**	9	0	213	**32**	**62**	**29**	40	12	**14**
12	KMA/01	Turquoise	24	273	**1841**	**33**	**18**	325	5	70	37526	189	118	18	204	14	**150**	69	23	168	**25**	**50**	**21**	120	10	**24**
13	KMA/02	Turquoise	23	257	**1421**	**27**	**18**	295	5	72	31985	177	110	20	180	11	**129**	128	32	148	**22**	**42**	**17**	99	8	**18**
14	KMA/03	Yellow	18	273	**2434**	**41**	**27**	278	13	16	66	1243	88	24	115	17	**197**	18573	70	167	**31**	**63**	**26**	118950	12	**32**
15	SM/01	Purple	35	171	**500**	**15**	**1**	11325	33	15	75	125	24	53	191	5	**61**	548	0	156	**9**	**16**	**7**	604	3	**1**
16	SM/02	Yellow	11	163	**1827**	**34**	**23**	232	4	13	130	1927	21	21	140	13	**156**	19087	50	180	**26**	**51**	**21**	128838	9	**24**
17	SM/03	Dark-Blue	34	163	**492**	**7**	**34**	302	4387	167	310	18	1549	53	194	5	**91**	70	2	135	**9**	**16**	**7**	617	3	**1**
18	SM/07	Turquoise	38	173	**448**	**7**	**4**	289	2	47	22984	28	93	46	192	5	**59**	276	14	164	**8**	**15**	**7**	753	3	**1**
19	SM/09	Yellow	12	186	**1884**	**35**	**27**	255	4	17	182	2382	28	18	162	13	**163**	24551	72	190	**25**	**50**	**21**	136172	9	**25**
20	SM/10	Dark-Blue	37	161	**420**	**7**	**9**	266	3619	60	137	29	1386	53	175	4	**54**	48	1	147	**7**	**13**	**6**	647	3	**1**
21	CR/05	Green	29	134	**341**	**6**	**3**	232	4	40	18324	4317	122	41	103	4	**58**	20343	26	73	**6**	**10**	**5**	124694	2	**1**
22	CR/06	Green	22	121	**298**	**5**	**0**	244	4	28	14006	3230	61	35	99	4	**59**	31504	119	76	**6**	**12**	**6**	162248	2	**1**
23	CR/07	Green	22	109	**1968**	**42**	**15**	196	73	46	13252	76	109	26	125	12	**85**	26158	101	210	**26**	**52**	**22**	119824	11	**104**
24	CR/11	Dark-Blue	41	163	**392**	**7**	**2**	362	5342	392	382	59	1949	54	113	6	**69**	5	1	139	**8**	**14**	**6**	101	3	**1**
25	CR/12	Dark-Blue	36	133	**375**	**6**	**1**	277	5014	435	826	54	1305	42	106	7	**57**	91	2	92	**7**	**12**	**5**	977	2	**1**
26	CR/19	Turquoise	29	210	**434**	**8**	**2**	271	5	31	23286	54	47	34	195	5	**67**	56	8	107	**8**	**15**	**7**	329	3	**1**
27	CR/20	Turquoise	31	162	**405**	**7**	**1**	222	2	29	20421	55	64	48	149	5	**58**	29	17	110	**7**	**14**	**6**	382	3	**1**
28	TS/01	Purple	32	201	**439**	**11**	**8**	6206	10	10	70	53	9	41	195	6	**54**	7	0	155	**8**	**15**	**7**	521	3	**1**
29	TS/03	Dark-Blue	29	223	**461**	**8**	**7**	320	2536	196	247	31	620	36	218	5	**62**	6	1	155	**8**	**15**	**7**	115	3	**1**
30	TS/06	Green	28	146	**467**	**7**	**2**	233	12	56	23550	5132	91	32	159	5	**65**	28312	48	149	**12**	**43**	**10**	180509	4	**1**
31	TS/10	Dark-Blue	30	207	**474**	**8**	**3**	277	2166	140	215	62	516	36	203	5	**76**	6	1	169	**9**	**16**	**7**	187	3	**1**
32	TS/12	Green	3	366	**475**	**16**	**7**	115	5	29	8014	16418	78	11	33	5	**73**	39905	689	579	**10**	**19**	**8**	530449	4	**56**

The association of arsenic and nickel with the cobalt colorant (as determined through EPMA-WDS) is also validated through the trace element compositional data, relatively elevated values for the two elements being noted in all the examined dark-blue glaze samples. The likely employment of two varieties of cobalt in the colouring of the dark-blue glazes is likewise confirmed through the values attained for cobalt and its associated elements across the examined samples. While the nickel to cobalt proportions are generally consistent across the two groups, nickel values typically being a tenth of those of cobalt, the arsenic to cobalt ratios differ considerably. Arsenic is determined being roughly equivalent or in excess of cobalt in the Delhi/Agra group, including in the Lodhi sample SL/03, but is in significantly lower proportions in the Punjab sample group, about a third of the latter in most instances. An association between copper and cobalt is also apparent, but copper values are relatively less consistent than nickel or arsenic throughout, variations being to the tune of few hundreds of ppm across the dark-blue samples. Other significantly elevated values of individual elements are all on account of the colorants employed, lead and tin in the case of the yellow and green glazes, copper in the turquoise and green glazes, and manganese in the purple glazes.

Summary and comments

The Mughal glazes are determined as being of the same general character and composition as the Lodhi specimens, and consist similarly of two broad typologies (Type I and Type II), distinguished mainly through their magnesia and alumina contents. The distribution of the two glaze types follows the regional discrimination associated with the tile bodies, one type or variety being generally associated with the Delhi and Agra buildings and their tile-work, while the other is related to the Punjab buildings and their tiling styles. In most cases, all samples from individual buildings are of just one of the types. Similarities between the samples of each of the glaze types extend to their trace element compositions as well.

But for two exceptions, all the glazes of the Delhi and Agra buildings of the sixteenth and first quarter of the seventeenth century are of the Type II mineral soda variety, while the vast majority of the glazes from the first to third quarter of the seventeenth century Punjab buildings are Type I plant ash alkali glazes. Some variations in the chemical composition are noted between the Punjab glazes of the first quarter of the seventeenth century and those of a later date. The Agra CR glazes that date to the second quarter of the seventeenth century, like their bodies, are of a character similar to that of their Punjab contemporaries. The average reduced chemical compositions of the two glaze types are as given in Tables 7.7 and 7.8.

The glazes of both types are similar in their coloration, a more extensive palette with the addition of purple and orange colours existing in the case of the later Punjab glazes. All the turquoise and green glazes have copper oxide content, while cobalt oxide is found in all the dark-blue glazes. The Delhi/Agra dark-blue glazes, and those from Punjab from the first quarter of the seventeenth century, have notable arsenic content associated along with cobalt. Particles of the pigment lead stannate are found dispersed in all the yellow, green, and orange glazes, the particles that prevail in the orange glazes being a zinc-rich variant of the commonly employed pigment. No colorant is determined present in the white glazes, while significant manganese oxide values are associated with the purple glazes.

More detailed discussions on the characteristic features and technology of both the Mughal and Lodhi tile glazes are provided in the next chapter.

8. LODHI AND MUGHAL TILE-WORK: TECHNOLOGY AND DEVELOPMENT

All the examined Lodhi and Mughal tiles are determined to be of the stonepaste variety, comprising quartz-rich bodies and glazes that are divided over two broad typologies (Type I and Type II). The only exceptions to this classification are two glazed terracotta specimens of the Lodhi period which represent a very small minority of their kind. Interpretations on the material character and methods of production of the tiles, as discussed in the first section of this chapter, are accordingly largely being made through a comparison of the analytical results with published information on the production technology of Islamic stonepaste ware. Subsequent discussions that follow, on the organization of production and on issues of their origin and development, take into account the broader findings determined through the field survey. In so far as the deterioration of the tiles is concerned, only the aspect of glaze layer separation is deliberated upon, this being the only decay form that appears related to the technology of the tiles. For this some preliminary discussions have been initiated by relating compositional characteristics to *in situ* observations on their state.

8.1 Production technology

8.1.1 Raw materials

In the stonepaste tile bodies, while considering the shape of the quartz particles in identifying raw material (quartz/silica) used, the emphasis is laid on the larger (coarse) particles, these being perceived to be more likely ‘original’ and representative of their parent source. The finer particles in the matrices are usually considered as being derived by the crushing or grinding of larger ones. Rounded or well-rounded coarse particles are typically suggestive of the use of a sand source for the quartz, their roundedness arriving through stages of weathering and transportation when detached from the parent rock.

High angularity of grains on the other hand is evocative of a resource other than sand; usually either crushed pebbles or quarried quartz-rich rock. The angularity of the particles is taken to be a reflection of the relative freshness of breaks or fractures attained on the breaking down of a relatively larger rock source, and of a non-erosional history prior to their employment in the creation of the tile bodies.

Going by this, the rounded medium-coarse sized quartz grains in the Mughal Punjab group of tile bodies indicates that sand, probably of riverine origin given the abundance of rivers in the region, was most likely utilized in their fabrication. The likelihood of sand being the most probable quartz source is strengthened through the consistent determined presence of substantially large composite grains of quartz and feldspars in these bodies, associating them with the parent source as well (Freestone *et al.* 2009). Quartz used in the Lodhi stonepaste tiles from the Punjab appears to have been similarly sourced, the particles in these bodies being of the same general shape as in the Mughal Punjab type. Variations in the content of quartz-feldspar composite grains in the two body types (Lodhi and Mughal) however indicates that the sand used in the manufacture of the Lodhi tile bodies is different from the one employed for the Mughal specimens, probably on account of being sourced from a different river bed.

The angularity and elongated nature of the quartz particles in the Lodhi and Mughal Delhi body type on the other hand, imply that these are likely to have been obtained from pebbles or quarried rock. The presence of only fine individual grains of feldspars and no composite grains of quartz and feldspars in this body type, further enhances this attribution. It is interesting to note that quartz used in the manufacture of bodies in the traditional Blue Pottery industry is nowadays obtained from quarries in the hills of the province of Rajasthan, and that the material was being reportedly mined in the same area for use in the craft in the nineteenth century as well. Given the proximity of Rajasthan to Delhi and Agra, and the known existence of quartz-rich deposits in the province since long, it is quite possible that the quartz employed in the manufacture of tile bodies at Delhi and Agra during Lodhi and Mughal times was also being sourced from the hills in Rajasthan. The presence of significant numbers of iron-titanium mineral particles in this body type, most evident in the Mughal Nila Gumbad bodies, could tentatively be considered a supportive characteristic of the use of such a source. The Lodhi Sheesh Gumbad tile bodies are distinguished from the others of the Delhi type in this respect. The comparatively fewer numbers of iron-titanium minerals in their bodies, and their conspicuous bright white macroscopic appearance, suggest that quartz was probably obtained by crushing white pebbles or cobbles in their case.

Analytical results indicate that except for two possible aberrations (TS/07 and TS/12) all the Lodhi and Mughal glazes are of the soda type, manufactured using silica fluxed with either naturally occurring soda, or with soda obtained through the burning of plants to make ash. The consistently low lime levels of c. 4-4.5 wt% associated with the Lodhi and Mughal Type I plant ash glazes indicate that a plant variety different from those found in Islamic lands further west was used, lime contents in excess of 5 wt% being frequently reported in the latter case (Mason *et al.* 2001, Fabbri *et al.* 2002, Tite *et al.* 2006). A local and likely contender for the Lodhi and Mughal glazes is the low lime-bearing *Haloxylon recurvum*, the ashes of which are known to be employed in the manufacture of glazes for a traditional pottery industry still existent in Pakistan Punjab, and in the soap and glass industry in the region in general (Rye and Evans 1976, Tite *et al.* 2006). *Haloxylon recurvum* is also widely cultivated in the arid regions of Rajasthan, which borders both Indian and Pakistan Punjab, for the production of *sajji-khar*, a crude soda ash finding extensive use in the local *papad* (poppadum) food industry (Rathore *et al.* 2012). The common use of this plant species as a soda source in the region is strongly indicative of it being the source of the plant ash flux utilized in glass and glaze production in earlier times as well. That Lodhi and Mughal tiles with plant ash glazes are largely confined to the Punjab region further strengthens its case.

While the low magnesia values of c. 1 wt% for the Lodhi and Mughal Type II glaze variety signify the use of a natural mineral soda flux, the unusual enhanced associated potash levels of c. 2 wt% are suggestive of the use of a particular local resource, such values of magnesia and potash being reported on the analyses of a wide range of early glasses said to be of Indian origin (Brill 1987, Lankton and Dussubieux 2006). The most likely soda source for the Type II glazes seems to have been the evaporite *reh*, deposits of which are known to exist in the alluvial plains of northern India as described in Chapter 5. As argued in the case of the plant ash glazes, the use of *reh* as the soda source for the Type II glazes is further supported by the fact that most tile glazes at Delhi and Agra are of this variety, both places located in the general region where *reh* was being harvested in significant quantities for glass manufacture till recent times.

The utilization of glass frit and clay in the manufacture of some of the tile bodies may be construed from the bulk chemical compositions of the bodies, and through the analyses of interparticle glass in their matrices. Discussions on the probability of their employment as raw materials in each of the body groups are given in the following section. The source, synthesis and use of mineral oxide pigments for colouring of the glazes are likewise detailed in the next section while discussing the methods of production of the glazes.

8.1.2 Methods of production

Tile bodies

While the shape of the quartz particles in the bodies has been utilized in determining raw material sources as described above, their size and distribution in the matrices in some cases reflect other stages involved in the technological sequence of tile production. The existence of distinct size groups of quartz particles indicates that a typical body batch required the addition of fixed proportions of quartz particles of different sizes, which would have been sieved beforehand, and probably stacked separately as well, before being brought together for the manufacture of the bodies. The mesh sizes of the sieves would be equivalent to the size of the largest of the particles in each of the size groups. Evidence of sieving is clearly visible in the case of the Mughal Punjab tile bodies, the uniform-sized fine particles of the slip layer being ostensibly attained through such an act, these being also determined to be of similar dimensions as the finer quartz particles in the body matrices. A similar technology is likely to have been employed in the case of the Lodhi Sheesh Gumbad samples as well, where the distinction between the particle size groups is most apparent. The use of more than one sieve can be less conclusively stated for the other Lodhi and Mughal tiles, particularly for the Mughal Delhi specimens, where the particles are more evenly distributed across the size ranges. In any case at least one sieve would have been used in all instances to filter out unwanted quartz particles of a larger than desired size.

An estimate of the quantities of glass frit and clay, the other ingredients considered utilized for the manufacture of the tile bodies as per Abu'l Qasim's recipe, can be made through calculations on the chemical compositions of the bodies and the interparticle glass found within. On an average the soda content is around 1-1.5 wt% in the sampled bodies, and about 17-18 wt% in the glazes. Assuming that the glass frit added to the bodies would be similar to the frit used for the production of glazes, and have similar soda:silica proportions as in the glaze bulk composition, the frit added to make the bodies of the sampled tiles can be calculated to be about 5-10 wt% on an average. The Mughal Punjab tile bodies, which typically have soda in concentrations of c. 1 wt%, would thus have had 5-6 wt% of glass frit added for their fabrication, half the figure proposed by Abu'l Qasim, while the Mughal Delhi tiles with a soda content of 1.5 wt% are closer to the classical proportions outlined by him, near about 10 wt% of frit being added in their case. For the Lodhi bodies, the proportion of glass frit used can similarly be determined to be about 7-10 wt% or so for their Punjab specimens, while results for the Delhi Sheesh Gumbad samples suggest that little glass frit, around 3 wt%, was generally employed for them.

Barring the Sheesh Gumbad specimens, with the average alumina in the measured bulk composition being 1.5 wt% or so, and alumina content typically being 16-20 wt% in ordinary clay, it would appear that approximately 8-10 wt% of clay was also added in the manufacture of the bodies in general. The recording of higher values of iron oxide and alumina in the interparticle glass of the tile bodies in general, as compared to their concentrations in the corresponding glazes, also indicate that clay is likely to have been added in most cases. Cognisance however needs to be taken of the alkali feldspars present in the body matrices while evaluating the proportions of clay used. Enhanced potash contents in the interparticle glass of all the body types as compared to the glazes indicates that not all alumina detected in the bodies comes from added clay, feldspar grains associated with the silica source also contributing to its recorded content. Abnormally high values of alumina and potash noted in many individual analyses of interparticle glass seem to further indicate that the glassy phase has a preferential tendency to develop or form in the vicinity of inherent alkali feldspar grains. The various determined body types therefore require a case by case examination to evaluate the addition of clay in their making. The model calculated results can be applied with greater certainty in the case of the Mughal Delhi tiles, where similar alumina values are noticed in the compositions of the interparticle glass and glazes, and where few alkali feldspars are found dispersed in the matrices. In the Lodhi Punjab tiles, the use of clay can be stated with confidence based on the significantly higher alumina content in the interparticle glass over that in the glazes, but cannot be accurately calculated on account of the increased feldspathic content in the body matrices, most of which is seemingly associated with the quartz source. Still a figure of at least 7-10 wt% can be assumed based on recorded alumina values and from the noted existence of well-developed interparticle glass in the matrices. An indicator of the alumina content in local clay can be determined from the body composition of the two glazed brick specimens, HM/03 and HM/04, both reporting 16 wt% of alumina in their body bulk.

The proportions and employment of clay as an ingredient is less certain for the Mughal Punjab tiles. Although alumina content of the interparticle glass in their bodies is higher than that found in their glazes, a general poor development of the glassy phase makes the addition of clay suspect in their case. Given the high numbers of feldspars grains associated with the silica source present in their matrices, it seems little clay, certainly not exceeding 5 wt%, was utilized or required for their forming. Little clay was also apparently used for the making of the Lodhi Sheesh Gumbad bodies; the very low alumina values recorded in their body bulk composition attainable possibly even through their inherent feldspathic content. The possibility that no clay was employed in their fabrication cannot be ruled out.

In general, all the examined tile bodies are found to be quite similar in character and composition to specimens from the central Islamic lands, each of them essentially comprising quartz-rich stonepaste bodies with some interparticle glass (Mason and Tite 1994, Freestone *et al.* 2009, Tite *et al.* 2011). Although the overall less-vitrified matrices make these tiles lack in stress durability, their strength is sufficient for the purpose of their employment as a means of surface embellishment where the application of direct pressure is not a concern (Henderson and Raby 1989, Freestone *et al.* 2009). The less-vitrified matrices in fact make the tiles porous and lightweight, advantageous properties that permit their facile embedment in mortar, and securer fitment on vertical wall surfaces.

The two Lodhi glazed brick specimens (HM/03 and HM/04) from Sirhind in Punjab have fired terracotta bodies. The clay that was used in their manufacture, being easily available in the region, would doubtless have been procured locally, most likely in the vicinity of where the bricks were being manufactured. Although probably shaped and cast in moulds like the bricks employed in the construction of the building, the noted comparative superiority of the glazed brick body matrices indicates that the clay used for them was an improved version of that used in ordinary bricks, having passed through a post-collection stage of refinement for the removal of organic matter and other unwanted impurities.

Glazes

The addition of equivalent portions of silica and soda for glaze preparation as described in Abu'l Qasim's historical recipe (Allan 1973) is evidently applicable to the sampled Lodhi and Mughal specimens, their analyses revealing fairly consistent soda values of c. 17-18 wt%, matching those reported for well-preserved coeval tiles and ceramics from the core Islamic lands (e.g. Tite 1989, Fabbri *et al.* 2002, Mason 2004, Paynter *et al.* 2004). Supportive evidence is determined through ethnographic studies of pottery and ceramic crafts in Iran (Wulff 1966) and Pakistan (Rye and Evans 1976, Khan 1985), where continuity in tradition of use of similar materials and proportions to recent times has been documented. The traditional stonepaste Blue Pottery craft in India is also noted to use equal parts of crushed quartz and flux in its glaze manufacture, although the flux here is not soda but a mix of equal portions of borax and lead oxide.

Microstructures of the analysed samples indicate that both the Lodhi and Mughal glazes would have been directly applied to the tile bodies as a pre-fired ground frit, being consistent with observations reported on experimental trials (Tite and Bimson 1986). Different methods of preparation would however have been employed for the two determined glaze types. Frit for the Lodhi and Mughal Type I plant ash glazes is most likely to have been prepared in the manner described by Hallifax (1892) and Rye and Evans (1976), through the manufacture of glass balls in a furnace, which were then broken down and milled to produce a glaze powder. Roughly equal proportions of quartz-rich sand, probably of riverine origin as stated earlier, and plant ash soda would have been used as the raw material for the production of the balls. The sand or silica would probably have been derived from the same source as that for the tile bodies. Plant ash would typically have been obtained in the manner reported by Rathore *et al.* (2012) and Rye and Evans (1976, 180-185), utilizing *Haloxylon recurvum* (*Haloxylon stocksii)*, a local desert plant, and common alkali source, that grows in arid patches in Rajasthan in India, and Punjab in Pakistan. Semi-dried plants of this species, harvested in December and sun-dried for a period of about a month, would be burnt in a circular pit dug in the ground for a period of at least 7-8 hours to yield lumps of ash of different qualities that could be further refined for use. The likely use of *Haloxylon recurvum* is further inferred through an evaluation of the soda, potash, magnesia, and lime contents of the Type I glazes, the soda to potash ratios (Na_2O/K_2O) and normalised lime-plus-magnesia contents [$(CaO + MgO)/(Na_2O + K_2O)$] of the glazes, their average values of around 5 and 0.3 respectively matching those given by Tite *et al.* (2006) for the plant species. Preparation of the frit on the lines described by Abu'l Qasim and Wulff (1966) for workshops in Iran, by melting of the ingredients in a furnace (in a vessel/crucible) and the subsequent pouring of molten glass in water to solidify as frit is less likely to have been employed here, the existence of such technologies unknown and as yet unreported in the region of northern India and Pakistan. It is seen therefore that while the raw materials used in the manufacture of the Lodhi and Mughal plant ash glazes are similar to those known to be employed in the central Islamic lands, the processes involved in their transformation from the raw state to the glass frit are of a local character.

The Lodhi and Mughal Type II mineral soda glazes have more indigenous features comparatively. Their overall composition and particularly low magnesia and high alumina contents, which typically range over c. 0.7-1 wt% and 5-8 wt% respectively, is remarkably similar to that of Indian mineral soda glass. While such glass was previously thought to have been manufactured using approximately equal proportions of a specific high-alumina local sand variety fluxed with locally available mineral soda (Brill 1987, Lankton and Dussubieux 2006), investigations carried out as part of this study reveal that a technology of a different kind utilizing only a single ingredient, crude mineral soda *reh,* is more likely to have been used. Given the close match between the composition of the Type II glazes and that reported for typical Indian mineral soda glass (Brill 1987, Lankton and Dussubieux 2006), it seems highly likely that the raw glass (or frit) sourced for the making of these glazes was also manufactured in the manner determined through this study, by the melting of just crude *reh* (as described in Chapter 5), either in a tank furnace or in crucibles placed within a furnace. Given the uncertainty of the antiquity of the tank furnace industry before the nineteenth century, and confirmed evidence of the use of crucibles elsewhere in India in the medieval and post-medieval era (Dikshit 1969, 139-144, Chaudhuri 1983), the latter method seems more likely to have been employed. Gathered evidence from the ethnographic studies undertaken, corroborated to an extent through Dobbs' (1895) authoritative monograph, indicates that the raw glass was probably produced independently, and then transported to other workshops engaged in the manufacture of glazed ceramics, where it was powdered to frit and put to use. No intermediate refining stage apparently existed between the production of the glass and its powdering to frit. This is determined from the similarity in concentrations of the base glass oxides in the analysed glaze samples and in glass specimens found in the region (Roy and Varshneya 1953, Kanungo et al. 2010) where the *reh*-based technology is likely to have prevailed in earlier times.

Silica was apparently not required, or sourced, as a separate individual ingredient for this glaze type. It would seem that the efflorescing of *reh* on the soil surface and the rudimentary methods employed for its collection allowed for the incorporation of sufficient quantities of silica into its bulk that was required for the formation of glass. Indeed Coggin Brown and Dey (1955, 513) while reporting on the analysis of samples of *reh* collected from various locations in the Gangetic plains remark '…it is only seldom that *reh* as collected contains more than 10 per cent of soluble components; the remainder being admixed silt'. The soluble components reported by them comprise sodium carbonate, sodium bicarbonate, sodium sulphate, and sodium chloride in varying proportions, the concentrations of these salts together in some of the samples interestingly being as high as c. 30 wt%. Given the described circumstances of the collection of *reh*, the high alumina content noted for this type of glass or glazes is therefore most probably a reflection of its concentrations in the soil, alumina being itself introduced into the *reh* bulk as a component of the soil/silt. The unusual enhanced potash and low lime levels noted for this mineral soda glaze type can be similarly explained. The possibility of enhanced values of potash being on account of absorption of fuel ash vapours during the melting stage (Paynter 2009, Yin *et al.* 2011) cannot also be ruled out at the same time. The rather low levels of lime that could have led to potentially less-stable compositions for this glaze type is compensated for by the presence of adequate alumina, which acts as a stabiliser in lieu.

In both the above-described cases, the fritted glaze powder would typically have been first mixed with water to form slurry, and then applied to the surface of the tile body through the dipping or pouring techniques, in much the same manner as in current traditional practice (Wulff 1966, 164, Rye and Evans 1976, 98, Yadav 1999). Metal oxide colorants, in similar quantities as determined in the analyses, would have been employed for the colouring of the glazes. The clustered appearance of undissolved lead stannate pigment particles in the green and yellow Mughal Delhi mineral soda glazes (see Figure 7.66) indicate that the colorants are likely to have been added to the glaze powders in dry form, prior to the conversion of the latter into slurry. This in all probability would have been the prevailing technique for the colouring of all the different monochrome glazes manufactured during Mughal times up to the first quarter of the seventeenth century. A similar technology is likely to have been employed by the Lodhis for their tile-work too. Such colouring techniques, of dry mixing of pigment and glaze powders, are known to be employed in current traditional practice as well (Wulff 1966, 163-164, Khan 1985, 48-49), the studied Blue Pottery craft industry included.

Less supportive evidence of this colouring method is available in the case of the later Mughal Punjab tiles on the other hand. An overall greater separation between the individual lead stannate particles in the green, yellow, and orange glazes of this period, and their more even distribution across the glaze layers in fact seems to indicate that pre-coloured powdered frits were made use of in the manufacture of these glazes.

The Lodhi and Mughal underglaze-painted tiles, few as they are, would have in all likelihood been glazed and decorated in the manner followed in the making of Blue Pottery ware, such techniques known to be utilized elsewhere in the medieval Islamic world as well. The colours would have been mixed with an organic adhesive, probably locally available *katira* (Tragacanth gum) in this case, and applied with a brush on the body or slip. The tiles would then have been coated with a transparent glaze frit and fired.

The three outliers (TS/05, TS/07, and TS/12) among the Tomb of Shagird tile specimens are of a different category from all others, these being macroscopically related to a recorded repair of the tile-work that took place a little more than a century ago. Their glaze and body characteristics are thus reflective of a technological transformation from the period of original application of the tile-work on the monument in the mid-seventeenth century to the time of their manufacture or the restoration undertaken in the early twentieth century. TS/05, which is the sole mineral soda glaze type among these, probably represents the technology employed for glazes other than those coloured by lead stannate, while TS/07 and TS/12 indicate that the green, yellow, and possibly orange glazes were deliberately manufactured to be of the lead type. The exceptionally high lead oxide content of TS/07 and TS/12 could however also be on account of the diffusion of excessive quantities of lead-oxide from the added lead stannate colorant into the melt, altering the character of the samples significantly.

Colorants

A total of four colorants are identified as being used over the course of Lodhi and Mughal tiling, sufficient between them for the realization of the seven glaze colours found in the later phase of Mughal tiling, this being the maximum number ever attained. A consistency is further noted in the employment of these colorants irrespective of period or region, the same colorants being used to obtain the same glaze colours over Lodhi and Mughal times. The four colorants determined used include copper oxide, cobalt oxide, lead stannate (lead-tin yellow), and manganese oxide.

Of these, lead stannate finds use in the yellow, green, and orange glazes, the pigment being found dispersed as undissolved particles in the glaze layers of these. Analyses reveal that the yellow and orange glazes were coloured through the exclusive use of lead stannate, while the green glazes are found to contain the colorant copper oxide as well. Spot analyses and Raman spectra of the pigment particles indicate that two varieties of lead stannate were employed, one being the common silica-containing lead-tin yellow Type II employed for the colouring of glass, and the other being a little-known variant. The variant, given the name lead-tin orange (Gill and Rehren 2014), is distinguished from the common Type II form in its composition, through the constantly determined presence of some associated zinc in addition to lead and tin, instead of silica, and from its Raman spectrum which is distinct from that of the common Type II form. A consistency in the atomic ratios of the constituents of both the lead-tin orange and lead-tin yellow particles across the sampled glazes, and the exclusive presence of lead-tin orange particles in the orange glazes, suggests that two varieties were deliberate manufactured as independent colorants. This is supported by the field observations on *in* *situ* tile-work, where orange coloured tiles are found employed in artistic compositions in a manner to be deliberately distinct from yellow coloured tiles. With tin oxide content in the yellow, green, and orange glaze compositions being a proportional measure of the colorant particles present, and tin:lead atomic ratio known through spot analysis, particles of lead-tin yellow and lead-tin orange that lie suspended in all these glazes are found on an average to contribute to 8-10 wt% of the bulk glaze composition.

Lead-tin yellow Type II is likely to have been prepared by heating a mixture of pre-synthesized lead-tin yellow Type I with silica to temperatures between 800 and 950 °C (Rooksby 1964, Kühn 1968, Clark *et al.* 1995). Alternatively it could have been manufactured through the heating of lead and tin oxides with a small amount of glass as a flux (Heck *et al.* 2003). Lead-tin orange would probably have been similarly produced, either in two stages by heating pre-synthesized lead-tin yellow Type I with a zinc compound, or directly by heating a mixture of all its constituent materials in appropriate proportions. Such apparently seems to be the case for the Mughal Punjab variety of glazes. The consistent detected presence of few lead-tin orange particles among the predominant lead-tin yellow dispersed in the Mughal Delhi variety of yellow and green glazes suggests that a third method of manufacture may have been used in their case. This would have potentially involved the intentional addition of a small amount of a zinc compound in the batch material for the manufacture of lead-tin yellow Type II, resulting in the formation of few discrete particles of lead-tin orange within a mass or bulk of lead-tin yellow particles. This may have been done to facilitate the attainment of a specific desired rich yellow colour tone for the glazes. The possibility that the zinc was an impurity associated with the batch materials used, as demonstrated by Molina *et al.* (2014) in studies on the colorant lead-antimonate yellow, cannot be ruled out at the same time.

A turquoise colour was achieved using copper oxide by itself, usually in concentrations of 2-4 wt%, while green was obtained when it was employed with lead-tin yellow. Undissolved copper-tin oxide particles found in some of the glazes indicate that the turquoise-blue colorant was at times obtained from bronze scrap, probably by the roasting of the alloy and then scraping off the oxide forming on its surface for use. The tin oxide particles that lie suspended in some of the Lodhi (Bibi Taj-ka Maqbara and Hathi-ka Maqbara) and Mughal (Tomb of Atgah Khan) glazes are most likely to have been originally copper-tin oxide particles as well, the copper in this case having gone in the melt, leaving relatively less-soluble tin oxide behind.

Dark blue was attained by the addition of small amounts of cobalt oxide, typically 0.3 wt% or so, three distinct varieties of the (cobalt) colorant being determined used over Lodhi and Mughal times (see pages 193 and 261-264). One variety is limited to the Lodhi Sheesh Gumbad glazes, while a second is found employed in the later Mughal glazes of the Punjab type only. A third variety, with a significant associated arsenic content, prevailed over the sixteenth and first quarter of the seventeenth century, being employed in the glazes of the Delhi mineral soda type, and most likely in the earlier Punjab typology of glazes as well. This variety was probably locally sourced, similarities being evidenced in its composition and that reported for a cobalt pigment obtained from ore deposits in Khetri in Rajasthan province (Mallet 1887, 27, Gill *et al.* 2014).

Shades of purple have been realized through the addition of around 1 wt% manganese oxide. No colorant is present in the white glazes, the effect or shade achieved by the opacification of a transparent glaze through a basal layer of fine grained silica present at the glaze-body interface. The technology of employing tin oxide to produce a white glaze (through the opacification of a transparent glaze) was seemingly unknown, or at least not employed, this in a way confirming that the tin oxide particles present in the turquoise glazes are more likely to be associated with the copper colorant.

Firing

Estimated firing temperatures determined through the Fluegel (2007) calculator for the different alkali glass compositions indicate melting temperatures of around 800-825 °C for the mineral soda glazes and around 850-875 °C for the plant ash ones. These conform to predictable temperatures attained through the use of updraft kilns, which are known to have been widely employed in the medieval Islamic world. In all probability similar kilns would also have been used in the manufacture of tiles in northern India during Lodhi and Mughal times. Although the firing temperatures ascribed to these glazes cannot be wholly corroborated by any means, the appearance of lead stannate particles in the yellow, green, and orange glazes can be utilized to infer that temperatures in excess of 900 °C are unlikely to have been employed, the decomposition of these particles known to occur at temperatures of c. 950 °C (Clark *et al.* 1995). This correspondingly indicates that some sort of control on the firing seems to have been exercised by the artisans, as the maximum temperatures achievable in these kilns would have been typically higher, around 950-1050 °C or so (Rye and Evans 1976, 143-147, Tite *et al.* 1998).

The numbers of firings that may have been involved in the production of the tiles is more difficult to determine. While signs of a single-firing can be read in the high degree of penetration achieved for the majority of the Lodhi tile glazes, or in the pinholing noted for the Mughal Delhi glazes, these cannot be taken as definite evidence of the same. Similar characteristics are equally attainable in instances of double-firings as well, being governed by a range of factors other than just numbers of firings. No clear information on the use of single or double-firings could likewise be deduced by examining the quantities of bubbles in the glazes (higher numbers indicating single-firing), or by observing the interaction between the body and glaze, these being too variable for any pattern to be determined. Given the monochrome nature of the vast majority of the tile-work employed, it would be however reasonable to assume that a single firing would have been preferred and employed for economic reasons in most if not all cases.

8.2 Organization of production

The overall uniformity in glaze and body characteristics of samples from within a site, and of a particular glaze or body type in general, indicates that a high degree of standardization was attained in their production. This in turn implies that a fairly well-organized tile-work industry was functioning over the period of Lodhi and Mughal rule in northern India. Significant compositional variations noted between the tiles from Delhi and Agra on the one hand, and those from the Punjab on the other, make it apparent that more than one centre of production existed and that more than one workshop was involved in the manufacture and supply of tiles over the period.

At Delhi, the transformation of the tile glazes from being plant ash to mineral soda in the early sixteenth century signals the advent of a new manufacturing technology, and the founding of an industry that was to develop its own hallmark technological style (mineral soda glazes and stonepaste bodies with quartz sourced from quarried rock or pebbles). While the close similarities in composition and character of the tile-work employed on numerous buildings at Delhi and Agra over the sixteenth and first quarter of the seventeenth century are a testimony to the firm establishment of this industry, small but noticeable variations in the technologies employed on the tile-work on individual buildings indicate the existence of more than one workshop. The higher interparticle glass content in the Arab-ki Sarai bodies as compared to their other contemporaries for instance, or the distinguishing features of the colorant employed in the Tomb of Atgah Khan turquoise glazes, can both be attributed to variations in recipes employed by different workshops. The presence of two samples with plant ash glazes among a majority of mineral soda specimens at Nila Gumbad likewise, suggests that more than one workshop was involved in the manufacture of its tile-work, and that more than one workshop associated with tile-work production was functional at Delhi during the period. However, as both these plant ash glazed tiles are the only samples from the building that have white coloured glazes, and otherwise have bodies that are largely similar in composition to the others from the building, this may also be interpreted to mean that the glaze frit being utilized in the manufacture of the tiles at Nila Gumbad was being sourced from more than one place. Such an interpretation fits well with the inference made earlier, that the frit for the Delhi type of tile glazes was probably being sourced from independent glass production centres or workshops, and not manufactured by the artisans in-house in their own workshops.

The industry at Punjab apparently remained distinctive in technological style (plant ash glazes and stonepaste bodies with quartz sourced from riverine sand) from that at Delhi throughout, but generally similar within the region particularly in raw material use. Macro- and microstructural discrepancies noted between the Lodhi and Mughal tiles, and between the Mughal tiles of the first quarter of the seventeenth century and those of a later date, however indicate that the technologies were not entirely consistent throughout. The variations in this case are however more on account of technological differences associated with different forms of tile-work, rather than being differences in practice followed by individual workshops for the same product. The consistent high quality tile-work that was being produced for the later phase of Mughal tiling in the region in fact indicates that production at this time was highly systemized, the workshops operating in a cohesive and regulated manner.

As regards the internal functioning of the workshops, little can be added to what has been stated while discussing methods of production. With the raw materials used differing in the two industries, it is apparent that the workshops in the two regions would have been differently organized. The Punjab workshops were probably more self-contained units, with fabrication, fritting, and firing all being carried out in-house (Figure 8.1), as was the common practice in the Islamic world, while those at Delhi/Agra seem to have had fewer activities associated, the raw glass for them being probably sourced externally (Figure 8.2), from separate workshops specifically engaged in glass production as stated earlier. The workshops in both cases are most likely to have been part of a larger ensemble, a separate part or department of which was concerned with the fitment of the finished tiles on buildings.

Variances to these proposed models however apparently existed, workshops set up at distant sites differently organized from those located at the centre. Similarities evidenced in the trace element compositions of the later Mughal Punjab tile glazes on individual buildings located at Nakodar, Sirhind, and Agra indicate that the principal ingredient (silica) was being constantly sourced from the same general location for them. This accordingly suggests that all the tiles of this type were being produced at one central location, from where they were then being shipped to different work sites for their employment on buildings. No provisions for fabrication or firing would therefore have been established at the sites in such cases, the workshops and the artisans here being primarily engaged in the cutting and shaping of the tiles and their installation on the buildings.

Some evidence on the existence of the workshops can also be gained from the few anomalies that exist among the tile-work of the Punjab type. The samples from Doraha Sarai (DS/09, DS/10, and DS/13), Sheesh Mahal (SM/02 and SM/09), and Chini-ka Rauza (CR/07 and CR/14) which are compositionally similar to those of the Delhi type, indicate that at least one workshop following the Delhi technological style was functional during the period ascribed to these buildings. This is significant as it shows continuity in the tradition of manufacture of the Delhi type of tiles, even after the cessation of tiling activities in the general Delhi/Agra region involving the local industry. These tiles would probably have been employed parallel to the majority Punjab variety at the time of original installation of the tile-work on the three buildings, but could also represent an unrecorded restoration of a later date.

It is clear that regional and chronological variances detected through analyses are also echoed macroscopically in the tile-work on the buildings. The Delhi (and Agra) tiles through Lodhi and Mughal times are stylistically quite different from those of the Punjab variety, as are the Mughal Punjab specimens of the early and later seventeenth century between each other. An inclination to restrained application is also evident on the monuments of Delhi, whereas larger areas of tiled expanses and more liberal employment are evinced on the Punjab monuments. With the Lodhi tiles being determined variable in character not only between their Delhi and Punjab buildings, but also between those located at Delhi, the scale and location of the industry existent in their times cannot be accurately projected. Given that appreciable numbers of their tiled buildings are located at Delhi, it can be still assumed that at least a single workshop or small production centre was existent through the Lodhi period at Delhi, catering to the requirements of the local building industry.

For the sixteenth and seventeenth century periods of Mughal rule however, it can be stated with confidence that two distinct industries manufacturing architectural glazed tiles were functional (although not always concurrently); one centred on Delhi and the other in the Punjab region at Lahore, their stylistic and technological influences embracing areas in their vicinity. With increased patronage and commissions, reflected in the larger numbers of tiled monuments from this era, it is even more apparent that more than one local workshop would have been established and operational at each of the regions. Moreover, as tile-work typologies associated with their particular production centres are preponderant, if not exclusively present, at both Mughal Delhi and Punjab, one may reason that tile-work decoration in conception and application during this period was influenced and dependent on artisans and their availability as much as on design inputs provided by architects and patrons. In the case of the Punjab tile-mosaic, the aspect of desired decoration seems to go further so as to influence building design itself, with surfaces being deliberately planned in a manner to accommodate tile-work, indicative of the importance and inclusion of its designers in the higher echelons of the building department hierarchy.

8.3 Origin, influences, and development

The Delhi industry

Although there is a general inclination to assume that the tile-work of the Lodhis and Mughals, and particularly of the latter as often stated, is essentially imitative or derived from Iran or Central Asia, there is reason to believe that the industry that flourished at Delhi during the time of Mughal rule is an independent development, with local roots. Most apparent support towards this premise is the gradual evolution witnessed in application, commencing with the sparse and simplistic use of tiles during the early Lodhi period to its culmination in the multifaceted compositions that adorn the Mughal monuments. Intermediate stages that would be expected can be found in chronological sequence, monochrome bands leading to polychromatic compositions, tile-inlay in stucco progressing to the tile-mosaic. Indicative is also the nature of glazes typically associated with the Delhi style of tile-work, their compositional characteristics linking them to an indigenous traditional glass industry existent in the region from probably pre-Islamic times.

Compositional inconsistencies between the tile glazes from various Lodhi period buildings at Delhi and those of Mughal times however affirm that the beginnings of the Delhi technological style do not coincide with the commencement of the Lodhi tiling in the region. The earliest of the Lodhi glazes at Delhi, of Bagh-e Alam-ka Gumbad (1501 CE) and Sheesh Gumbad (c. 1500 CE), are in fact of a typology associated with the region of Punjab. Given that a few Lodhi buildings of a contemporary date are also known to exist in the Punjab, mutual influences in the technologies between the two regions would not have been entirely unexpected. The examined Lodhi tiles (of Bibi Taj-ka Maqbara and Hathi-ka Maqbara) from the Punjab however, although of a similar glaze type, are determined to be different in their overall character, more in line with their later Mughal counterparts from the same region than with their contemporaries in Delhi. These are therefore clearly an independent category, representing a variety of tile-work manufactured in their region, either at Sirhind where the buildings are located and where a workshop may have been functional, or imported from a location further west where a similar technology is likely to have been in existence, Multan being a possible source. Parihar’s (2006, 108) assertion that the Lodhi buildings at Sirhind are imitative of those at Delhi in architecture and style certainly does not hold good in respect of their tile-work, at least not for their technology.

The early Lodhi tile-work at Delhi consequently could either have been locally manufactured or imported from a third location elsewhere. Considering the overall numbers of Lodhi tiled buildings that are known to exist, and the exclusive use of only turquoise coloured tiles on almost all of them, it would seem that a workshop engaged in the manufacture of just turquoise coloured tiles was probably operational in the initial stages of Lodhi tiling, prior to the establishment of a formal industry. That the three securely dated Lodhi tiled buildings are all from this early period, and are all adorned with turquoise coloured tiles only, in a way confirms the same. The tiles manufactured at this time are most likely to be of a variety similar to that of the Bagh-e Alam-ka Gumbad. While this would potentially indicate the existence of yet another technological style, the numbers of samples examined from this period are too few for any conjecture on the subject to be made as yet.

The Sheesh Gumbad, which is also considered to be of a similar early period, is an anomaly in this respect. Its rather elaborate tiling for the time, and the macro- and microstructural discrepancies associated with its tile-work, suggest that the tiles on this building are most probably an import. With comparative technical information on tile-work elsewhere in the subcontinent lacking, a possible source for these tiles cannot also be confidently stated. The Malwa region however seems most likely given its proximity to Delhi and the tiling activities known to be taking place there at around the same time. The same source could perhaps also have been the stimulus for the commencement of a tiling tradition and the setting up of the first of the workshops by the Lodhis. The possibility that the Sheesh Gumbad tiles were imported from beyond the borders of the Indian subcontinent also cannot be ruled out at the same time. The compositional peculiarities of its cobalt colorant could perhaps aid in this regard, being potentially useful for establishing relationships with other dark-blue tiles originating from the same workshop or same general source. It may be added that no use of this variety of the colorant elsewhere is yet reported or known.

With the tiles on the Tomb of Sikandar Lodhi being the earliest of the examined buildings to exhibit compositional characteristics of the Delhi technological style, its assigned date of c. 1518 CE can be tentatively taken to mark the formal founding of the Delhi industry. It is interesting to note that the tile-work of this building is unusual for its extended palette of four glaze colours, green and yellow glazes being noted used for the first time in addition to the common turquoise and rare dark-blue. It is also interesting to note that the ascribed date of the building coincides with the appropriation of Gwalior Fort by the Lodhis, a part of the fort being known to be elaborately decorated with tiles in the same four glaze colours as on the tomb-building. Considering that the tile-work of Gwalior Fort is of an earlier date, being certainly installed on the fort prior to its capture, and given the similarities between the tile-work of the two sites along with the given turn of events, it would not be unreasonable to assume that the tiling undertaken on the Tomb of Sikandar Lodhi was the handiwork of artisans brought in from Gwalior following its falling into the hands of the Lodhis. This would also explain why the tile-work on the tomb is more sophisticated than hitherto seen, the skills of experienced artisans allowing the creation of more intricate compositions, besides providing an impetus to the development of the craft in the region. The founding of the Delhi tile industry is therefore most likely to be related to the historical event of the capture of the Gwalior Fort by the Lodhis, and new influences brought about by the inward migration of artisans. Future studies on the tiles of Gwalior Fort would determine whether the new influences were both stylistic and technological, or just limited to the former only.

While the erection of monumental tomb-buildings during the Lodhi era was clearly not only the prerogative of the sultans, those of their high nobles being of a similar size and construction, a distinction between the tombs of the rulers and their subordinates seems to have been maintained in their tile-work decoration. Of all the tiled Lodhi tomb-buildings, it is only at the Sheesh Gumbad and the Tomb of Sikandar Lodhi that tiles of a colour other than turquoise are found. These two are in fact the only Lodhi tiled buildings, tombs or otherwise, in which the palette of colours goes beyond the use of turquoise. The very few yellow tiles of Jahaz Mahal being near invisible in placement hardly count as being part of the decorative scheme, the building itself also perhaps being of the Mughal period. Considering that the Tomb of Sikandar Lodhi is known to mark the resting place of the second Lodhi sultan, its rather lavish tile decoration can be seen to be a deliberate attempt to distinguish it from the others, the use of colours other than turquoise being kept reserved for royalty. In that case, the Sheesh Gumbad, with its rather unusual and rich tile-work decoration for its time, is also most likely to be a funerary structure of one of the royal family. Digby's (1975) view that the Sheesh Gumbad is the tomb of the first Lodhi sultan, Bahlul Lodhi, therefore has merit in it, and needs to be further explored. That Sheesh Gumbad predates Sikandar Lodhi's tomb is determined through the compositions of its tile glazes, these being of a (plant ash) variety that ceased to be employed after the establishment of the Delhi tile industry.

The Delhi tile industry apparently flourished once established, all the examined tile bodies and glazes (except NG/01 and NG/16) of the Surs and Mughals at Delhi and Agra up to the reign of Jahangir being determined to be of the same technology. The glazes of Jahaz Mahal are also of this type. Interestingly, while four of the five colours that mark the palette of the Delhi style are found employed on the Tomb of Sikandar Lodhi, the fifth colour, white, is also first encountered on a non-Mughal building, on the Sur period Tomb of Isa Khan. In technique of application too, the tile-mosaic favoured in employment by the Mughals at Delhi/Agra has its antecedents in the Sur period buildings of Lal Darwaza and gateways of Purana Qila. With the little progression in the advancement of the craft noted for the early Mughal period, before that of Akbar, it would be fair to credit the full development of the Delhi industry in both technology and style to the Lodhis and Surs. The role of the Mughals in the promotion of the craft particularly that of Akbar, and to a lesser extent Jahangir, cannot at the same time be understated, given the large numbers of tiled buildings at Delhi and Agra associated with their times. In summation it may thus be said that the tile-work found on Mughal buildings at Delhi and Agra, up to the period of Jahangir's rule, represent a logical development on an indigenous precedent set by the Lodhis and Surs at Delhi, and hence may not be considered an import although new influences would certainly have shaped its evolution. It would be also apt to state that significant proof exists to show that the institution and full development of the craft in the region pre-dates its widespread employment by the Mughals, necessitating a comprehensive review of the sequence of its development, and of the credit usually ascribed to the Mughals for its founding and promotion.

The Punjab industry of the Mughals

New influences and changing tastes are also most apparent in the early tile-work in Punjab, which correspond to the period of Jahangir's rule. The tiles inlaid in brickwork compositions on Doraha Sarai, Fathehabad Sarai, and Tomb of Shagird, have been demonstrated to be distinctive not only for their unusual mode of fitment, but also for their technology, these being the first to have the glazes and bodies of a significantly different composition from those made at Delhi. The numbers of tiled buildings of this kind are however too few to suggest the beginnings of an industry, the tiling in this case being more likely carried out by itinerant artisans engaged for specific commissions.

As the appearance of the tiled buildings in Punjab coincides with a marked decline and near closure of the Delhi/Agra industry, it is evident that the change in taste was accompanied by a westward shift in activities. All ties with the Delhi/Agra industry were apparently not severed, the use of the same cobalt colorant, and the same colours and colouring techniques of the glazes being noted for both places. That some artisans from Delhi or Agra facilitated this marrying of technologies for the new incumbents at Punjab seems highly probable. Significant advancements noted in the style of application of tile-work on the contemporary Naubat Khana at Agra, the tiles of which are attributed to the Delhi industry, indicate that the converse also may have occurred.

Such interrelations are conspicuously absent in the next phase of tiling in the region with the arrival of the tile-mosaic of seven colours at around the end of Jahangir's rule. This highly refined tile-work form that was seemingly centred on Punjab (at Lahore) has all the markings of being of foreign origin, no evolutionary phase preceding its arrival being visible. Although of a general similar compositional character as the inlaid tile-work that it supplanted, this form is clearly distinguished from the latter in the sophistication of its finish, and intricacy in application. With analysis demonstrating a number of similarities in material character between specimens of this kind and those from central Islamic lands, and given the fairly long period of their prolific use, it is most apparent that a production centre in Punjab, at Lahore, was established in the early years of Shah Jahan's rule, likely organized on the lines of workshops existent in western/central Asia, and possibly staffed by migrant artisans imported from these lands for the purpose.

Having said that, it is then vital to better identify the region from where this latest form of the craft may have been imported, and the circumstances surrounding its arrival. In all the history of Islamic northern India, a closer association with the regions of Khurasan and Central Asia is witnessed as compared to that with central Iran or Turkey. This is manifest both politically, in the association of the Indian ruling dynasties with the former two regions, and in architecture and its decoration, the Indian buildings exhibiting consistent influences from the same two places. In Indian tile-work decoration too, the complete absence of the elaborate painting and glaze-decoration techniques for which Iranian and Turkish tiles are known, suggest that little influence emanated from there, the tiles being more likely to be inspired or derived from Khurasan or Central Asia which are closer geographically as well. The fact that the Punjab tile-mosaic specimens are of a generally similar character as tiles employed in these two regions further supports this argument. Between the Safavids and the Uzbeks who controlled these regions in the early seventeenth century, and who were the chief patrons of the craft in the larger region around, a consistent use of the tile-mosaic is seen associated only with the Uzbeks; the Safavids (Shah Abbas) at this stage choosing to employ the more economic *haft rang* form as outlined in Chapter 2 (page 53). Given that the tile-mosaic was the prevailing form employed across these lands up to this time, Shah Abbas' decision would have quite certainly led to a fairly large pool of tile-work artisans being rendered jobless. It therefore appears that a change in demand in tiling preferences in the region, instigated by the Safavids, led to the migration of a group of skilled tile-mosaic artisans to the Mughal courts, who proceeded to establish an industry in Punjab there. That the artisans relocated following an invitation extended by the Mughals is a strong possibility, given the increased interest evinced by the Mughal emperors (Jahangir and Shah Jahan) at that time in connecting with their ancestral lands and traditions. At the very least it seem probable and reasonable to state that the skills of the artisans involved in the propagation of the craft in Punjab were derived from their association with tiling activities commissioned in Khurasan-Central Asia. The dominance of orange and yellow shades in the tile-mosaic employed in Punjab, however, differs from the preferred blues of the central Islamic lands, suggesting that a regional style was founded either on the adaption to new requirements or due to access to new materials, or both. Notable is that in colour scheme a closer relationship between the Punjab tile-mosaic and the Safavid *haft rang* tiles is seen to exist, indicating a possible partial amalgamation of styles and technologies taking place locally.

The synchronous relationship between tiling and architecture in the region apparently lasted till the very end. Just as the beginnings of the tile-work industry are associated with resurgence in building activities under the Lodhis, the demise of the craft can be correlated with the decline of the Mughal building industry. Given that the last of the tile-mosaic commissions was of as high a quality as its precursors, it would seem that the circumstances of the arrival of this tile-work form was repeated at its departure, the tile-mosaic artisans preferring to migrate to other lands for better prospects. No evidence of this is however available, the end of tiling in the region apparently coinciding with the termination of employment of the tile-mosaic across the central Islamic lands.

8.4 Technology and deterioration

From the appraisal of extant tile-work carried out it is clear that the prime reason for their *in situ* deteriorated state is the 'peeling' or separation of the glaze layer from the underlying body. The phenomenon is noted common for all the tile-work, occurring on all the buildings, and independent of any relationship with body type, glaze type, glaze colour, region, or location of the structure. Peeling as such is symptomatic of a poor glaze-fit, and known to occur on account of mismatch in thermal expansions of the body and its glaze layer. The glaze layer in such cases is being subject to excessive compression, the stonepaste body having shrunk or contracted more than required, or perhaps too rapidly.

Taken together this seems to imply that the tile-work in general is inherently defective, reasons for which should lie in material use and production technologies employed. Observations on the tiling on Sikandar Lodhi's tomb and Khairul Manzil Masjid however suggest that this may not to be entirely true, the tile-work in these two buildings being in a good state of preservation where applied indoors, but exhibiting the same separation of the glazes on the exteriors. Although the possibility that the indoor tiles are differently manufactured from those on the outdoors cannot be ruled out, this seems highly unlikely, their sheltering from the environment being a more likely logical reason for their better-preserved state. Well-preserved tiles with little signs of glaze separation are also noticed existent on the Fathehabad Sarai gateways and on Tomb of Ustad, the tiles in this case being located on the exteriors. With compositional differences between these tiles and those from other buildings in the region being negligible, the little peeling of their glazes can be only explained by examining the unusual conditions in which they exist. It would appear that their peculiar technique of fitment, involving the embedding of individual tiles within bricks, resulted in the tiles being tightly wedged when installed, their bodies and glazes being thereby less prone to differential variations in expansion and contraction even when exposed directly to the environment. When such protection was lacking on the buildings, as in the case of the tiles on the cupolas on the roof of Tomb of Ustad, these were equally susceptible to separation occurring. In both the presented cases it is seen that the glazes were capable of remaining adhered as long as the tiles were not exposed to the environment. It would therefore be more appropriate to relate the peeling of the glazes to the unsuitability of the tiles to the climatic conditions in the country rather than to shortcomings in production technology of the tile-work. Whether this decay occurred in a short or long time span cannot be determined but it would be logical to assume that should the former have been the case, attempts would have been made by the industry to ensure necessary modifications were incorporated in the technology.

At the same time it seems necessary to examine the possibility of adjustments in the technology that could potentially aid reconstructed tiles of a similar general character to survive on the buildings for long. The three specimens (TS/05, TS/07, and TS/12) from Tomb of Shagird considered representative of the documented restoration work on the building may be singled out for some attention in this regard. Considering that the restored tiles still extant on the building are in a particularly good condition and exhibit little or no separation of the glaze layers, the glaze and body peculiarities of these three specimens could potentially aid in determining reasons for their better-preserved state. As noted earlier, these differ majorly from the others on the building, and from earlier Mughal tile-work from the Punjab region in general, by having relatively thicker glazes, which in the case of TS/07 and TS/12 are of the lead or high-lead type, and to an extent in the better degree of development of interparticle glass in the bodies. With just this information to go on, it can be only surmised that for tile-work on the exteriors lead glazes on stonepaste bodies are overall more stable and less prone to separation as compared to alkali glazes on the same body type, and that instances of glaze separation are probably less likely to occur if the interparticle glass in the tile bodies is fairly well-developed, and if the applied glazes are of a sufficient thickness, of the order of 500 µm or so. While the superiority of high-lead glazes and the evaluation of various glaze types in matters of glaze-fit have already been commented upon by others (Tite *et al.* 1998, Paynter 2009), the relationship between interparticle glass content and glaze-fit is yet to be explored in detail. Moreover, as the use of alkali glazes cannot be dispensed with in any proposed reconstruction, as this would alter the basic character of the tile-work, it becomes even more important to seek adjustments in the body technologies, interparticle glass content being a possible starting point. Much more study is however needed for a better understanding and evaluation of glaze-fit in relation to glaze or body characteristics before attempting any reconstruction for installing tiles on buildings. Besides experimental work, this would perhaps necessitate direct sampling from the building, as paradoxically the tile samples that are usually made available for analysis are those that have their glaze layers intact, and cannot really be deemed to be representing the decay form in question.

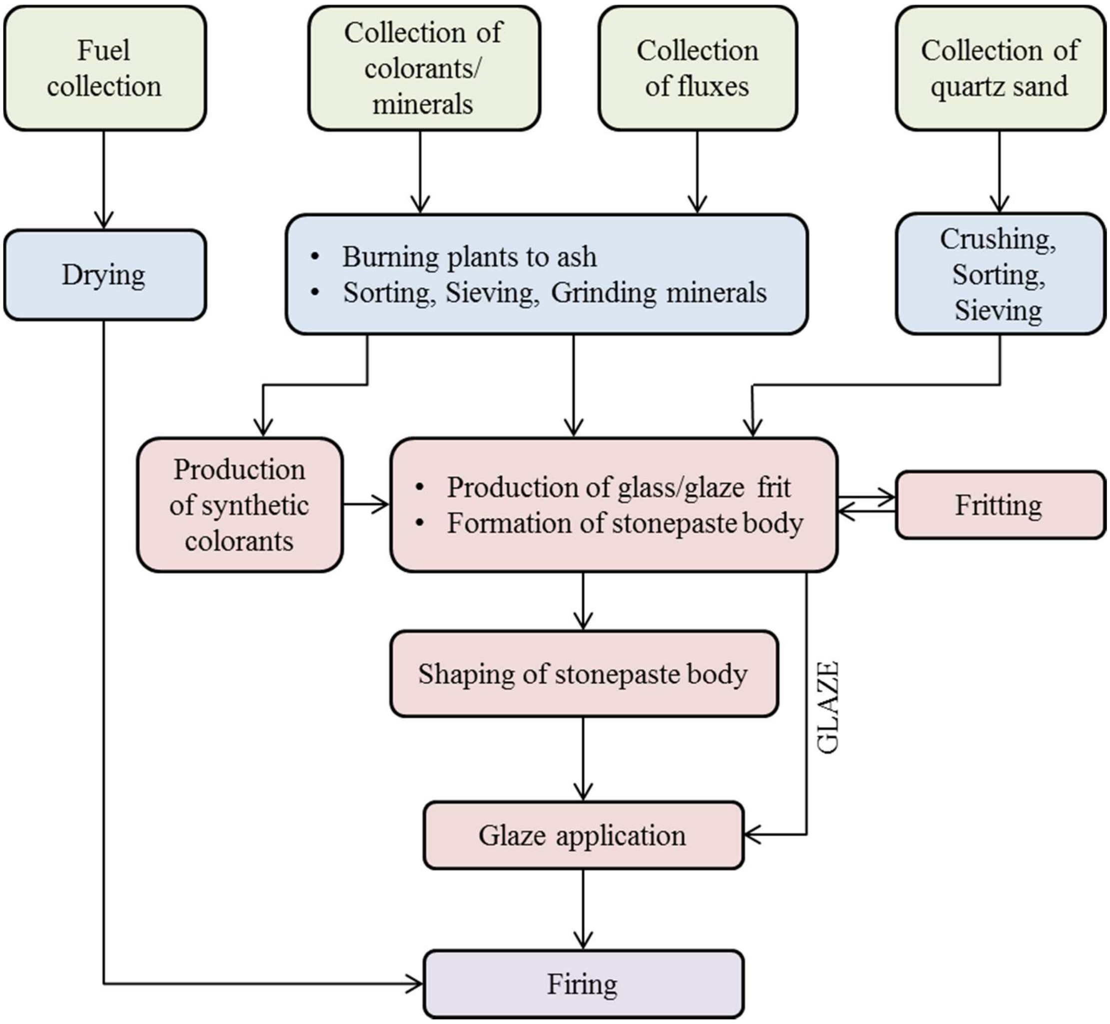

Figure 8.1 Process outline for Punjab Type of glazed tile production.

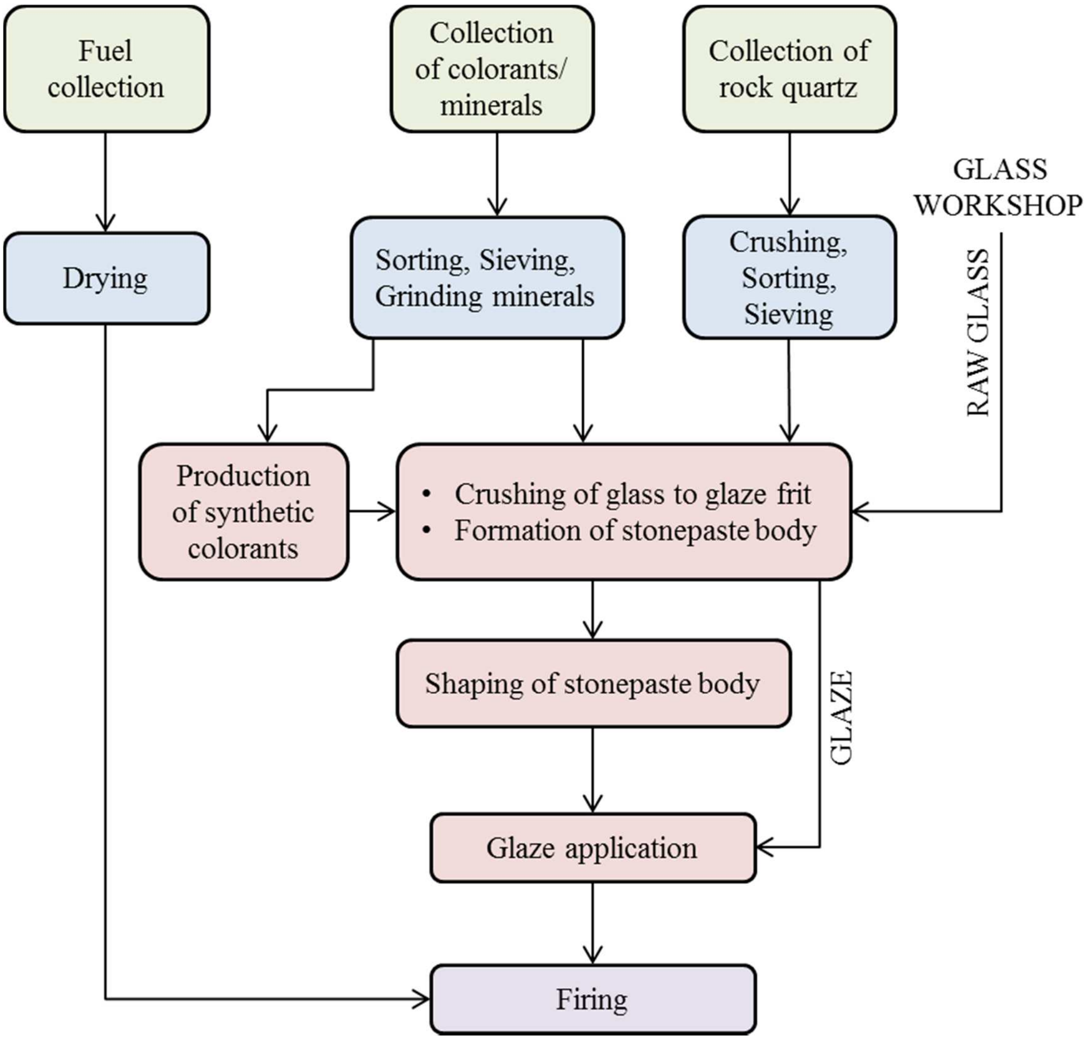

Figure 8.2 Process outline for Delhi Type of glazed tile production.

9. CONCLUSION

This study, utilizing a combination of laboratory and field research methods, has brought forth significant new information on the origin, character, and technology of Lodhi and Mughal glazed tile-work in northern India. The analytical techniques that were chosen to be employed - principally SEM-EDS and EPMA-WDS - have provided meaningful new data allowing an enhanced interpretation of the materials and technologies involved in the production of these tiles. The field data collected through surveys, besides aiding the technological interpretations that were the primary focus of the research, have better facilitated the placement of the craft and its development in the wider context of culture, society, and polity of that time. A summary of the main findings of the study, and avenues for future research are given as below.

In the broadest sense, the findings confirm that the glazed tiles employed on Lodhi and Mughal buildings in northern India over the sixteenth and seventeenth century are indeed part of the bigger family of Islamic tiles and ceramics, being manufactured largely on the lines described in Abu'l Qasim's historical recipe. While the tiles are united in their basic character, having silica-rich stonepaste bodies and alkali glazes, analyses have revealed that two distinct technologies were employed for the production of two main types or varieties of tile-work during Lodhi and Mughal times. The existence of two main production centres has accordingly been proposed, one located in Delhi, where the maximum number of buildings with tiles of one variety are found, and the other in the region of Punjab (centred on Lahore), where tiles of the second type are almost exclusively employed on all the tiled buildings.

The tiles of the Delhi variety, or Delhi technological style, have been determined to consist of stonepaste bodies made of quartz sourced from quarried rock or pebbles, and silica-soda glazes that were produced using mineral soda *reh*. The glazes of these tiles are of a local character, their typical high-alumina plus low-magnesia contents relating them to an indigenous traditional glass industry that is known to produce glass with similar compositional characteristics. Ethno-archaeological studies carried out as part of this research have better illuminated the technologies involved in such traditional glass manufacture. The glass, and consequently the glaze frit obtained by the crushing of the glass, is determined to have been manufactured using just crude *reh* as a single ingredient. This is a significant finding that presents an alternative to the conventional way of understanding glass and glaze technology, but needs further work for better substantiation.

The tiles of the Punjab variety, or Punjab technological style, have been shown to comprise stonepaste bodies made of quartz drawn from riverine sand, and silica-soda glazes that were produced using plant ash derived from a local desert plant. The plant variety here has been identified to be *Haloxylon recurvum* (*Haloxylon stocksii),* a common desert plant found in the provinces of Rajasthan in India, and Punjab in Pakistan. Although the glazes of these tiles are notably similar in composition to those from Islamic lands further west, and made essentially from the same raw materials, ethnographic information suggests that technologies of a different kind are likely to have been employed at the two places. The frit for the Punjab tile glazes is proposed to have been prepared by the powdering of glass balls fused in a furnace, in line with local traditional methods, rather than by the typical method of melting glass in a furnace and its subsequent pouring in water, as reported for other places in the Islamic world.

The composition and technologies of tiles representing an early phase of Lodhi tiling at Delhi, predating the Delhi technological style, remain somewhat obscure, and require further work for better clarity. From the limited samples available it would appear that the bodies were constructed as for the Delhi variety, while the glazes were manufactured as for the Punjab type.

New findings have come to light through investigations on the glaze colorants. The existence of a little-known orange form of the pigment lead stannate has been determined. This artificial zinc-rich variant of the pigment is shown to have been intentionally manufactured and exclusively employed for the colouring of orange glazes associated with a particular tile-work form that was widely employed in seventeenth century Punjab. Its presence in small proportions along with regular lead stannate in some earlier green and yellow glazes at Delhi in the sixteenth century as well indicates a possible earlier history of deliberate manufacture and use. Three different varieties of a cobalt colorant have likewise been shown to exist, each used to colour a different compositional group of dark-blue glazes, from a different region or period. One variety, with high associated arsenic content, has features of being of Indian origin, enhancing the indigenous attributes of the Delhi variety of tiles in which it finds employment. The other glaze colours and their respective colorants include turquoise from copper, purple from manganese, yellow from lead stannate, and green from lead stannate with copper-blue. No colorant is determined in the white glazes.

Significant additions have been made to the body of knowledge on the history and origin of Lodhi and Mughal tiles. The Mughal tile-work at Delhi is determined to have originated locally. The evolution and full development of the craft, in both technology and style, is shown to have occurred during the period of the Lodhis and Surs, prior to its large-scale employment by the Mughals. This contrasts with the common assumption of these tiles being an import, and of the Mughals being mainly credited for the propagation of the craft in the region. A gradual advancement in complexity of application, and in range of glaze colours employed, is determined to have commenced with the earliest phase of Lodhi tiling. A formal tile industry is subsequently shown to have been established at Delhi during the terminal years of Lodhi rule, the tiles employed on the Tomb of Sikandar Lodhi being the first to manifest characteristics of the distinctive Delhi technological style. This style then prevailed in employment at Delhi and Agra up to the end of Jahangir's rule, all the Mughal tiled buildings in this region up to the end of the first quarter of the seventeenth century showcasing its use.

The highly sophisticated seventeenth century Mughal tile-work found in Punjab on the other hand has been established to be of foreign origin. This is apparent from the absence of an evolutionary phase preceding its employment in the region and from the close similarities evidenced in the technologies of these tiles with those from western/central Asia. The gap of about a century between Lodhi and Mughal tiling in the region rules out any relationship between the two. The first phase of Mughal tiling in the region, undertaken in the period corresponding to Jahangir's rule, has been ascribed to individual commissions by itinerant tile-makers. An industry is then shown to have been established commensurate with the arrival of the tile-mosaic of seven colours in the early years of Shah Jahan's rule. The tile-mosaic once established proliferated all over, being the only form of tile-work found employed over the second and third quarter of the seventeenth century. This tile-work is suggested to have been executed by artisans from Central Asia-Khurasan, who migrated to the Mughal courts in search of new opportunities, or were invited to relocate by the Mughal emperors of that time. The end of the tile-mosaic, in the third quarter of the seventeenth century, marks the end of the tiling traditions in northern India as well.

Future research

While the study has succeeded in achieving the initially outlined aims and objectives, much more requires to be done for a fuller and more comprehensive understanding of Lodhi and Mughal tile-work and tiling traditions. Lodhi tile-work in particular warrants more research. A larger corpus of samples from a wider range of their buildings is needed for some of the interpretations to be better substantiated and missing links put in place. Analysis of samples from the dated Tomb of Subhan if made available for instance, would confirm whether all Lodhi tile-work at Sirhind was indeed of a variety different from that found at Delhi. Should they match those of Bibi Taj-ka Maqbara and Hathi-ka Maqbara in their body and glaze characteristics, then the existence of a workshop at Sirhind can be more assertively stated. A mismatch on the other hand, or determined similarities with the Delhi tile-work, would open up a new set of questions and new lines of inquiry. At Delhi likewise, investigating a wider set of samples spanning the chronology of Lodhi tile-work can shed more light on the nature of the tiling that was taking place prior to the establishment of the Delhi industry, and also assist corroborate whether the Tomb of Sikandar Lodhi is indeed the first of the Lodhi buildings to have tile-work of the Delhi technological style. The tile-work on Gwalior

Fort is meritorious of attention in this regard as well, to determine its possible role in the transmission of the same style.

In the case of Mughal tile-work, the research needs to be expanded beyond the frontiers of northern India to gain a more holistic appreciation of the tiling traditions associated with their times. Investigating the tile-work on their Lahore buildings in Pakistan for example would better inform the origin and spread of the Punjab industry, while also confirming commonalities in technology with their Indian counterparts. Studies on the Multan tile industry, known to have been in existence from pre-Mughal times, are likely to bring forth significant new information on technologies of a different kind from those reported in this study. The technologies associated with Mughal *haft rang* tiles at Lahore, and Kashmir and Agra as well, none of which could be sourced for this study, can also be illuminated through further work, and utilized for comparative studies with *haft rang* tiles employed in other regions in the Islamic world.

From the art historical perspective, a detailed physical survey encompassing tiled buildings away from the Badshahi Sadak would aid in more accurately ascribing various tile-work forms to sub-periods, while recording the geographic spread of their employment through the duration of Lodhi and Mughal rule. This would enhance an understanding of the evolution of stylistic typological forms and contribute towards their characterisation.

On the analytical front, scope exists for further studies using proven methods and techniques. Mass spectrometry can be employed for the glazes and bodies to detect trace element concentrations, which can be utilized to provenance some of the raw materials, and potentially relate tiles from different buildings to a common production centre. Spectrophotometry can be utilized to accurately measure and characterise the glaze colours, removing the ambiguity associated with visual methods, particularly on describing varying tones of the same colour. The use of instruments such as the p-XRF, with advantageous features of portability and non-destructive analysis, would give access to a much larger sample pool than otherwise obtainable, although in such cases the efficacy of the instrument in returning data of value may need some model testing to be carried out beforehand. In the study related to deterioration, the aspect of glaze-fit and delamination resistivity that was studied to an extent needs more scientific inputs to arrive at better informed conclusions. Further studies and trials, including the experimental reconstruction of tiles and their testing in simulated environmental conditions are warranted for the same.

Clearly the elucidation of the technologies and traditions associated with Lodhi and Mughal tiling requires more than just this research, which like any other study has its share of shortcomings. The limitations in this case are however quite apparently not just on account of constraints in sampling or access, but equally so for the sheer vastness or scale of the subject, and the little so far that has come out about it. This pilot project that has attempted to integrate the disciplines of science and art history is a significant first step in this respect, providing a base on which further studies may be built. It is hoped that the information collated through this research has contributed to a better understanding of Lodhi and Mughal tile-work, and will pave the way for future works on the subject.

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Appendix 4.1 Chemical compositions of glass standards as published and analysed by SEM-EDS. All results are in wt%, and normalised to 100 %.

No.	Standard	Date	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	MnO	Fe_2O_3	CoO	CuO	Sb_2O_5	ZnO	P_2O_5	SO_3	BaO	PbO
1	Corning A	22-01-2015	14.3	2.6	0.9	67.5	3.0	5.3	1.1	1.1	1.0	0.2	1.3	1.8	0.0	0.0	0.0	0.0	0.0
	Corning A	27-11-2014	14.2	2.6	0.9	67.6	2.9	5.3	1.0	1.1	1.0	0.1	1.3	1.9	0.0	0.0	0.0	0.0	0.0
	Corning A	18-02-2014	14.3	2.6	0.8	67.7	3.0	5.3	1.0	1.1	1.1	0.2	1.3	1.7	0.0	0.0	0.0	0.0	0.0
	Corning A	19-12-2013	13.7	2.6	0.8	68.3	3.1	5.0	1.0	1.1	1.0	0.2	1.3	1.7	0.0	0.0	0.0	0.0	0.0
	Corning A	26-10-2013	14.0	2.6	0.9	68.3	3.2	4.9	1.0	1.1	1.0	0.2	1.3	1.6	0.0	0.0	0.0	0.0	0.0
	Corning A	17-06-2013	14.1	2.7	0.9	68.2	3.1	5.0	1.0	1.1	1.0	0.1	1.2	1.6	0.0	0.0	0.0	0.0	0.0
	Corning A	01-02-2012	14.0	2.6	0.9	68.8	3.0	4.8	0.9	1.0	1.0	0.2	1.3	1.5	0.0	0.0	0.0	0.0	0.0
	Corning A	**Average**	**14.1**	**2.6**	**0.9**	**68.1**	**3.0**	**5.1**	**1.0**	**1.1**	**1.0**	**0.2**	**1.3**	**1.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
2	Corning B	22-01-2015	17.0	1.1	4.1	62.6	1.1	8.8	0.0	0.3	0.4	0.0	2.8	0.0	0.2	0.9	0.7	0.0	0.0
	Corning B	27-11-2014	17.0	1.1	4.1	62.7	1.1	8.8	0.0	0.2	0.3	0.0	2.7	0.0	0.2	1.0	0.7	0.0	0.0
	Corning B	18-02-2014	17.0	1.1	4.1	62.5	1.1	8.8	0.0	0.2	0.3	0.0	2.8	0.0	0.3	1.0	0.7	0.0	0.0
	Corning B	19-12-2013	16.7	1.1	4.1	62.8	1.1	8.9	0.0	0.3	0.3	0.0	2.8	0.0	0.3	1.0	0.7	0.0	0.0
	Corning B	26-10-2013	17.0	1.0	4.0	62.9	1.1	8.8	0.0	0.2	0.3	0.0	2.9	0.0	0.2	0.8	0.8	0.0	0.0
	Corning B	17-06-2013	16.4	1.1	4.2	62.7	1.1	9.2	0.0	0.3	0.3	0.0	3.0	0.0	0.2	0.9	0.6	0.0	0.0
	Corning B	01-02-2012	17.8	1.0	3.8	62.7	1.0	9.1	0.0	0.1	0.3	0.0	2.5	0.0	0.1	0.6	0.8	0.0	0.0
	Corning B	**Average**	**17.0**	**1.1**	**4.1**	**62.7**	**1.1**	**8.9**	**0.0**	**0.2**	**0.3**	**0.0**	**2.8**	**0.0**	**0.2**	**0.9**	**0.7**	**0.0**	**0.0**
3	Corning C	22-01-2015	1.0	2.6	0.8	33.7	2.8	5.2	0.8	0.0	0.3	0.2	1.2	0.0	0.0	0.0	0.0	12.3	39.1
	Corning C	27-11-2014	1.0	2.6	0.8	33.5	2.9	5.1	0.9	0.0	0.2	0.2	1.1	0.0	0.0	0.0	0.0	12.3	39.4
	Corning C	18-02-2014	1.0	2.6	0.8	33.5	2.9	5.1	0.8	0.0	0.3	0.2	1.2	0.0	0.0	0.0	0.0	12.3	39.2
	Corning C	19-12-2013	1.0	2.6	0.8	34.0	2.8	5.2	0.9	0.0	0.3	0.2	1.2	0.0	0.0	0.0	0.0	12.4	38.6
	Corning C	26-10-2013	1.1	2.6	0.8	33.5	2.9	5.1	0.9	0.0	0.4	0.2	1.2	0.0	0.0	0.0	0.0	12.3	39.2
	Corning C	17-06-2013	1.0	2.5	0.8	33.4	2.8	5.1	0.7	0.0	0.3	0.2	1.2	0.0	0.0	0.0	0.0	12.7	39.3
	Corning C	01-02-2012	1.0	2.5	0.8	33.5	2.9	5.1	0.7	0.0	0.3	0.0	1.1	0.0	0.0	0.0	0.0	12.6	39.4
	Corning C	**Average**	**1.0**	**2.6**	**0.8**	**33.6**	**2.9**	**5.1**	**0.8**	**0.0**	**0.3**	**0.2**	**1.2**	**0.0**	**0.0**	**0.0**	**0.0**	**12.4**	**39.2**

Appendix 4.2 Chemical compositions of glass standards as published and analysed by EPMA-WDS at a magnification of 800x. All results are in wt%.

No.	Standard	Date	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SiO_2	SO_3	As_2O_5	Total
1	Corning A	02-03-2014	14.23	5.00	2.91	2.65	1.03	1.07	0.76	1.59	1.04	1.18	0.12	0.18	0.07	0.08	0.05	0.44	0.04	66.55	0.11	0.00	99.08
	Corning A	18-02-2014	14.42	5.04	2.77	2.78	0.97	1.15	0.78	1.76	1.00	1.24	0.12	0.18	0.04	0.02	0.11	0.53	0.14	66.25	0.03	0.00	99.30
	Corning A	20-11-2013	14.26	4.63	2.93	2.83	0.85	1.13	0.73	1.64	1.01	1.04	0.11	0.18	0.04	0.00	0.09	0.42	0.11	65.42	0.12	0.00	97.54
	Corning A	19-02-2013	14.32	4.46	3.08	2.81	0.98	0.89	0.75	1.68	0.88	1.17	0.11	0.17	0.07	0.00	0.04	0.41	0.09	67.60	0.10	0.00	99.60
	Corning A	22-10-2012	14.19	5.15	2.80	2.64	0.91	0.90	0.77	1.53	0.87	1.17	0.11	0.18	0.15	0.05	0.10	0.44	0.00	65.99	0.10	0.00	98.06
	Corning A	18-10-2012	14.27	5.07	2.90	2.71	0.94	0.90	0.75	1.27	0.86	1.20	0.11	0.16	0.02	0.05	0.00	0.37	0.07	65.56	0.10	0.00	97.31
	Corning A	15-05-2012	14.49	4.93	2.77	2.67	0.85	0.99	0.78	1.46	0.95	1.26	0.15	0.16	0.10	0.04	0.04	0.44	0.07	66.04	0.14	0.00	98.33
	Corning A	02-02-2012	14.08	4.95	2.97	2.64	0.90	1.05	0.76	1.69	0.99	1.16	0.14	0.15	0.03	0.00	0.01	0.44	0.09	65.76	0.11	0.00	97.92
	Corning A	**Average**	**14.28**	**4.90**	**2.89**	**2.72**	**0.93**	**1.01**	**0.76**	**1.58**	**0.95**	**1.18**	**0.12**	**0.17**	**0.07**	**0.03**	**0.06**	**0.44**	**0.08**	**66.15**	**0.10**	**0.00**	**98.39**
2	Corning B	02-03-2014	16.81	8.57	1.05	0.98	4.69	0.34	0.09	0.50	0.26	2.59	0.03	0.05	0.45	0.08	0.12	0.09	0.93	61.46	0.42	0.00	99.50
	Corning B	18-02-2014	17.11	8.61	1.02	1.19	4.66	0.32	0.10	0.48	0.22	2.73	0.04	0.00	0.36	0.09	0.17	0.05	0.90	61.70	0.27	0.00	100.01
	Corning B	20-11-2013	16.72	8.45	1.07	1.05	4.56	0.34	0.10	0.40	0.24	2.43	0.03	0.06	0.44	0.07	0.14	0.09	0.78	61.23	0.43	0.00	98.61
	Corning B	19-02-2013	17.09	8.63	1.08	1.12	4.65	0.34	0.08	0.45	0.23	2.71	0.03	0.01	0.48	0.13	0.20	0.06	0.92	62.75	0.34	0.00	101.27
	Corning B	22-10-2012	17.05	8.84	1.03	1.08	4.59	0.28	0.08	0.41	0.20	2.55	0.04	0.00	0.45	0.14	0.23	0.08	0.67	61.49	0.41	0.00	99.62
	Corning B	18-10-2012	17.30	8.77	1.05	1.05	4.51	0.23	0.09	0.52	0.21	2.49	0.06	0.00	0.49	0.10	0.20	0.08	0.75	61.00	0.42	0.00	99.33
	Corning B	15-05-2012	17.21	8.59	1.03	1.03	4.18	0.32	0.11	0.36	0.23	2.77	0.00	0.00	0.44	0.09	0.25	0.04	0.76	61.83	0.69	0.00	99.93
	Corning B	02-02-2012	17.10	8.47	1.01	0.98	4.15	0.27	0.11	0.32	0.20	2.86	0.04	0.03	0.36	0.09	0.15	0.09	0.92	61.26	0.59	0.00	99.00
	Corning B	**Average**	**17.05**	**8.62**	**1.04**	**1.06**	**4.50**	**0.31**	**0.10**	**0.43**	**0.22**	**2.64**	**0.03**	**0.02**	**0.43**	**0.10**	**0.18**	**0.07**	**0.83**	**61.59**	**0.44**	**0.00**	**99.66**
3	Corning C	02-03-2014	1.25	5.12	2.94	2.80	1.00	0.32	0.95	0.00	0.01	1.20	0.14	0.12	36.63	0.08	0.02	11.81	0.04	34.47	0.00	0.00	98.90
	Corning C	18-02-2014	1.25	4.98	3.00	2.78	0.97	0.25	0.99	0.00	0.02	1.12	0.14	0.10	35.19	0.00	0.00	11.67	0.12	34.49	0.00	0.00	97.03
	Corning C	20-11-2013	1.19	5.10	2.74	2.76	0.92	0.26	0.96	0.00	0.00	1.18	0.11	0.11	36.98	0.12	0.13	11.83	0.01	34.18	0.00	0.00	98.59
	Corning C	19-02-2013	1.24	5.07	2.87	2.89	0.96	0.32	0.76	0.00	0.00	1.11	0.12	0.18	37.59	0.06	0.00	11.46	0.12	35.49	0.00	0.00	100.24
	Corning C	22-10-2012	1.23	5.11	3.03	2.99	0.99	0.25	0.98	0.00	0.02	1.03	0.11	0.20	37.48	0.03	0.11	11.58	0.12	36.55	0.00	0.00	101.82
	Corning C	18-10-2012	1.27	5.11	2.92	2.94	0.72	0.28	1.11	0.00	0.00	1.24	0.13	0.14	36.61	0.05	0.07	11.58	0.08	35.53	0.00	0.00	99.77
	Corning C	15-05-2012	1.30	5.28	2.79	2.97	0.71	0.25	1.02	0.00	0.00	1.10	0.12	0.09	35.06	0.05	0.00	11.02	0.23	35.58	0.00	0.00	97.55
	Corning C	02-02-2012	1.25	5.03	2.99	2.82	0.87	0.35	1.27	0.00	0.00	1.19	0.15	0.11	37.38	0.00	0.00	11.85	0.15	35.62	0.00	0.00	101.03
	Corning C	**Average**	**1.25**	**5.10**	**2.91**	**2.87**	**0.89**	**0.28**	**1.00**	**0.00**	**0.01**	**1.15**	**0.13**	**0.13**	**36.62**	**0.05**	**0.04**	**11.60**	**0.11**	**35.24**	**0.00**	**0.00**	**99.37**
4	Sheffield #3	02-03-2014	0.19	0.00	11.16	0.00	0.02	0.03	0.04	0.00	0.00	0.02	0.00	0.00	31.72	0.07	0.13	0.00	0.00	56.15	0.00	0.83	100.34
	Sheffield #3	18-02-2014	0.17	0.03	11.18	0.00	0.00	0.01	0.00	0.00	0.05	0.05	0.00	0.00	32.40	0.00	0.03	0.08	0.00	56.07	0.00	0.85	100.90
	Sheffield #3	20-11-2013	0.18	0.00	11.13	0.00	0.00	0.08	0.00	0.00	0.00	0.02	0.01	0.00	32.03	0.00	0.00	0.02	0.00	56.07	0.00	0.82	100.37
	Sheffield #3	19-02-2013	0.17	0.01	10.96	0.00	0.01	0.00	0.02	0.00	0.00	0.01	0.00	0.00	30.23	0.06	0.00	0.03	0.00	56.00	0.00	0.79	98.28
	Sheffield #3	22-10-2012	0.15	0.02	11.12	0.00	0.03	0.05	0.00	0.00	0.00	0.07	0.00	0.00	32.12	0.00	0.01	0.00	0.00	56.06	0.00	0.81	100.43
	Sheffield #3	18-10-2012	0.19	0.00	11.12	0.00	0.01	0.06	0.00	0.00	0.04	0.00	0.00	0.00	32.52	0.00	0.00	0.01	0.00	55.78	0.00	0.88	100.61
	Sheffield #3	15-05-2012	0.21	0.00	11.44	0.00	0.00	0.05	0.00	0.00	0.00	0.02	0.02	0.00	31.77	0.00	0.00	0.03	0.06	57.31	0.00	0.72	101.62
	Sheffield #3	02-02-2012	0.19	0.00	11.27	0.00	0.06	0.00	0.04	0.00	0.00	0.02	0.00	0.00	31.22	0.00	0.06	0.00	0.06	55.73	0.00	0.70	99.35
	Sheffield #3	**Average**	**0.18**	**0.01**	**11.17**	**0.00**	**0.02**	**0.03**	**0.01**	**0.00**	**0.01**	**0.03**	**0.00**	**0.00**	**31.75**	**0.02**	**0.03**	**0.02**	**0.01**	**56.15**	**0.00**	**0.80**	**100.24**

Appendix 4.3 Chemical compositions of glass standards as published and analysed by EPMA-WDS at a magnification of 2000x. All results are in wt%.

No.	Standard	Date	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SiO_2	SO_3	As_2O_5	Total
1	Corning A	07-03-2014	13.86	4.80	2.94	2.53	0.89	1.12	0.77	1.89	0.83	1.19	0.14	0.21	0.00	0.13	0.13	0.47	0.29	67.44	0.19	0.00	99.81
	Corning A	24-02-2014	14.05	5.22	2.82	2.67	0.89	1.07	0.75	1.67	1.04	1.08	0.11	0.13	0.25	0.00	0.00	0.52	0.00	68.28	0.10	0.00	100.66
	Corning A	13-12-2013	14.36	5.20	2.82	2.55	0.92	0.97	0.74	1.50	0.99	1.01	0.12	0.25	0.00	0.00	0.06	0.46	0.13	67.29	0.19	0.00	99.55
	Corning A	28-02-2013	14.53	5.19	2.95	2.81	0.90	1.02	0.80	1.86	0.90	1.22	0.16	0.13	0.21	0.05	0.00	0.44	0.06	68.38	0.04	0.00	101.65
	Corning A	22-02-2012	14.85	4.81	2.87	2.67	0.96	1.03	0.79	1.64	0.94	1.31	0.10	0.22	0.12	0.04	0.06	0.42	0.25	66.47	0.17	0.00	99.71
	Corning A	**Average**	**14.33**	**5.04**	**2.88**	**2.64**	**0.91**	**1.04**	**0.77**	**1.71**	**0.94**	**1.16**	**0.13**	**0.19**	**0.12**	**0.04**	**0.05**	**0.46**	**0.15**	**67.57**	**0.14**	**0.00**	**100.27**
2	Corning B	07-03-2014	16.79	8.33	0.89	1.12	4.41	0.31	0.10	0.50	0.19	2.55	0.11	0.04	0.45	0.16	0.21	0.16	0.84	62.71	0.40	0.00	100.25
	Corning B	24-02-2014	16.64	8.77	1.09	1.02	4.19	0.22	0.11	0.56	0.25	2.49	0.00	0.00	0.52	0.12	0.02	0.11	1.27	62.06	0.52	0.00	99.94
	Corning B	13-12-2013	17.29	8.96	0.92	1.12	4.25	0.24	0.15	0.53	0.20	2.42	0.04	0.00	0.32	0.07	0.22	0.12	0.76	64.39	0.49	0.00	102.50
	Corning B	28-02-2013	17.24	9.15	1.15	1.06	4.38	0.28	0.10	0.44	0.19	2.58	0.03	0.00	0.50	0.14	0.06	0.02	0.76	63.30	0.48	0.00	101.85
	Corning B	22-02-2012	17.67	8.68	1.07	1.00	4.27	0.32	0.10	0.44	0.24	2.74	0.06	0.03	0.58	0.09	0.21	0.08	0.80	61.78	0.46	0.00	100.62
	Corning B	**Average**	**17.12**	**8.78**	**1.02**	**1.06**	**4.30**	**0.27**	**0.11**	**0.50**	**0.21**	**2.56**	**0.05**	**0.01**	**0.48**	**0.12**	**0.14**	**0.10**	**0.88**	**62.85**	**0.47**	**0.00**	**101.03**
3	Corning C	07-03-2014	1.32	5.02	2.98	2.92	0.86	0.39	1.09	0.00	0.08	1.29	0.18	0.14	36.59	0.12	0.03	10.88	0.16	36.45	0.00	0.00	100.47
	Corning C	24-02-2014	0.98	4.62	2.94	2.83	0.85	0.42	1.12	0.00	0.03	1.34	0.20	0.11	34.35	0.05	0.20	10.95	0.05	37.17	0.00	0.00	98.22
	Corning C	13-12-2013	1.00	4.96	2.95	2.93	0.89	0.42	1.12	0.00	0.08	1.09	0.15	0.11	36.66	0.15	0.00	11.49	0.23	35.91	0.00	0.00	100.12
	Corning C	28-02-2013	1.34	5.45	2.87	2.88	0.91	0.34	0.99	0.00	0.00	1.20	0.20	0.07	36.12	0.00	0.01	11.26	0.00	37.41	0.00	0.00	101.05
	Corning C	22-02-2012	1.27	5.26	3.04	2.85	0.86	0.26	1.13	0.00	0.00	1.09	0.10	0.13	38.38	0.08	0.00	12.24	0.08	35.73	0.10	0.00	102.59
	Corning C	**Average**	**1.18**	**5.06**	**2.95**	**2.88**	**0.87**	**0.36**	**1.09**	**0.00**	**0.04**	**1.20**	**0.17**	**0.11**	**36.42**	**0.08**	**0.05**	**11.36**	**0.10**	**36.54**	**0.02**	**0.00**	**100.49**
4	Sheffield #3	07-03-2014	0.19	0.00	10.78	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	31.82	0.01	0.00	0.00	0.06	54.56	0.00	0.79	98.23
	Sheffield #3	24-02-2014	0.18	0.01	11.04	0.05	0.06	0.09	0.04	0.00	0.01	0.00	0.00	0.00	32.11	0.00	0.03	0.08	0.01	54.62	0.00	1.03	99.35
	Sheffield #3	13-12-2013	0.13	0.02	10.92	0.00	0.03	0.00	0.02	0.00	0.04	0.00	0.00	0.00	31.65	0.05	0.02	0.08	0.00	54.77	0.00	0.95	98.69
	Sheffield #3	28-02-2013	0.21	0.00	11.12	0.00	0.10	0.00	0.00	0.00	0.00	0.06	0.00	0.00	31.10	0.00	0.06	0.05	0.29	55.16	0.00	0.66	98.80
	Sheffield #3	22-02-2012	0.12	0.00	10.70	0.00	0.06	0.06	0.04	0.00	0.00	0.00	0.03	0.00	31.10	0.00	0.06	0.01	0.13	55.66	0.00	0.62	98.59
	Sheffield #3	**Average**	**0.17**	**0.01**	**10.91**	**0.01**	**0.05**	**0.03**	**0.02**	**0.00**	**0.01**	**0.02**	**0.01**	**0.00**	**31.56**	**0.01**	**0.03**	**0.04**	**0.10**	**54.95**	**0.00**	**0.81**	**98.73**

Appendix 6.1 List of tile-embellished buildings of the Lodhi era at Delhi, Punjab, and other locations alongside the Badshahi Sadak. Buildings taken up for a detailed study are highlighted in bold. The buildings are listed by region, and within the region in their most probable chronological order.

No.	Building	Region	Date/Period	Typology
1	**Bagh-e Alam-ka Gumbad**	**Delhi**	**1501 CE**	**Tomb**
2	**Sheesh Gumbad**	**Delhi**	**c. 1500 CE**	**Tomb**
3	Nili Masjid	Delhi	1505-1506 CE	Mosque
4	Tomb at Rajon-ki Baoli	Delhi	1506 CE	Tomb
5	Bara Lao-ka Gumbad	Delhi	16th century	Tomb
6	Chhote Khan-ka Gumbad	Delhi	16th century	Tomb
7	Moth-ki Masjid	Delhi	16th century	Tomb
8	Muhammad-wali Masjid	Delhi	16th century	Mosque
9	Bhure Khan-ka Gumbad	Delhi	16th century	Tomb
10	Tomb at Lado Sarai	Delhi	16th century	Tomb
11	Tomb at Rajon-ki Baoli	Delhi	16th century	Tomb
12	**Madhi Masjid**	**Delhi**	**16th century**	**Mosque**
13	**Tomb of Sikandar Lodhi**	**Delhi**	**c. 1518 CE**	**Tomb**
14	**Jahaz Mahal**	**Delhi**	**16th century**	**Tomb**
15	Tomb of Khwaja Khizr	Haryana	1524 CE	Tomb
16	Tomb of Subhan	Punjab	1496-1497 CE	Tomb
17	**Bibi Taj-ka Maqbara**	**Punjab**	**15th/16th century**	**Tomb**
18	**Hathi-ka Maqbara**	**Punjab**	**15th/16th century**	**Tomb**
19	Machhiwara Masjid	Punjab	1517 CE	Mosque

Appendix 6.2 Chemical compositions of the (stonepaste) tile bodies from Lodhi buildings at Delhi determined through SEM-EDS analyses. All results are in wt%, and normalised to 100 %.

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
1	SG/01	Dark-Blue	Sheesh Gumbad	09-05-2012	I	98.5	0.6	0.4	0.2	0.2	0.0	0.2	100.0
	SG/01	Dark-Blue	Sheesh Gumbad	09-05-2012	II	97.6	0.6	0.9	0.2	0.3	0.2	0.3	100.0
	SG/01	Dark-Blue	Sheesh Gumbad	27-11-2014	III	98.1	0.5	0.6	0.2	0.3	0.2	0.2	100.0
	SG/01	**Dark-Blue**	**Sheesh Gumbad**	**09-05-2012**	**Average**	**98.0**	**0.6**	**0.6**	**0.2**	**0.2**	**0.1**	**0.2**	100.0
	SG/01	**Dark-Blue**	**Sheesh Gumbad**	**09-05-2012**	**Std. Dev.**	**0.4**	**0.1**	**0.3**	**0.0**	**0.1**	**0.1**	**0.1**	
2	SG/02	Dark-Blue	Sheesh Gumbad	13-03-2012	I	97.1	1.3	0.5	0.4	0.4	0.0	0.3	100.0
	SG/02	Dark-Blue	Sheesh Gumbad	13-03-2012	II	97.9	1.0	0.3	0.3	0.2	0.0	0.3	100.0
	SG/02	Dark-Blue	Sheesh Gumbad	13-03-2012	III	97.4	1.1	0.3	0.2	0.3	0.4	0.2	100.0
	SG/02	**Dark-Blue**	**Sheesh Gumbad**	**13-03-2012**	**Average**	**97.5**	**1.1**	**0.4**	**0.3**	**0.3**	**0.1**	**0.3**	100.0
	SG/02	**Dark-Blue**	**Sheesh Gumbad**	**13-03-2012**	**Std. Dev.**	**0.4**	**0.2**	**0.1**	**0.1**	**0.1**	**0.3**	**0.1**	
3	SG/03	Turquoise	Sheesh Gumbad	09-05-2012	I	98.7	0.2	0.3	0.2	0.3	0.0	0.4	100.0
	SG/03	Turquoise	Sheesh Gumbad	09-05-2012	II	99.1	0.4	0.3	0.2	0.0	0.0	0.1	100.0
	SG/03	Turquoise	Sheesh Gumbad	09-05-2012	III	99.1	0.2	0.3	0.2	0.0	0.0	0.2	100.0
	SG/03	**Turquoise**	**Sheesh Gumbad**	**09-05-2012**	**Average**	**99.0**	**0.2**	**0.3**	**0.2**	**0.1**	**0.0**	**0.2**	100.0
	SG/03	**Turquoise**	**Sheesh Gumbad**	**09-05-2012**	**Std. Dev.**	**0.2**	**0.1**	**0.0**	**0.0**	**0.1**	**0.0**	**0.2**	
4	SG/04	Turquoise	Sheesh Gumbad	09-05-2012	I	94.5	1.5	0.7	0.7	0.3	1.2	1.0	100.0
	SG/04	Turquoise	Sheesh Gumbad	09-05-2012	II	95.4	1.0	1.0	0.6	0.5	0.9	0.6	100.0
	SG/04	Turquoise	Sheesh Gumbad	09-05-2012	III	96.2	1.3	0.6	0.5	0.3	0.6	0.5	100.0
	SG/04	**Turquoise**	**Sheesh Gumbad**	**09-05-2012**	**Average**	**95.4**	**1.3**	**0.8**	**0.6**	**0.4**	**0.9**	**0.7**	100.0
	SG/04	**Turquoise**	**Sheesh Gumbad**	**09-05-2012**	**Std. Dev.**	**0.8**	**0.2**	**0.2**	**0.1**	**0.1**	**0.3**	**0.3**	
5	SG/05	Dark-Blue	Sheesh Gumbad	15-06-2012	I	98.6	0.5	0.4	0.3	0.0	0.0	0.2	100.0
	SG/05	Dark-Blue	Sheesh Gumbad	15-06-2012	II	98.8	0.5	0.5	0.2	0.0	0.0	0.0	100.0
	SG/05	Dark-Blue	Sheesh Gumbad	15-06-2012	III	97.9	0.6	0.8	0.2	0.0	0.0	0.4	100.0
	SG/05	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Average**	**98.4**	**0.5**	**0.6**	**0.3**	**0.0**	**0.0**	**0.2**	100.0
	SG/05	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Std. Dev.**	**0.5**	**0.1**	**0.2**	**0.1**	**0.0**	**0.0**	**0.2**	
6	SG/06	Dark-Blue	Sheesh Gumbad	15-06-2012	I	98.4	0.4	0.5	0.0	0.2	0.0	0.5	100.0
	SG/06	Dark-Blue	Sheesh Gumbad	15-06-2012	II	97.9	0.6	0.5	0.4	0.3	0.0	0.3	100.0
	SG/06	Dark-Blue	Sheesh Gumbad	15-06-2012	III	98.9	0.3	0.4	0.0	0.3	0.0	0.1	100.0
	SG/06	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Average**	**98.4**	**0.4**	**0.5**	**0.1**	**0.3**	**0.0**	**0.3**	100.0
	SG/06	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Std. Dev.**	**0.5**	**0.2**	**0.1**	**0.2**	**0.1**	**0.0**	**0.2**	
7	SG/07	Dark-Blue	Sheesh Gumbad	15-06-2012	I	98.3	0.7	0.5	0.2	0.3	0.0	0.0	100.0
	SG/07	Dark-Blue	Sheesh Gumbad	15-06-2012	II	96.2	0.7	1.3	0.3	0.6	0.9	0.0	100.0
	SG/07	Dark-Blue	Sheesh Gumbad	15-06-2012	III	98.4	0.3	0.7	0.0	0.4	0.0	0.3	100.0
	SG/07	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Average**	**97.6**	**0.5**	**0.8**	**0.1**	**0.4**	**0.3**	**0.1**	100.0
	SG/07	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Std. Dev.**	**1.3**	**0.2**	**0.4**	**0.1**	**0.2**	**0.5**	**0.1**	
8	SG/08	Dark-Blue	Sheesh Gumbad	15-06-2012	I	98.7	0.2	0.4	0.4	0.2	0.0	0.1	100.0
	SG/08	Dark-Blue	Sheesh Gumbad	15-06-2012	II	99.1	0.2	0.5	0.0	0.2	0.0	0.0	100.0
	SG/08	Dark-Blue	Sheesh Gumbad	15-06-2012	III	99.0	0.1	0.5	0.2	0.2	0.0	0.0	100.0
	SG/08	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Average**	**98.9**	**0.2**	**0.5**	**0.2**	**0.2**	**0.0**	**0.0**	100.0
	SG/08	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Std. Dev.**	**0.2**	**0.1**	**0.0**	**0.2**	**0.0**	**0.0**	**0.1**	
9	SG/09	Dark-Blue	Sheesh Gumbad	15-06-2012	I	98.2	0.7	0.5	0.2	0.3	0.1	0.0	100.0
	SG/09	Dark-Blue	Sheesh Gumbad	15-06-2012	II	96.2	0.7	1.3	0.3	0.6	0.9	0.0	100.0
	SG/09	Dark-Blue	Sheesh Gumbad	15-06-2012	III	98.3	0.3	0.7	0.1	0.4	0.0	0.3	100.0
	SG/09	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Average**	**97.6**	**0.5**	**0.8**	**0.2**	**0.4**	**0.3**	**0.1**	100.0
	SG/09	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Std. Dev.**	**1.2**	**0.2**	**0.4**	**0.1**	**0.2**	**0.5**	**0.1**	
10	SG/10	Dark-Blue	Sheesh Gumbad	15-06-2012	I	98.0	0.3	0.3	0.3	0.2	0.7	0.2	100.0
	SG/10	Dark-Blue	Sheesh Gumbad	15-06-2012	II	98.6	0.3	0.4	0.2	0.2	0.3	0.0	100.0
	SG/10	Dark-Blue	Sheesh Gumbad	15-06-2012	III	98.4	0.2	0.4	0.3	0.5	0.3	0.0	100.0
	SG/10	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Average**	**98.3**	**0.2**	**0.4**	**0.3**	**0.3**	**0.4**	**0.1**	100.0
	SG/10	**Dark-Blue**	**Sheesh Gumbad**	**15-06-2012**	**Std. Dev.**	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.1**	

Appendix 6.3 Chemical compositions of the stonepaste tile bodies from Lodhi buildings at Punjab determined through SEM-EDS analyses. All results are in wt%, and normalised to 100 %.

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
1	BT/01	Turquoise	Bibi Taj-ka Maqbara	23-01-2013	I	94.5	1.7	0.4	0.7	0.2	2.2	0.3	100.0
	BT/01	Turquoise	Bibi Taj-ka Maqbara	23-01-2013	II	96.2	1.1	0.4	0.6	0.3	1.2	0.3	100.0
	BT/01	Turquoise	Bibi Taj-ka Maqbara	23-01-2013	III	95.4	1.4	0.3	0.7	0.2	1.7	0.3	100.0
	BT/01	Turquoise	Bibi Taj-ka Maqbara	23-01-2013	IV	95.1	1.5	0.5	0.7	0.3	1.6	0.4	100.0
	BT/01	Turquoise	Bibi Taj-ka Maqbara	23-01-2013	V	94.8	1.6	0.4	0.6	0.2	2.1	0.3	100.0
	BT/01	**Turquoise**	**Bibi Taj-ka Maqbara**	**23-01-2013**	**Average**	**95.2**	**1.5**	**0.4**	**0.7**	**0.2**	**1.8**	**0.3**	100.0
	BT/01	**Turquoise**	**Bibi Taj-ka Maqbara**	**23-01-2013**	**Std. Dev.**	**0.6**	**0.2**	**0.0**	**0.0**	**0.0**	**0.4**	**0.0**	
2	BT/02	Turquoise	Bibi Taj-ka Maqbara	23-01-2013	I	94.8	1.7	0.6	0.8	0.4	1.4	0.4	100.0
	BT/02	Turquoise	Bibi Taj-ka Maqbara	23-01-2013	II	94.7	1.4	0.6	1.1	0.3	1.6	0.4	100.0
	BT/02	Turquoise	Bibi Taj-ka Maqbara	23-01-2013	III	95.6	1.3	0.5	0.7	0.3	1.3	0.4	100.0
	BT/02	Turquoise	Bibi Taj-ka Maqbara	23-01-2013	IV	95.2	1.1	0.7	0.7	0.3	1.5	0.5	100.0
	BT/02	Turquoise	Bibi Taj-ka Maqbara	23-01-2013	V	95.3	1.4	0.6	0.8	0.2	1.4	0.4	100.0
	BT/02	**Turquoise**	**Bibi Taj-ka Maqbara**	**23-01-2013**	**Average**	**95.1**	**1.4**	**0.6**	**0.8**	**0.3**	**1.4**	**0.4**	100.0
	BT/02	**Turquoise**	**Bibi Taj-ka Maqbara**	**23-01-2013**	**Std. Dev.**	**0.4**	**0.2**	**0.1**	**0.2**	**0.0**	**0.1**	**0.1**	
3	BT/03	Turquoise	Bibi Taj-ka Maqbara	03-02-2014	I	94.5	1.7	0.6	0.7	0.4	1.7	0.4	100.0
	BT/03	Turquoise	Bibi Taj-ka Maqbara	03-02-2014	II	95.9	1.2	0.7	0.6	0.3	0.9	0.4	100.0
	BT/03	Turquoise	Bibi Taj-ka Maqbara	03-02-2014	III	95.1	1.4	0.6	0.7	0.3	1.3	0.5	100.0
	BT/03	Turquoise	Bibi Taj-ka Maqbara	03-02-2014	IV	96.1	1.2	0.5	0.7	0.2	1.0	0.3	100.0
	BT/03	Turquoise	Bibi Taj-ka Maqbara	03-02-2014	V	95.4	1.4	0.6	0.7	0.3	1.2	0.4	100.0
	BT/03	**Turquoise**	**Bibi Taj-ka Maqbara**	**03-02-2014**	**Average**	**95.4**	**1.4**	**0.6**	**0.7**	**0.3**	**1.2**	**0.4**	100.0
	BT/03	**Turquoise**	**Bibi Taj-ka Maqbara**	**03-02-2014**	**Std. Dev.**	**0.6**	**0.2**	**0.1**	**0.0**	**0.1**	**0.3**	**0.1**	
4	BT/04	Turquoise	Bibi Taj-ka Maqbara	30-01-2013	I	93.7	1.4	0.5	1.0	0.3	2.7	0.5	100.0
	BT/04	Turquoise	Bibi Taj-ka Maqbara	30-01-2013	II	93.7	1.1	0.7	1.0	0.5	2.4	0.7	100.0
	BT/04	Turquoise	Bibi Taj-ka Maqbara	30-01-2013	III	94.2	1.2	0.6	1.0	0.4	2.1	0.6	100.0
	BT/04	Turquoise	Bibi Taj-ka Maqbara	30-01-2013	IV	93.5	1.2	0.6	1.0	0.4	2.7	0.7	100.0
	BT/04	Turquoise	Bibi Taj-ka Maqbara	30-01-2013	V	90.9	1.7	0.8	1.3	0.5	3.9	1.0	100.0
	BT/04	**Turquoise**	**Bibi Taj-ka Maqbara**	**30-01-2013**	**Average**	**93.2**	**1.3**	**0.6**	**1.1**	**0.4**	**2.7**	**0.7**	100.0
	BT/04	**Turquoise**	**Bibi Taj-ka Maqbara**	**30-01-2013**	**Std. Dev.**	**1.3**	**0.2**	**0.1**	**0.1**	**0.1**	**0.7**	**0.2**	
5	HM/01	Turquoise	Hathi-ka Maqbara	12-02-2015	I	95.5	1.5	0.5	0.5	0.3	1.4	0.3	100.0
	HM/01	Turquoise	Hathi-ka Maqbara	12-02-2015	II	94.1	1.9	0.7	0.8	0.4	1.9	0.3	100.0
	HM/01	Turquoise	Hathi-ka Maqbara	12-02-2015	III	95.7	1.3	0.6	0.5	0.3	1.4	0.3	100.0
	HM/01	Turquoise	Hathi-ka Maqbara	12-02-2015	IV	95.6	1.4	0.5	0.5	0.2	1.6	0.2	100.0
	HM/01	**Turquoise**	**Hathi-ka Maqbara**	**12-02-2015**	**Average**	**95.2**	**1.5**	**0.6**	**0.6**	**0.3**	**1.6**	**0.3**	**100.0**
	HM/01	**Turquoise**	**Hathi-ka Maqbara**	**12-02-2015**	**Std. Dev.**	**0.8**	**0.3**	**0.1**	**0.1**	**0.1**	**0.3**	**0.0**	
6	HM/02	Turquoise	Hathi-ka Maqbara	12-02-2015	I	95.6	1.3	0.6	0.5	0.3	1.5	0.2	100.0
	HM/02	Turquoise	Hathi-ka Maqbara	12-02-2015	II	93.8	1.9	0.7	0.6	0.4	2.3	0.3	100.0
	HM/02	Turquoise	Hathi-ka Maqbara	12-02-2015	III	96.2	1.2	0.6	0.4	0.2	1.3	0.2	100.0
	HM/02	Turquoise	Hathi-ka Maqbara	12-02-2015	IV	95.4	1.4	0.5	0.6	0.3	1.6	0.3	100.0
	HM/02	**Turquoise**	**Hathi-ka Maqbara**	**12-02-2015**	**Average**	**95.2**	**1.4**	**0.6**	**0.5**	**0.3**	**1.7**	**0.2**	**100.0**
	HM/02	**Turquoise**	**Hathi-ka Maqbara**	**12-02-2015**	**Std. Dev.**	**1.0**	**0.3**	**0.1**	**0.1**	**0.1**	**0.4**	**0.1**	

Appendix 6.4 Chemical composition of interparticle glass in the bodies of tiles from Lodhi buildings at Delhi and Punjab. All results are in wt% from SEM-EDS analyses, and normalised to 100 %.

No.	Sample	Colour	Building	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
1	SG/01	Dark-Blue	Sheesh Gumbad	I	71.8	14.6	5.5	4.3	3.1	0.5	0.4	100.0
	SG/01	Dark-Blue	Sheesh Gumbad	II	73.4	12.8	3.1	4.5	2.7	2.6	1.0	100.0
	SG/01	Dark-Blue	Sheesh Gumbad	III	74.9	13.4	3.3	3.7	3.5	0.6	0.6	100.0
	SG/01	Dark-Blue	Sheesh Gumbad	IV	75.9	10.0	3.9	4.1	3.1	1.8	1.2	100.0
	SG/01	**Dark-Blue**	**Sheesh Gumbad**	**Average**	**74.0**	**12.7**	**3.9**	**4.1**	**3.1**	**1.4**	**0.8**	**100.0**
	SG/01	**Dark-Blue**	**Sheesh Gumbad**	**Std. Dev.**	**1.8**	**2.0**	**1.1**	**0.3**	**0.4**	**1.0**	**0.4**	
2	SG/02	Dark-Blue	Sheesh Gumbad	I	74.2	13.0	2.8	4.3	3.2	1.7	0.9	100.0
	SG/02	Dark-Blue	Sheesh Gumbad	II	74.5	12.7	2.4	4.2	3.0	1.8	1.4	100.0
	SG/02	Dark-Blue	Sheesh Gumbad	III	76.3	11.8	2.5	3.6	2.0	2.4	1.5	100.0
	SG/02	**Dark-Blue**	**Sheesh Gumbad**	**Average**	**75.0**	**12.5**	**2.5**	**4.0**	**2.8**	**2.0**	**1.3**	**100.0**
	SG/02	**Dark-Blue**	**Sheesh Gumbad**	**Std. Dev.**	**1.1**	**0.6**	**0.2**	**0.4**	**0.7**	**0.4**	**0.3**	
3	SG/03	Turquoise	Sheesh Gumbad	I	76.2	5.8	1.0	5.5	0.7	1.7	9.3	100.0
	SG/03	Turquoise	Sheesh Gumbad	II	73.7	7.2	2.2	5.2	0.6	1.4	9.8	100.0
	SG/03	Turquoise	Sheesh Gumbad	III	77.8	7.8	1.6	4.3	0.8	1.4	6.4	100.0
	SG/03	**Turquoise**	**Sheesh Gumbad**	**Average**	**75.9**	**6.9**	**1.6**	**5.0**	**0.7**	**1.5**	**8.5**	**100.0**
	SG/03	**Turquoise**	**Sheesh Gumbad**	**Std. Dev.**	**2.1**	**1.0**	**0.6**	**0.6**	**0.1**	**0.1**	**1.8**	
4	SG/04	Turquoise	Sheesh Gumbad	I	73.5	11.8	4.1	3.9	1.6	2.1	3.0	100.0
	SG/04	Turquoise	Sheesh Gumbad	II	76.4	9.6	3.2	3.4	2.1	2.9	2.4	100.0
	SG/04	Turquoise	Sheesh Gumbad	III	74.9	10.7	3.6	3.5	2.0	2.4	3.0	100.0
	SG/04	**Turquoise**	**Sheesh Gumbad**	**Average**	**74.9**	**10.7**	**3.7**	**3.6**	**1.9**	**2.4**	**2.8**	**100.0**
	SG/04	**Turquoise**	**Sheesh Gumbad**	**Std. Dev.**	**1.4**	**1.1**	**0.5**	**0.3**	**0.3**	**0.4**	**0.3**	
5	SG/08	Dark-Blue	Sheesh Gumbad	I	82.1	4.6	3.6	3.4	4.6	1.1	0.5	100.0
	SG/08	Dark-Blue	Sheesh Gumbad	II	80.9	3.1	1.5	4.5	1.9	6.3	1.8	100.0
	SG/08	**Dark-Blue**	**Sheesh Gumbad**	**Average**	**81.5**	**3.8**	**2.5**	**3.9**	**3.3**	**3.7**	**1.2**	**100.0**
	SG/08	**Dark-Blue**	**Sheesh Gumbad**	**Std. Dev.**	**0.9**	**1.0**	**1.5**	**0.7**	**1.9**	**3.6**	**0.9**	
6	BT/01	Turquoise	Bibi Taj-ka Maqbara	I	72.4	9.5	2.8	5.0	1.5	7.3	1.5	100.0
	BT/01	Turquoise	Bibi Taj-ka Maqbara	II	72.6	9.2	3.3	4.7	1.6	7.1	1.5	100.0
	BT/01	Turquoise	Bibi Taj-ka Maqbara	III	70.2	9.7	2.5	5.4	1.7	9.1	1.3	100.0
	BT/01	Turquoise	Bibi Taj-ka Maqbara	IV	73.7	8.3	2.1	4.9	1.0	8.8	1.0	100.0
	BT/01	Turquoise	Bibi Taj-ka Maqbara	V	74.5	9.5	3.3	4.2	1.8	5.5	1.3	100.0
	BT/01	**Turquoise**	**Bibi Taj-ka Maqbara**	**Average**	**72.7**	**9.2**	**2.8**	**4.9**	**1.5**	**7.6**	**1.3**	**100.0**
	BT/01	**Turquoise**	**Bibi Taj-ka Maqbara**	**Std. Dev.**	**1.6**	**0.5**	**0.5**	**0.4**	**0.3**	**1.5**	**0.2**	
7	BT/02	Turquoise	Bibi Taj-ka Maqbara	I	74.2	10.0	3.0	4.7	2.2	4.1	1.7	100.0
	BT/02	Turquoise	Bibi Taj-ka Maqbara	II	74.2	10.4	3.8	4.4	2.1	3.9	1.2	100.0
	BT/02	Turquoise	Bibi Taj-ka Maqbara	III	73.4	10.1	4.9	4.5	1.4	4.6	0.9	100.0
	BT/02	Turquoise	Bibi Taj-ka Maqbara	IV	71.8	9.4	2.5	5.5	1.7	7.6	1.5	100.0
	BT/02	Turquoise	Bibi Taj-ka Maqbara	V	72.5	9.5	2.7	5.2	1.6	6.8	1.6	100.0
	BT/02	**Turquoise**	**Bibi Taj-ka Maqbara**	**Average**	**73.2**	**9.9**	**3.4**	**4.9**	**1.8**	**5.4**	**1.4**	**100.0**
	BT/02	**Turquoise**	**Bibi Taj-ka Maqbara**	**Std. Dev.**	**1.0**	**0.4**	**1.0**	**0.4**	**0.3**	**1.7**	**0.3**	
8	BT/04	Turquoise	Bibi Taj-ka Maqbara	I	74.2	9.0	3.2	5.0	1.3	6.1	1.3	100.0
	BT/04	Turquoise	Bibi Taj-ka Maqbara	II	74.4	9.5	3.2	4.6	2.0	4.2	2.1	100.0
	BT/04	Turquoise	Bibi Taj-ka Maqbara	III	73.1	8.3	2.1	5.5	1.2	8.8	1.0	100.0
	BT/04	Turquoise	Bibi Taj-ka Maqbara	IV	73.8	8.9	3.2	5.1	1.5	5.8	1.8	100.0
	BT/04	Turquoise	Bibi Taj-ka Maqbara	V	74.1	9.3	3.8	4.6	1.7	4.6	2.0	100.0
	BT/04	**Turquoise**	**Bibi Taj-ka Maqbara**	**Average**	**73.9**	**9.0**	**3.1**	**5.0**	**1.5**	**5.9**	**1.6**	**100.0**
	BT/04	**Turquoise**	**Bibi Taj-ka Maqbara**	**Std. Dev.**	**0.5**	**0.4**	**0.6**	**0.4**	**0.3**	**1.8**	**0.5**	
9	HM/01	Turquoise	Hathi-ka Maqbara	I	70.1	11.1	2.7	4.2	1.4	9.9	0.6	100.0
	HM/01	Turquoise	Hathi-ka Maqbara	II	72.2	11.6	3.3	3.8	2.1	5.8	1.2	100.0
	HM/01	Turquoise	Hathi-ka Maqbara	III	73.6	10.9	3.8	3.7	2.1	5.4	0.5	100.0
	HM/01	Turquoise	Hathi-ka Maqbara	IV	72.2	10.8	2.8	4.1	2.1	7.5	0.6	100.0
	HM/01	**Turquoise**	**Hathi-ka Maqbara**	**Average**	**72.0**	**11.1**	**3.1**	**4.0**	**1.9**	**7.2**	**0.7**	**100.0**
	HM/01	**Turquoise**	**Hathi-ka Maqbara**	**Std. Dev.**	**1.5**	**0.4**	**0.5**	**0.2**	**0.3**	**2.1**	**0.3**	
10	HM/02	Turquoise	Hathi-ka Maqbara	I	75.1	9.7	3.4	3.4	1.9	6.1	0.4	100.0
	HM/02	Turquoise	Hathi-ka Maqbara	II	72.4	10.9	4.0	3.5	2.6	6.0	0.6	100.0
	HM/02	Turquoise	Hathi-ka Maqbara	III	69.9	10.7	2.8	3.8	1.7	10.0	1.0	100.0
	HM/02	**Turquoise**	**Hathi-ka Maqbara**	**Average**	**72.5**	**10.4**	**3.4**	**3.6**	**2.1**	**7.4**	**0.7**	**100.0**
	HM/02	**Turquoise**	**Hathi-ka Maqbara**	**Std. Dev.**	**2.6**	**0.7**	**0.6**	**0.2**	**0.5**	**2.3**	**0.3**	

Appendix 6.5 Chemical compositions of the terracotta tile bodies from Lodhi buildings at Punjab determined through SEM-EDS analyses. All results are in wt%, and normalised to 100 %.

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
1	HM/03	Turquoise	Hathi-ka Maqbara	15-02-2015	I	68.7	1.5	1.4	3.3	1.9	17.1	6.1	100.0
	HM/03	Turquoise	Hathi-ka Maqbara	15-02-2015	II	70.2	1.1	1.1	3.5	1.9	16.2	6.1	100.0
	HM/03	Turquoise	Hathi-ka Maqbara	15-02-2015	III	70.0	1.1	1.1	3.6	1.9	16.4	6.0	100.0
	HM/03	Turquoise	Hathi-ka Maqbara	15-02-2015	IV	72.0	1.2	1.0	3.4	1.7	15.0	5.7	100.0
	HM/03	**Turquoise**	**Hathi-ka Maqbara**	**15-02-2015**	**Average**	**70.2**	**1.2**	**1.1**	**3.5**	**1.9**	**16.2**	**6.0**	**100.0**
	HM/03	**Turquoise**	**Hathi-ka Maqbara**	**15-02-2015**	**Std. Dev.**	**1.4**	**0.2**	**0.2**	**0.1**	**0.1**	**0.9**	**0.2**	
2	HM/04	Turquoise	Hathi-ka Maqbara	15-02-2015	I	68.2	1.3	1.5	3.5	2.2	16.9	6.3	100.0
	HM/04	Turquoise	Hathi-ka Maqbara	15-02-2015	II	68.9	1.5	1.4	3.6	2.1	16.6	5.9	100.0
	HM/04	Turquoise	Hathi-ka Maqbara	15-02-2015	III	68.6	1.2	1.5	3.6	2.2	16.7	6.3	100.0
	HM/04	Turquoise	Hathi-ka Maqbara	15-02-2015	IV	70.7	1.0	1.3	3.4	2.1	15.5	6.0	100.0
	HM/04	**Turquoise**	**Hathi-ka Maqbara**	**15-02-2015**	**Average**	**69.1**	**1.3**	**1.4**	**3.5**	**2.1**	**16.4**	**6.1**	**100.0**
	HM/04	**Turquoise**	**Hathi-ka Maqbara**	**15-02-2015**	**Std. Dev.**	**1.1**	**0.2**	**0.1**	**0.1**	**0.1**	**0.6**	**0.2**	

Appendix 6.6 Average chemical compositions of the tile glazes from Lodhi buildings at Delhi determined through EPMA-WDS analyses. All results are in wt%. '-' indicates ‘not detected’ or 'below detection limit’.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	MnO	CuO	NiO	SnO_2	CoO	As_2O_5	ZnO	BaO	P_2O_5	SO_3	Total
1	BAG/01	Turquoise	Bagh-e Alam-ka Gumbad	63.7	19.1	3.58	3.03	3.12	1.47	0.54	0.07	0.10	2.36	-	-	-	-	-	-	0.45	0.14	97.74
2	BAG/02	Turquoise	Bagh-e Alam-ka Gumbad	62.6	19.1	3.54	2.97	3.02	1.60	0.53	0.08	0.11	2.63	-	-	-	-	-	-	0.46	0.18	96.97
3	SG/01	Dark-Blue	Sheesh Gumbad	66.4	17.0	4.77	2.89	2.88	1.33	1.34	0.07	-	0.23	0.31	-	0.31	0.08	-	-	0.46	0.34	98.51
4	SG/02	Dark-Blue	Sheesh Gumbad	68.8	14.2	3.94	4.16	2.41	1.16	1.42	0.07	-	0.33	0.27	-	0.24	-	-	-	0.36	0.33	97.71
5	SG/03	Turquoise	Sheesh Gumbad	63.5	17.2	4.04	4.96	2.96	1.41	0.51	0.09	-	1.92	-	-	-	-	0.18	-	0.37	0.24	97.53
6	SG/04	Turquoise	Sheesh Gumbad	64.7	17.3	4.87	2.76	3.09	1.37	0.53	0.06	-	2.23	-	-	-	-	-	-	0.44	0.27	97.67
7	SG/05	Dark-Blue	Sheesh Gumbad	64.5	16.5	4.44	2.91	2.80	1.33	1.43	0.07	0.06	0.29	0.28	-	0.29	0.13	-	-	0.41	0.37	95.82
8	SG/06	Dark-Blue	Sheesh Gumbad	62.2	16.8	4.85	2.87	3.00	1.29	1.33	0.07	-	0.31	0.24	-	0.27	0.10	-	-	0.47	0.36	94.24
9	SG/07	Dark-Blue	Sheesh Gumbad	64.7	17.5	5.01	2.48	3.27	1.34	1.25	0.08	0.15	0.15	0.20	-	0.22	-	-	-	0.41	0.30	97.15
10	SG/08	Dark-Blue	Sheesh Gumbad	64.3	18.4	5.18	2.23	3.20	1.33	1.30	0.06	0.12	0.19	0.16	-	0.22	-	-	-	0.44	0.32	97.47
11	SG/09	Dark-Blue	Sheesh Gumbad	63.3	18.9	4.27	3.71	3.11	1.05	1.22	0.06	0.05	0.14	0.19	-	0.24	-	-	-	0.46	0.31	97.03
12	SG/10	Dark-Blue	Sheesh Gumbad	64.1	19.5	4.13	2.72	3.02	1.08	1.18	0.05	-	0.12	0.15	-	0.24	-	-	-	0.45	0.28	97.17
13	MM/01	Turquoise	Madhi Masjid	65.3	16.8	3.43	2.70	2.97	1.67	0.58	0.09	-	4.38	-	-	-	-	0.12	-	0.42	0.23	98.80
14	MM/02	Turquoise	Madhi Masjid	63.0	17.6	3.45	2.63	3.12	1.69	0.60	0.10	0.05	4.73	-	-	-	-	0.11	-	0.44	0.19	97.80
15	SL/01	Turquoise	Tomb of Sikandar Lodhi	60.0	23.2	1.40	1.10	0.65	5.31	1.28	0.22	-	4.55	-	-	-	-	-	-	0.12	0.21	98.18
16	SL/02	Turquoise	Tomb of Sikandar Lodhi	63.9	18.5	1.34	2.45	0.41	4.58	1.28	0.27	-	3.31	-	-	-	-	-	-	0.17	0.29	96.65
17	SL/03	Dark-Blue	Tomb of Sikandar Lodhi	64.3	18.4	1.47	1.70	0.63	5.69	1.56	0.29	-	-	0.07	-	0.51	0.95	-	-	0.09	0.29	96.14
18	SL/04	Turquoise	Tomb of Sikandar Lodhi	62.3	17.9	1.54	2.81	0.65	4.65	1.27	0.27	-	4.01	-	-	-	-	0.05	0.05	0.21	0.31	96.09
19	SL/05	Turquoise	Tomb of Sikandar Lodhi	63.6	20.2	1.54	1.73	0.58	4.91	1.28	0.22	-	4.42	-	-	-	-	-	0.06	0.09	0.23	98.91
20	SL/06	Turquoise	Tomb of Sikandar Lodhi	62.5	21.4	1.53	1.12	0.54	5.27	1.40	0.23	-	4.60	-	-	-	-	-	-	0.12	0.27	99.17
21	JM/01	Turquoise	Jahaz Mahal	63.7	20.8	1.67	1.43	0.68	4.78	1.22	0.26	0.15	3.65	-	-	-	-	-	0.05	0.28	0.23	98.91
22	JM/02	Turquoise	Jahaz Mahal	63.3	20.2	1.64	1.45	0.66	4.64	1.11	0.24	0.16	3.82	-	-	-	-	0.10	-	0.29	0.22	97.86
23	JM/03	Turquoise	Jahaz Mahal	63.2	20.0	1.52	1.44	0.62	5.12	1.13	0.28	0.15	3.86	-	-	-	-	0.06	-	0.28	0.19	97.91
24	JM/04	Turquoise	Jahaz Mahal	65.4	19.8	1.06	1.27	0.37	2.93	0.78	0.13	-	5.12	-	-	-	-	0.49	-	0.26	0.19	97.89
25	JM/05	Turquoise	Jahaz Mahal	64.9	18.7	1.69	2.28	1.12	1.92	0.58	0.09	-	5.51	-	-	-	-	-	-	0.39	0.23	97.53

Appendix 6.7 Average chemical compositions of the tile glazes from Lodhi buildings at Punjab determined through EPMA-WDS analyses. All results are in wt%. '-' indicates ‘not detected’ or 'below detection limit’.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	MnO	CuO	NiO	SnO_2	CoO	As_2O_5	ZnO	BaO	P_2O_5	SO_3	Total
1	BT/01	Turquoise	Bibi Taj-ka Maqbara	62.7	15.8	4.57	3.06	3.00	1.48	0.54	0.05	-	4.11	-	0.08	-	-	-	-	0.54	0.20	96.25
2	BT/02	Turquoise	Bibi Taj-ka Maqbara	63.8	15.2	6.32	3.02	3.01	1.41	0.52	0.06	-	4.26	-	0.13	-	-	0.10	-	0.64	0.19	98.68
3	BT/03	Turquoise	Bibi Taj-ka Maqbara	62.9	15.2	6.45	3.03	3.03	1.39	0.51	0.05	0.05	4.03	-	0.10	-	-	0.06	-	0.73	0.24	97.75
4	BT/04	Turquoise	Bibi Taj-ka Maqbara	66.0	14.2	4.29	4.19	2.90	1.54	0.52	0.06	-	3.39	-	0.13	-	-	-	-	0.48	0.24	98.03
5	BT/05	Turquoise	Bibi Taj-ka Maqbara	64.4	15.5	4.78	3.49	3.24	1.57	0.60	0.07	-	3.21	-	0.11	-	-	-	-	0.51	0.27	97.82
6	BT/06	Turquoise	Bibi Taj-ka Maqbara	66.6	14.2	5.82	2.73	2.83	1.55	0.61	0.09	0.09	3.04	-	0.05	-	-	0.07	-	0.47	0.24	98.44
7	HM/01	Turquoise	Hathi-ka Maqbara	64.9	17.0	4.77	2.15	2.60	1.68	0.50	0.08	-	4.55	-	0.05	-	-	-	-	0.43	0.15	98.93
8	HM/02	Turquoise	Hathi-ka Maqbara	65.3	17.2	4.71	2.57	2.67	1.98	0.52	0.09	-	2.54	-	0.07	-	-	-	-	0.53	0.35	98.59
9	HM/03	Turquoise	Hathi-ka Maqbara	63.9	14.4	5.12	3.63	3.25	1.86	0.71	0.12	-	4.52	-	-	-	-	-	-	0.41	0.24	98.28
10	HM/04	Turquoise	Hathi-ka Maqbara	64.8	13.5	4.79	3.39	2.95	1.69	0.54	0.11	0.05	4.17	-	-	-	-	-	-	0.42	0.27	96.82

Appendix 6.8 Chemical compositions of the tile glazes from Lodhi buildings at Delhi determined through EPMA-WDS analyses. All results are in wt%.

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
1	BAG/01	Turquoise	20-11-2013	I	63.39	19.19	3.79	2.89	3.16	1.50	0.55	0.08	0.00	0.10	2.62	0.00	0.00	0.00	0.03	0.00	0.00	0.36	0.13	0.00	97.81
	BAG/01	Turquoise	20-11-2013	II	63.54	19.42	3.62	3.07	3.06	1.51	0.52	0.08	0.02	0.09	2.29	0.00	0.00	0.00	0.01	0.00	0.02	0.45	0.12	0.00	97.80
	BAG/01	Turquoise	20-11-2013	III	63.65	19.30	3.43	3.10	3.11	1.38	0.57	0.07	0.00	0.12	2.20	0.00	0.03	0.00	0.05	0.00	0.00	0.50	0.13	0.00	97.62
	BAG/01	Turquoise	20-11-2013	IV	64.09	18.87	3.54	3.15	3.07	1.43	0.52	0.06	0.04	0.10	2.18	0.01	0.02	0.07	0.00	0.00	0.03	0.53	0.19	0.00	97.87
	BAG/01	Turquoise	20-11-2013	V	63.93	18.77	3.52	2.94	3.19	1.53	0.54	0.08	0.00	0.10	2.54	0.00	0.00	0.00	0.02	0.00	0.02	0.41	0.13	0.00	97.71
	BAG/01	**Turquoise**	**20-11-2013**	**Average**	**63.72**	**19.11**	**3.58**	**3.03**	**3.12**	**1.47**	**0.54**	**0.07**	**0.01**	**0.10**	**2.36**	**0.00**	**0.01**	**0.01**	**0.02**	**0.00**	**0.01**	**0.45**	**0.14**	**0.00**	**97.76**
	BAG/01	**Turquoise**	**20-11-2013**	**Std. Dev.**	**0.29**	**0.28**	**0.14**	**0.11**	**0.06**	**0.06**	**0.02**	**0.01**	**0.02**	**0.01**	**0.20**	**0.00**	**0.02**	**0.03**	**0.02**	**0.00**	**0.01**	**0.07**	**0.03**	**0.00**	
2	BAG/02	Turquoise	20-11-2013	I	59.72	18.77	3.49	2.92	2.83	1.36	0.49	0.08	0.02	0.08	2.46	0.00	0.02	0.00	0.00	0.06	0.05	0.47	0.22	0.00	93.02
	BAG/02	Turquoise	20-11-2013	II	63.56	19.32	3.72	2.98	3.06	1.55	0.55	0.08	0.00	0.15	2.54	0.00	0.01	0.00	0.00	0.01	0.03	0.47	0.19	0.00	98.20
	BAG/02	Turquoise	20-11-2013	III	63.43	18.66	3.28	3.02	3.04	2.14	0.50	0.10	0.04	0.14	2.83	0.01	0.00	0.00	0.03	0.00	0.09	0.46	0.14	0.00	97.90
	BAG/02	Turquoise	20-11-2013	IV	63.23	19.45	3.54	3.00	3.09	1.65	0.66	0.06	0.00	0.08	2.75	0.00	0.00	0.01	0.03	0.05	0.00	0.46	0.17	0.00	98.24
	BAG/02	Turquoise	20-11-2013	V	63.26	19.45	3.69	2.93	3.06	1.31	0.47	0.08	0.00	0.12	2.57	0.00	0.00	0.04	0.04	0.00	0.00	0.44	0.18	0.00	97.62
	BAG/02	**Turquoise**	**20-11-2013**	**Average**	**62.64**	**19.13**	**3.54**	**2.97**	**3.02**	**1.60**	**0.53**	**0.08**	**0.01**	**0.11**	**2.63**	**0.00**	**0.01**	**0.01**	**0.02**	**0.02**	**0.03**	**0.46**	**0.18**	**0.00**	**96.99**
	BAG/02	**Turquoise**	**20-11-2013**	**Std. Dev.**	**1.64**	**0.38**	**0.18**	**0.04**	**0.11**	**0.33**	**0.08**	**0.01**	**0.02**	**0.03**	**0.15**	**0.00**	**0.01**	**0.02**	**0.02**	**0.03**	**0.04**	**0.01**	**0.03**	**0.00**	
3	SG/01	Dark-Blue	08-03-2012	I	66.53	17.27	4.65	3.03	2.81	1.31	1.34	0.06	0.00	0.05	0.28	0.30	0.00	0.00	0.32	0.06	0.00	0.39	0.31	0.05	98.74
	SG/01	Dark-Blue	08-03-2012	II	64.95	17.30	4.97	2.98	3.09	1.39	1.42	0.09	0.00	0.03	0.21	0.34	0.00	0.00	0.29	0.00	0.00	0.47	0.37	0.07	97.97
	SG/01	Dark-Blue	08-03-2012	III	67.82	16.43	4.70	2.65	2.76	1.29	1.27	0.06	0.00	0.03	0.19	0.29	0.00	0.00	0.34	0.04	0.00	0.52	0.34	0.11	98.83
	SG/01	**Dark-Blue**	**08-03-2012**	**Average**	**66.43**	**17.00**	**4.77**	**2.89**	**2.88**	**1.33**	**1.34**	**0.07**	**0.00**	**0.04**	**0.23**	**0.31**	**0.00**	**0.00**	**0.31**	**0.04**	**0.00**	**0.46**	**0.34**	**0.08**	**98.51**
	SG/01	**Dark-Blue**	**08-03-2012**	**Std. Dev.**	**1.44**	**0.49**	**0.17**	**0.21**	**0.18**	**0.05**	**0.08**	**0.02**	**0.00**	**0.01**	**0.05**	**0.03**	**0.00**	**0.00**	**0.03**	**0.03**	**0.00**	**0.06**	**0.03**	**0.03**	
4	SG/02	Dark-Blue	08-03-2012	I	71.59	13.59	3.09	4.00	1.80	1.25	1.54	0.10	0.03	0.04	0.29	0.25	0.01	0.05	0.30	0.07	0.01	0.36	0.30	0.00	98.64
	SG/02	Dark-Blue	08-03-2012	II	68.65	14.38	4.28	4.21	2.74	1.10	1.36	0.05	0.00	0.05	0.35	0.25	0.00	0.03	0.26	0.00	0.00	0.35	0.31	0.00	98.37
	SG/02	Dark-Blue	08-03-2012	III	66.04	14.54	4.45	4.28	2.70	1.14	1.36	0.06	0.00	0.03	0.35	0.23	0.00	0.00	0.25	0.00	0.04	0.38	0.39	0.00	96.22
	SG/02	**Dark-Blue**	**08-03-2012**	**Average**	**68.76**	**14.17**	**3.94**	**4.16**	**2.41**	**1.16**	**1.42**	**0.07**	**0.01**	**0.04**	**0.33**	**0.24**	**0.00**	**0.03**	**0.27**	**0.02**	**0.01**	**0.36**	**0.33**	**0.00**	**97.74**
	SG/02	**Dark-Blue**	**08-03-2012**	**Std. Dev.**	**2.78**	**0.51**	**0.74**	**0.15**	**0.53**	**0.08**	**0.10**	**0.03**	**0.02**	**0.01**	**0.03**	**0.01**	**0.00**	**0.02**	**0.03**	**0.04**	**0.02**	**0.01**	**0.05**	**0.00**	
5	SG/03	Turquoise	08-03-2012	I	63.65	17.36	4.21	4.98	3.01	1.42	0.48	0.09	0.00	0.07	1.80	0.00	0.00	0.04	0.00	0.19	0.03	0.50	0.21	0.00	98.04
	SG/03	Turquoise	08-03-2012	II	64.64	16.02	3.91	4.95	2.85	1.41	0.51	0.11	0.00	0.00	1.99	0.00	0.02	0.00	0.04	0.15	0.00	0.32	0.22	0.00	97.14
	SG/03	Turquoise	08-03-2012	III	62.27	18.27	4.02	4.95	3.02	1.42	0.54	0.08	0.00	0.05	1.96	0.01	0.01	0.03	0.01	0.21	0.06	0.29	0.30	0.00	97.48
	SG/03	**Turquoise**	**08-03-2012**	**Average**	**63.52**	**17.22**	**4.04**	**4.96**	**2.96**	**1.41**	**0.51**	**0.09**	**0.00**	**0.04**	**1.92**	**0.00**	**0.01**	**0.02**	**0.02**	**0.18**	**0.03**	**0.37**	**0.24**	**0.00**	**97.55**
	SG/03	**Turquoise**	**08-03-2012**	**Std. Dev.**	**1.19**	**1.13**	**0.15**	**0.02**	**0.10**	**0.01**	**0.03**	**0.02**	**0.00**	**0.04**	**0.10**	**0.01**	**0.01**	**0.02**	**0.02**	**0.03**	**0.03**	**0.12**	**0.05**	**0.00**	
6	SG/04	Turquoise	08-03-2012	I	65.07	16.70	4.73	2.91	3.03	1.31	0.47	0.06	0.00	0.03	2.50	0.00	0.00	0.00	0.00	0.06	0.01	0.43	0.27	0.00	97.57
	SG/04	Turquoise	08-03-2012	II	66.05	17.08	4.69	2.84	2.93	1.28	0.51	0.08	0.00	0.04	1.54	0.02	0.02	0.00	0.00	0.00	0.06	0.42	0.28	0.00	97.84
	SG/04	Turquoise	08-03-2012	III	62.88	17.98	5.18	2.53	3.30	1.53	0.62	0.06	0.00	0.05	2.65	0.00	0.00	0.03	0.02	0.03	0.05	0.47	0.27	0.00	97.63
	SG/04	**Turquoise**	**08-03-2012**	**Average**	**64.67**	**17.26**	**4.87**	**2.76**	**3.09**	**1.37**	**0.53**	**0.06**	**0.00**	**0.04**	**2.23**	**0.01**	**0.01**	**0.01**	**0.01**	**0.03**	**0.04**	**0.44**	**0.27**	**0.00**	**97.68**
	SG/04	**Turquoise**	**08-03-2012**	**Std. Dev.**	**1.62**	**0.65**	**0.27**	**0.20**	**0.19**	**0.14**	**0.08**	**0.01**	**0.00**	**0.01**	**0.60**	**0.01**	**0.01**	**0.01**	**0.01**	**0.03**	**0.03**	**0.03**	**0.01**	**0.00**	
7	SG/05	Dark-Blue	13-06-2012	I	66.85	15.91	4.07	2.97	2.57	1.06	1.48	0.07	0.00	0.07	0.36	0.27	0.00	0.00	0.29	0.00	0.02	0.34	0.34	0.16	96.81
	SG/05	Dark-Blue	13-06-2012	II	65.50	17.13	4.34	3.07	2.78	1.19	1.37	0.07	0.00	0.05	0.25	0.33	0.00	0.00	0.29	0.00	0.04	0.36	0.25	0.12	97.13
	SG/05	Dark-Blue	13-06-2012	III	61.21	16.63	4.69	2.69	2.86	1.45	1.52	0.07	0.00	0.08	0.20	0.28	0.01	0.01	0.29	0.01	0.03	0.41	0.49	0.06	93.00
	SG/05	Dark-Blue	13-06-2012	IV	64.34	16.35	4.65	2.93	3.00	1.61	1.35	0.09	0.00	0.04	0.34	0.28	0.00	0.00	0.25	0.00	0.03	0.52	0.40	0.17	96.35
	SG/05	**Dark-Blue**	**13-06-2012**	**Average**	**64.48**	**16.50**	**4.44**	**2.91**	**2.80**	**1.33**	**1.43**	**0.07**	**0.00**	**0.06**	**0.29**	**0.29**	**0.00**	**0.00**	**0.28**	**0.00**	**0.03**	**0.41**	**0.37**	**0.13**	**95.82**
	SG/05	**Dark-Blue**	**13-06-2012**	**Std. Dev.**	**2.41**	**0.51**	**0.29**	**0.16**	**0.18**	**0.25**	**0.08**	**0.01**	**0.00**	**0.02**	**0.07**	**0.03**	**0.01**	**0.00**	**0.02**	**0.01**	**0.01**	**0.08**	**0.10**	**0.05**	
8	SG/06	Dark-Blue	13-06-2012	I	62.85	17.73	5.15	2.86	2.91	1.37	1.24	0.08	0.01	0.00	0.31	0.27	0.00	0.07	0.26	0.00	0.01	0.53	0.35	0.10	96.08
	SG/06	Dark-Blue	13-06-2012	II	57.50	16.27	4.97	2.66	2.97	1.31	1.28	0.04	0.05	0.04	0.43	0.29	0.01	0.01	0.19	0.01	0.05	0.46	0.34	0.08	88.96
	SG/06	Dark-Blue	13-06-2012	III	63.55	17.20	4.82	2.94	3.25	1.45	1.56	0.11	0.00	0.03	0.16	0.27	0.00	0.01	0.27	0.12	0.00	0.51	0.45	0.17	96.86

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	SG/06	Dark-Blue	13-06-2012	IV	64.71	16.20	4.45	3.03	2.87	1.06	1.24	0.06	0.04	0.03	0.35	0.25	0.00	0.00	0.23	0.00	0.00	0.39	0.31	0.03	95.24
	SG/06	**Dark-Blue**	**13-06-2012**	**Average**	**62.15**	**16.85**	**4.85**	**2.87**	**3.00**	**1.29**	**1.33**	**0.07**	**0.02**	**0.02**	**0.31**	**0.27**	**0.00**	**0.02**	**0.24**	**0.03**	**0.02**	**0.47**	**0.36**	**0.10**	**94.29**
	SG/06	**Dark-Blue**	**13-06-2012**	**Std. Dev.**	**3.19**	**0.75**	**0.29**	**0.16**	**0.17**	**0.17**	**0.16**	**0.03**	**0.02**	**0.02**	**0.11**	**0.02**	**0.00**	**0.03**	**0.03**	**0.06**	**0.02**	**0.06**	**0.06**	**0.06**	
9	SG/07	Dark-Blue	13-06-2012	I	65.57	17.08	4.49	2.63	3.18	1.44	1.16	0.10	0.02	0.12	0.07	0.21	0.00	0.04	0.20	0.11	0.00	0.32	0.28	0.00	97.00
	SG/07	Dark-Blue	13-06-2012	II	63.52	17.78	5.34	2.38	3.37	1.37	1.48	0.07	0.00	0.17	0.26	0.25	0.00	0.00	0.22	0.03	0.01	0.52	0.31	0.05	97.11
	SG/07	Dark-Blue	13-06-2012	III	65.57	17.33	4.80	2.52	3.21	1.32	1.16	0.09	0.00	0.14	0.09	0.18	0.00	0.04	0.17	0.03	0.02	0.42	0.34	0.00	97.44
	SG/07	Dark-Blue	13-06-2012	IV	64.25	17.73	5.43	2.37	3.34	1.21	1.19	0.08	0.00	0.17	0.18	0.23	0.00	0.06	0.22	0.00	0.03	0.38	0.27	0.07	97.21
	SG/07	**Dark-Blue**	**13-06-2012**	**Average**	**64.73**	**17.48**	**5.01**	**2.48**	**3.27**	**1.34**	**1.25**	**0.08**	**0.01**	**0.15**	**0.15**	**0.22**	**0.00**	**0.03**	**0.20**	**0.04**	**0.01**	**0.41**	**0.30**	**0.03**	**97.19**
	SG/07	**Dark-Blue**	**13-06-2012**	**Std. Dev.**	**1.01**	**0.33**	**0.45**	**0.12**	**0.09**	**0.09**	**0.15**	**0.01**	**0.01**	**0.02**	**0.09**	**0.03**	**0.00**	**0.02**	**0.02**	**0.05**	**0.01**	**0.08**	**0.03**	**0.04**	
10	SG/08	Dark-Blue	13-06-2012	I	63.31	18.65	5.33	2.14	3.42	1.51	1.51	0.08	0.00	0.13	0.19	0.24	0.00	0.00	0.17	0.04	0.00	0.58	0.31	0.06	97.66
	SG/08	Dark-Blue	13-06-2012	II	63.68	18.61	5.31	2.18	3.20	1.36	1.26	0.06	0.02	0.12	0.16	0.19	0.01	0.11	0.18	0.01	0.02	0.44	0.30	0.00	97.21
	SG/08	Dark-Blue	13-06-2012	III	65.46	18.04	4.84	2.27	3.02	1.22	1.09	0.04	0.00	0.09	0.21	0.22	0.00	0.00	0.14	0.01	0.00	0.38	0.39	0.00	97.40
	SG/08	Dark-Blue	13-06-2012	IV	64.88	18.18	5.22	2.31	3.17	1.23	1.35	0.04	0.10	0.14	0.19	0.23	0.00	0.00	0.16	0.00	0.00	0.36	0.26	0.00	97.83
	SG/08	**Dark-Blue**	**13-06-2012**	**Average**	**64.33**	**18.37**	**5.18**	**2.23**	**3.20**	**1.33**	**1.30**	**0.06**	**0.03**	**0.12**	**0.19**	**0.22**	**0.00**	**0.03**	**0.16**	**0.01**	**0.01**	**0.44**	**0.32**	**0.01**	**97.52**
	SG/08	**Dark-Blue**	**13-06-2012**	**Std. Dev.**	**1.01**	**0.31**	**0.23**	**0.08**	**0.16**	**0.14**	**0.18**	**0.02**	**0.05**	**0.02**	**0.02**	**0.02**	**0.00**	**0.05**	**0.02**	**0.02**	**0.01**	**0.10**	**0.05**	**0.03**	
11	SG/09	Dark-Blue	13-06-2012	I	63.15	19.20	4.08	3.64	3.13	1.07	1.25	0.06	0.00	0.03	0.16	0.23	0.00	0.03	0.16	0.08	0.06	0.47	0.26	0.00	97.07
	SG/09	Dark-Blue	13-06-2012	II	63.23	19.03	4.25	3.76	3.10	1.11	1.26	0.06	0.02	0.05	0.12	0.23	0.00	0.00	0.18	0.00	0.00	0.46	0.35	0.00	97.20
	SG/09	Dark-Blue	13-06-2012	III	62.93	18.78	4.39	3.74	3.11	1.01	1.16	0.07	0.00	0.02	0.14	0.26	0.00	0.00	0.26	0.00	0.00	0.40	0.33	0.00	96.59
	SG/09	Dark-Blue	13-06-2012	IV	63.73	18.53	4.36	3.71	3.10	1.01	1.21	0.07	0.00	0.09	0.13	0.26	0.02	0.00	0.16	0.09	0.01	0.49	0.28	0.08	97.33
	SG/09	**Dark-Blue**	**13-06-2012**	**Average**	**63.26**	**18.89**	**4.27**	**3.71**	**3.11**	**1.05**	**1.22**	**0.06**	**0.01**	**0.05**	**0.14**	**0.24**	**0.01**	**0.01**	**0.19**	**0.04**	**0.02**	**0.46**	**0.31**	**0.02**	**97.05**
	SG/09	**Dark-Blue**	**13-06-2012**	**Std. Dev.**	**0.34**	**0.29**	**0.14**	**0.05**	**0.01**	**0.05**	**0.05**	**0.01**	**0.01**	**0.03**	**0.02**	**0.02**	**0.01**	**0.02**	**0.05**	**0.05**	**0.03**	**0.04**	**0.04**	**0.04**	
12	SG/10	Dark-Blue	13-06-2012	I	63.89	19.71	4.10	2.71	3.03	1.09	1.16	0.05	0.00	0.03	0.14	0.20	0.00	0.00	0.14	0.05	0.03	0.44	0.27	0.00	97.05
	SG/10	Dark-Blue	13-06-2012	II	64.17	19.49	4.09	2.69	3.08	1.08	1.36	0.05	0.02	0.03	0.19	0.28	0.00	0.01	0.16	0.00	0.01	0.38	0.26	0.00	97.37
	SG/10	Dark-Blue	13-06-2012	III	63.62	19.89	4.38	2.63	2.98	1.10	0.98	0.06	0.03	0.03	0.11	0.25	0.00	0.00	0.16	0.04	0.02	0.54	0.31	0.05	97.17
	SG/10	Dark-Blue	13-06-2012	IV	64.86	18.96	3.94	2.84	2.99	1.04	1.24	0.03	0.00	0.05	0.06	0.23	0.00	0.03	0.13	0.02	0.01	0.45	0.29	0.00	97.18
	SG/10	**Dark-Blue**	**13-06-2012**	**Average**	**64.13**	**19.51**	**4.13**	**2.72**	**3.02**	**1.08**	**1.18**	**0.05**	**0.01**	**0.04**	**0.12**	**0.24**	**0.00**	**0.01**	**0.15**	**0.03**	**0.02**	**0.45**	**0.28**	**0.01**	**97.19**
	SG/10	**Dark-Blue**	**13-06-2012**	**Std. Dev.**	**0.53**	**0.40**	**0.19**	**0.09**	**0.05**	**0.03**	**0.16**	**0.01**	**0.01**	**0.01**	**0.05**	**0.03**	**0.00**	**0.01**	**0.01**	**0.02**	**0.01**	**0.06**	**0.02**	**0.02**	
13	MM/01	Turquoise	05-12-2013	I	63.15	17.34	3.66	2.62	2.90	1.78	0.58	0.10	0.00	0.03	4.46	0.01	0.00	0.10	0.03	0.10	0.05	0.45	0.26	0.00	97.61
	MM/01	Turquoise	05-12-2013	II	65.47	16.43	3.15	2.85	2.78	1.58	0.53	0.11	0.00	0.05	4.23	0.00	0.00	0.00	0.03	0.19	0.01	0.35	0.18	0.00	97.93
	MM/01	Turquoise	05-12-2013	III	66.24	15.77	3.28	2.63	2.96	1.61	0.61	0.08	0.01	0.04	3.85	0.00	0.03	0.00	0.00	0.12	0.00	0.43	0.19	0.00	97.85
	MM/01	Turquoise	05-12-2013	IV	66.33	17.72	3.65	2.68	3.25	1.72	0.60	0.09	0.00	0.02	4.98	0.01	0.00	0.00	0.00	0.08	0.06	0.46	0.29	0.00	101.94
	MM/01	**Turquoise**	**05-12-2013**	**Average**	**65.30**	**16.81**	**3.43**	**2.70**	**2.97**	**1.67**	**0.58**	**0.09**	**0.00**	**0.04**	**4.38**	**0.00**	**0.01**	**0.02**	**0.01**	**0.12**	**0.03**	**0.42**	**0.23**	**0.00**	**98.83**
	MM/01	**Turquoise**	**05-12-2013**	**Std. Dev.**	**1.48**	**0.88**	**0.26**	**0.11**	**0.20**	**0.09**	**0.03**	**0.01**	**0.01**	**0.01**	**0.47**	**0.00**	**0.01**	**0.05**	**0.02**	**0.05**	**0.03**	**0.05**	**0.05**	**0.00**	
14	MM/02	Turquoise	05-12-2013	I	62.66	17.38	3.31	2.71	2.82	1.57	0.53	0.09	0.00	0.04	4.27	0.00	0.01	0.00	0.01	0.20	0.00	0.35	0.11	0.00	96.06
	MM/02	Turquoise	05-12-2013	II	62.43	17.93	3.52	2.70	3.33	1.84	0.60	0.11	0.04	0.01	5.11	0.00	0.06	0.00	0.03	0.13	0.01	0.49	0.25	0.00	98.57
	MM/02	Turquoise	05-12-2013	III	63.39	17.75	3.51	2.67	3.09	1.80	0.54	0.10	0.00	0.06	4.61	0.03	0.05	0.00	0.04	0.07	0.00	0.50	0.14	0.05	98.38
	MM/02	Turquoise	05-12-2013	IV	62.43	17.83	3.50	2.59	3.24	1.76	0.75	0.11	0.00	0.04	4.90	0.01	0.00	0.00	0.03	0.05	0.00	0.52	0.23	0.00	97.98
	MM/02	Turquoise	05-12-2013	V	64.06	17.27	3.41	2.47	3.12	1.52	0.57	0.08	0.00	0.08	4.78	0.00	0.02	0.03	0.01	0.09	0.01	0.34	0.23	0.00	98.08
	MM/02	**Turquoise**	**05-12-2013**	**Average**	**62.99**	**17.63**	**3.45**	**2.63**	**3.12**	**1.69**	**0.60**	**0.10**	**0.01**	**0.05**	**4.73**	**0.01**	**0.03**	**0.01**	**0.02**	**0.11**	**0.00**	**0.44**	**0.19**	**0.01**	**97.81**
	MM/02	**Turquoise**	**05-12-2013**	**Std. Dev.**	**0.72**	**0.29**	**0.09**	**0.10**	**0.20**	**0.14**	**0.09**	**0.01**	**0.02**	**0.03**	**0.32**	**0.01**	**0.03**	**0.01**	**0.01**	**0.06**	**0.01**	**0.09**	**0.06**	**0.02**	
15	SL/01	Turquoise	26-11-2013	I	59.38	23.43	1.38	0.97	0.75	5.12	1.34	0.20	0.03	0.03	4.50	0.00	0.00	0.00	0.00	0.05	0.04	0.07	0.20	0.02	97.51
	SL/01	Turquoise	26-11-2013	II	60.79	21.41	1.44	1.30	0.69	5.28	1.33	0.21	0.04	0.03	4.78	0.01	0.00	0.02	0.03	0.05	0.03	0.10	0.25	0.00	97.80
	SL/01	Turquoise	26-11-2013	III	59.56	23.90	1.45	1.06	0.66	5.28	1.24	0.23	0.00	0.04	4.98	0.00	0.00	0.00	0.03	0.00	0.06	0.09	0.21	0.00	98.79
	SL/01	Turquoise	26-11-2013	IV	60.05	23.74	1.34	1.08	0.60	5.51	1.28	0.24	0.03	0.04	4.42	0.01	0.01	0.00	0.03	0.02	0.04	0.20	0.17	0.00	98.80
	SL/01	Turquoise	26-11-2013	V	60.14	23.58	1.40	1.11	0.57	5.38	1.19	0.21	0.06	0.02	4.08	0.01	0.00	0.02	0.04	0.02	0.03	0.12	0.22	0.00	98.20
	SL/01	**Turquoise**	**26-11-2013**	**Average**	**59.99**	**23.21**	**1.40**	**1.10**	**0.65**	**5.31**	**1.28**	**0.22**	**0.03**	**0.03**	**4.55**	**0.00**	**0.00**	**0.01**	**0.03**	**0.03**	**0.04**	**0.12**	**0.21**	**0.00**	**98.22**

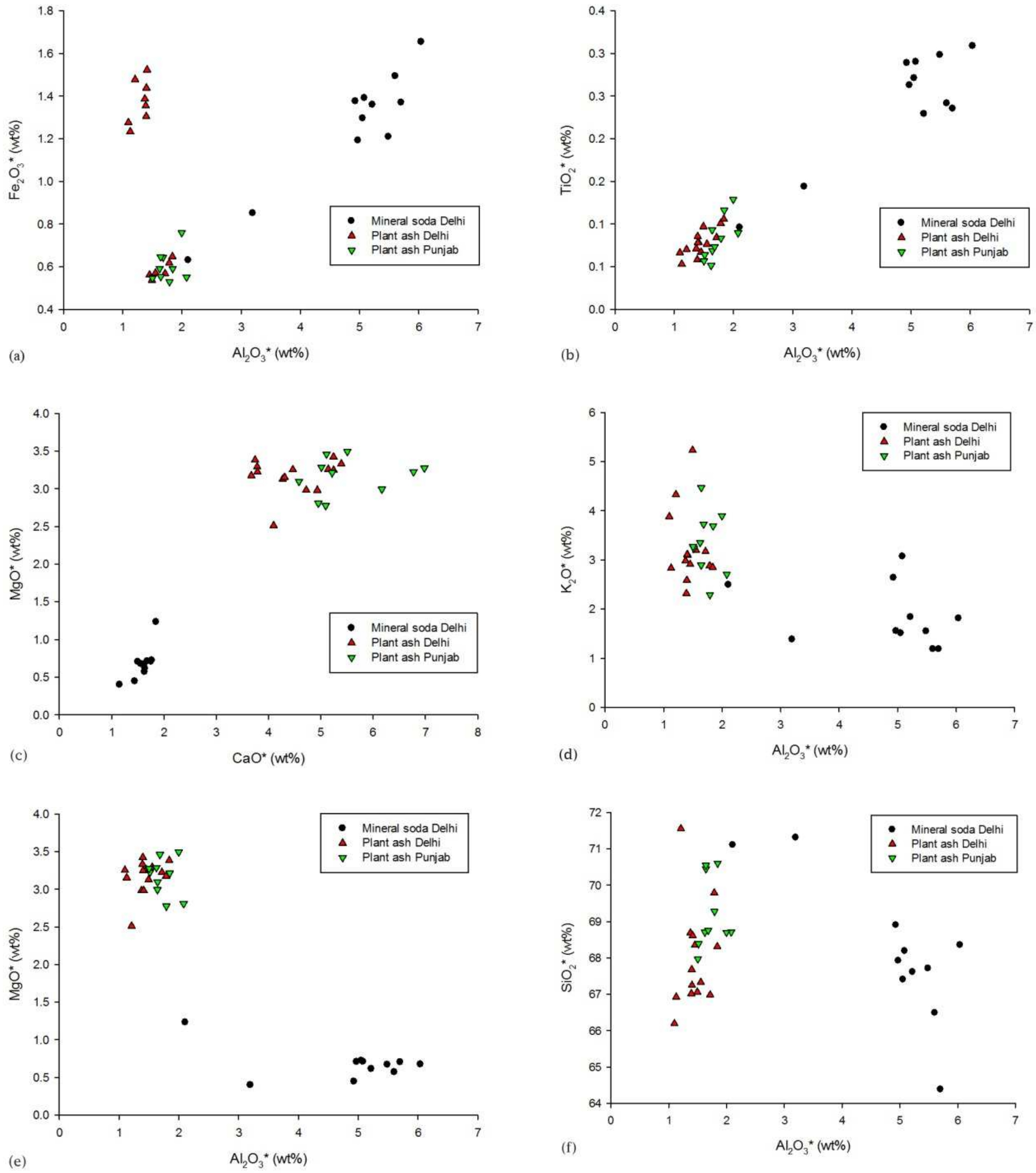
No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	SL/01	Turquoise	26-11-2013	Std. Dev.	0.55	1.02	0.04	0.12	0.07	0.14	0.06	0.02	0.02	0.01	0.35	0.00	0.01	0.01	0.01	0.02	0.01	0.05	0.03	0.01	
16	SL/02	Turquoise	29-11-2013	I	63.90	19.21	1.28	2.47	0.33	4.79	1.29	0.27	0.00	0.04	3.08	0.02	0.00	0.00	0.00	0.04	0.00	0.21	0.29	0.00	97.22
	SL/02	Turquoise	29-11-2013	II	63.77	17.39	1.50	2.31	0.46	4.29	1.28	0.26	0.00	0.03	3.92	0.02	0.00	0.02	0.05	0.02	0.05	0.19	0.29	0.00	95.86
	SL/02	Turquoise	29-11-2013	III	65.24	16.96	1.36	2.63	0.51	4.45	1.21	0.27	0.00	0.02	2.87	0.00	0.00	0.00	0.04	0.00	0.04	0.19	0.26	0.00	96.04
	SL/02	Turquoise	29-11-2013	IV	62.39	19.97	1.31	2.36	0.34	5.03	1.35	0.28	0.00	0.02	3.59	0.01	0.01	0.00	0.02	0.03	0.03	0.16	0.27	0.00	97.17
	SL/02	Turquoise	29-11-2013	V	64.27	19.11	1.26	2.46	0.41	4.32	1.25	0.26	0.00	0.02	3.11	0.01	0.00	0.06	0.02	0.01	0.03	0.12	0.34	0.00	97.05
	SL/02	Turquoise	29-11-2013	Average	63.91	18.53	1.34	2.45	0.41	4.58	1.28	0.27	0.00	0.03	3.31	0.01	0.00	0.02	0.03	0.02	0.03	0.17	0.29	0.00	96.67
	SL/02	Turquoise	29-11-2013	Std. Dev.	1.03	1.29	0.10	0.12	0.08	0.32	0.05	0.01	0.00	0.01	0.43	0.01	0.00	0.03	0.02	0.02	0.02	0.03	0.03	0.00	
17	SL/03	Dark-Blue	26-11-2013	I	63.82	17.29	1.35	1.62	0.75	5.20	1.26	0.27	0.00	0.02	0.01	0.54	0.00	0.10	0.07	0.00	0.04	0.06	0.26	1.10	93.76
	SL/03	Dark-Blue	26-11-2013	II	61.95	18.86	1.51	1.67	0.57	5.50	1.64	0.30	0.00	0.03	0.01	0.50	0.01	0.00	0.08	0.01	0.00	0.14	0.30	0.90	93.98
	SL/03	Dark-Blue	26-11-2013	III	66.88	18.40	1.40	1.75	0.58	5.71	1.44	0.27	0.03	0.03	0.00	0.41	0.00	0.00	0.04	0.03	0.05	0.12	0.25	0.60	97.99
	SL/03	Dark-Blue	26-11-2013	IV	65.36	19.14	1.53	1.66	0.65	5.91	1.28	0.27	0.00	0.02	0.16	0.46	0.00	0.00	0.03	0.07	0.02	0.07	0.37	0.97	97.94
	SL/03	Dark-Blue	26-11-2013	V	63.60	18.49	1.56	1.83	0.62	6.11	2.16	0.35	0.00	0.03	0.02	0.66	0.04	0.00	0.11	0.00	0.03	0.08	0.27	1.19	97.13
	SL/03	Dark-Blue	26-11-2013	Average	64.32	18.44	1.47	1.70	0.63	5.69	1.56	0.29	0.01	0.02	0.04	0.51	0.01	0.02	0.07	0.02	0.03	0.09	0.29	0.95	96.16
	SL/03	Dark-Blue	26-11-2013	Std. Dev.	1.87	0.70	0.09	0.09	0.07	0.35	0.37	0.04	0.01	0.01	0.07	0.10	0.02	0.04	0.03	0.03	0.02	0.04	0.05	0.23	
18	SL/04	Turquoise	29-11-2013	I	63.44	17.43	1.22	3.10	0.44	4.91	1.34	0.25	0.00	0.03	3.79	0.01	0.00	0.02	0.06	0.00	0.07	0.14	0.26	0.00	96.50
	SL/04	Turquoise	29-11-2013	II	62.87	17.74	1.35	2.84	0.58	4.58	1.33	0.24	0.01	0.01	3.83	0.02	0.00	0.05	0.00	0.08	0.03	0.20	0.35	0.00	96.10
	SL/04	Turquoise	29-11-2013	III	61.14	18.81	1.37	2.66	0.34	4.83	1.29	0.28	0.00	0.04	4.48	0.00	0.00	0.00	0.04	0.05	0.07	0.20	0.39	0.00	95.98
	SL/04	Turquoise	29-11-2013	IV	62.36	16.72	2.28	2.75	0.50	4.71	1.19	0.29	0.07	0.04	3.48	0.01	0.00	0.00	0.01	0.05	0.05	0.27	0.28	0.00	95.07
	SL/04	Turquoise	29-11-2013	V	61.76	18.77	1.47	2.69	1.37	4.20	1.21	0.27	0.00	0.03	4.46	0.03	0.00	0.00	0.02	0.05	0.03	0.26	0.30	0.02	96.94
	SL/04	Turquoise	29-11-2013	Average	62.32	17.90	1.54	2.81	0.65	4.65	1.27	0.27	0.02	0.03	4.01	0.01	0.00	0.01	0.03	0.05	0.05	0.21	0.31	0.01	96.12
	SL/04	Turquoise	29-11-2013	Std. Dev.	0.90	0.90	0.42	0.18	0.42	0.28	0.07	0.02	0.03	0.01	0.44	0.01	0.00	0.02	0.02	0.03	0.02	0.05	0.05	0.01	
19	SL/05	Turquoise	06-12-2013	I	64.09	20.08	1.56	1.77	0.47	4.43	1.85	0.17	0.00	0.01	3.64	0.01	0.00	0.00	0.00	0.06	0.07	0.08	0.20	0.00	98.49
	SL/05	Turquoise	06-12-2013	II	65.27	20.22	1.54	1.75	0.66	4.50	1.06	0.20	0.00	0.03	4.23	0.02	0.04	0.00	0.04	0.00	0.09	0.16	0.18	0.00	100.01
	SL/05	Turquoise	06-12-2013	III	63.34	20.33	1.49	1.67	0.40	4.84	1.06	0.19	0.00	0.01	4.61	0.01	0.02	0.00	0.00	0.06	0.07	0.00	0.28	0.00	98.39
	SL/05	Turquoise	06-12-2013	IV	62.32	20.30	1.67	1.70	0.68	5.49	1.26	0.26	0.00	0.04	4.79	0.00	0.00	0.00	0.03	0.00	0.03	0.15	0.24	0.00	98.94
	SL/05	Turquoise	06-12-2013	V	62.87	20.11	1.46	1.74	0.67	5.29	1.16	0.24	0.00	0.03	4.84	0.00	0.00	0.00	0.00	0.00	0.05	0.04	0.25	0.00	98.75
	SL/05	Turquoise	06-12-2013	Average	63.58	20.21	1.54	1.73	0.58	4.91	1.28	0.22	0.00	0.02	4.42	0.01	0.01	0.00	0.01	0.02	0.06	0.09	0.23	0.00	98.91
	SL/05	Turquoise	06-12-2013	Std. Dev.	1.15	0.11	0.08	0.04	0.13	0.47	0.33	0.04	0.00	0.02	0.50	0.01	0.02	0.00	0.02	0.03	0.02	0.07	0.04	0.00	
20	SL/06	Turquoise	06-12-2013	I	63.58	21.50	1.43	1.14	0.40	4.97	1.04	0.22	0.02	0.02	4.24	0.01	0.03	0.10	0.02	0.01	0.06	0.12	0.26	0.00	99.18
	SL/06	Turquoise	06-12-2013	II	61.90	21.22	1.63	1.18	0.73	5.35	1.14	0.25	0.03	0.03	5.21	0.00	0.00	0.00	0.05	0.00	0.01	0.13	0.27	0.00	99.15
	SL/06	Turquoise	06-12-2013	III	62.09	21.54	1.54	1.02	0.47	5.49	2.04	0.21	0.00	0.00	4.33	0.02	0.00	0.02	0.03	0.07	0.02	0.10	0.27	0.07	99.34
	SL/06	Turquoise	06-12-2013	Average	62.52	21.42	1.53	1.12	0.54	5.27	1.40	0.23	0.02	0.02	4.60	0.01	0.01	0.04	0.03	0.03	0.03	0.12	0.27	0.02	99.22
	SL/06	Turquoise	06-12-2013	Std. Dev.	0.92	0.17	0.10	0.08	0.18	0.27	0.55	0.02	0.01	0.02	0.54	0.01	0.02	0.05	0.02	0.04	0.02	0.02	0.01	0.04	
21	JM/01	Turquoise	25-02-2013	I	63.49	20.68	1.74	1.37	0.68	3.96	0.87	0.21	0.00	0.16	3.59	0.00	0.00	0.01	0.01	0.00	0.04	0.31	0.22	0.00	97.33
	JM/01	Turquoise	25-02-2013	II	62.78	20.56	1.66	1.40	0.81	5.25	1.18	0.38	0.00	0.17	3.68	0.01	0.00	0.00	0.02	0.05	0.09	0.24	0.22	0.00	98.48
	JM/01	Turquoise	25-02-2013	III	63.40	20.20	1.64	1.44	0.61	4.76	0.91	0.24	0.00	0.15	3.62	0.00	0.02	0.02	0.00	0.00	0.04	0.27	0.20	0.00	97.52
	JM/01	Turquoise	25-02-2013	IV	65.16	21.28	1.82	1.45	0.60	3.90	0.89	0.15	0.02	0.14	4.11	0.01	0.02	0.02	0.06	0.00	0.01	0.22	0.22	0.00	100.06
	JM/01	Turquoise	25-02-2013	V	63.61	21.08	1.50	1.47	0.71	6.03	2.27	0.30	0.00	0.14	3.28	0.01	0.00	0.07	0.02	0.09	0.05	0.36	0.31	0.00	101.30
	JM/01	Turquoise	25-02-2013	Average	63.69	20.76	1.67	1.43	0.68	4.78	1.22	0.26	0.00	0.15	3.65	0.01	0.01	0.02	0.02	0.03	0.05	0.28	0.23	0.00	98.94
	JM/01	Turquoise	25-02-2013	Std. Dev.	0.88	0.43	0.12	0.04	0.08	0.90	0.60	0.09	0.01	0.01	0.30	0.00	0.01	0.03	0.02	0.04	0.03	0.06	0.04	0.00	
22	JM/02	Turquoise	25-02-2013	I	63.50	20.22	1.64	1.44	0.73	4.72	1.13	0.24	0.01	0.17	3.85	0.00	0.00	0.08	0.02	0.10	0.05	0.35	0.21	0.00	98.45
	JM/02	Turquoise	25-02-2013	II	63.82	20.29	1.73	1.46	0.69	4.41	1.01	0.24	0.00	0.14	3.77	0.02	0.00	0.00	0.03	0.18	0.03	0.27	0.19	0.00	98.28
	JM/02	Turquoise	25-02-2013	III	63.44	20.49	1.60	1.40	0.41	4.22	1.04	0.20	0.00	0.16	3.79	0.00	0.00	0.07	0.01	0.15	0.00	0.25	0.26	0.00	97.49
	JM/02	Turquoise	25-02-2013	IV	63.36	19.21	1.69	1.50	0.63	4.46	1.12	0.26	0.00	0.17	3.91	0.00	0.00	0.05	0.00	0.03	0.08	0.29	0.24	0.00	97.00
	JM/02	Turquoise	25-02-2013	V	62.45	20.60	1.53	1.44	0.83	5.38	1.26	0.29	0.00	0.14	3.76	0.00	0.02	0.00	0.01	0.04	0.04	0.31	0.21	0.00	98.30

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	JM/02	**Turquoise**	**25-02-2013**	**Average**	**63.31**	**20.16**	**1.64**	**1.45**	**0.66**	**4.64**	**1.11**	**0.24**	**0.00**	**0.16**	**3.82**	**0.00**	**0.00**	**0.04**	**0.01**	**0.10**	**0.04**	**0.29**	**0.22**	**0.00**	**97.90**
	JM/02	**Turquoise**	**25-02-2013**	**Std. Dev.**	**0.51**	**0.55**	**0.08**	**0.04**	**0.16**	**0.45**	**0.10**	**0.03**	**0.01**	**0.01**	**0.06**	**0.01**	**0.01**	**0.04**	**0.01**	**0.07**	**0.03**	**0.04**	**0.03**	**0.00**	
23	JM/03	Turquoise	25-02-2013	I	63.04	20.11	1.63	1.46	0.63	5.32	1.11	0.30	0.00	0.16	3.92	0.00	0.02	0.05	0.00	0.00	0.04	0.29	0.19	0.00	98.24
	JM/03	Turquoise	25-02-2013	II	63.38	19.62	1.49	1.46	0.44	4.82	1.20	0.27	0.00	0.17	3.75	0.00	0.00	0.00	0.00	0.06	0.03	0.23	0.17	0.00	97.07
	JM/03	Turquoise	25-02-2013	III	62.63	20.24	1.31	1.43	0.62	5.57	1.08	0.31	0.00	0.14	3.79	0.00	0.06	0.00	0.00	0.12	0.02	0.25	0.19	0.00	97.76
	JM/03	Turquoise	25-02-2013	IV	63.00	19.92	1.55	1.51	0.68	5.14	1.18	0.27	0.00	0.15	4.02	0.00	0.00	0.00	0.05	0.00	0.00	0.30	0.16	0.00	97.92
	JM/03	Turquoise	25-02-2013	V	63.88	20.20	1.61	1.37	0.75	4.77	1.08	0.25	0.00	0.13	3.83	0.00	0.03	0.01	0.02	0.11	0.03	0.32	0.24	0.00	98.62
	JM/03	**Turquoise**	**25-02-2013**	**Average**	**63.19**	**20.02**	**1.52**	**1.44**	**0.62**	**5.12**	**1.13**	**0.28**	**0.00**	**0.15**	**3.86**	**0.00**	**0.02**	**0.01**	**0.01**	**0.06**	**0.02**	**0.28**	**0.19**	**0.00**	**97.92**
	JM/03	**Turquoise**	**25-02-2013**	**Std. Dev.**	**0.47**	**0.26**	**0.13**	**0.05**	**0.12**	**0.34**	**0.06**	**0.02**	**0.00**	**0.01**	**0.11**	**0.00**	**0.02**	**0.02**	**0.02**	**0.06**	**0.01**	**0.04**	**0.03**	**0.00**	
24	JM/04	Turquoise	26-11-2013	I	65.90	19.66	1.06	1.28	0.33	2.96	0.78	0.12	0.00	0.03	4.80	0.01	0.00	0.04	0.04	0.48	0.06	0.24	0.22	0.00	98.01
	JM/04	Turquoise	26-11-2013	II	65.55	19.89	1.08	1.29	0.36	2.93	0.86	0.13	0.00	0.00	5.08	0.00	0.00	0.00	0.05	0.49	0.05	0.25	0.21	0.00	98.22
	JM/04	Turquoise	26-11-2013	III	65.03	19.35	1.02	1.26	0.45	2.92	0.80	0.14	0.00	0.03	5.78	0.00	0.01	0.00	0.06	0.46	0.01	0.31	0.19	0.00	97.81
	JM/04	Turquoise	26-11-2013	IV	65.12	20.22	1.10	1.25	0.28	2.96	0.76	0.16	0.00	0.00	4.88	0.01	0.00	0.00	0.01	0.47	0.03	0.25	0.15	0.00	97.65
	JM/04	Turquoise	26-11-2013	V	65.49	19.80	1.04	1.27	0.41	2.89	0.71	0.12	0.01	0.04	5.07	0.00	0.01	0.00	0.00	0.54	0.03	0.23	0.19	0.00	97.83
	JM/04	**Turquoise**	**26-11-2013**	**Average**	**65.42**	**19.78**	**1.06**	**1.27**	**0.37**	**2.93**	**0.78**	**0.13**	**0.00**	**0.02**	**5.12**	**0.00**	**0.00**	**0.01**	**0.03**	**0.49**	**0.04**	**0.26**	**0.19**	**0.00**	**97.90**
	JM/04	**Turquoise**	**26-11-2013**	**Std. Dev.**	**0.35**	**0.32**	**0.03**	**0.01**	**0.07**	**0.03**	**0.05**	**0.02**	**0.00**	**0.02**	**0.39**	**0.00**	**0.00**	**0.02**	**0.03**	**0.03**	**0.02**	**0.03**	**0.03**	**0.00**	
25	JM/05	Turquoise	26-11-2013	I	65.48	18.71	1.59	2.07	1.15	1.94	0.60	0.09	0.00	0.01	5.40	0.02	0.00	0.03	0.02	0.05	0.02	0.47	0.29	0.00	97.93
	JM/05	Turquoise	26-11-2013	II	65.35	18.61	1.61	2.24	1.17	1.98	0.62	0.10	0.00	0.00	5.00	0.00	0.05	0.00	0.04	0.05	0.00	0.44	0.22	0.00	97.48
	JM/05	Turquoise	26-11-2013	III	64.28	18.35	1.69	2.13	1.13	1.92	0.58	0.09	0.00	0.06	6.07	0.00	0.00	0.00	0.02	0.00	0.04	0.36	0.21	0.00	96.91
	JM/05	Turquoise	26-11-2013	IV	64.55	19.13	1.83	2.44	1.01	1.87	0.53	0.08	0.00	0.01	5.51	0.01	0.00	0.01	0.00	0.00	0.04	0.38	0.22	0.00	97.61
	JM/05	Turquoise	26-11-2013	V	64.90	18.69	1.74	2.50	1.17	1.91	0.56	0.08	0.00	0.00	5.57	0.01	0.00	0.01	0.00	0.06	0.06	0.29	0.23	0.00	97.76
	JM/05	**Turquoise**	**26-11-2013**	**Average**	**64.91**	**18.70**	**1.69**	**2.28**	**1.12**	**1.92**	**0.58**	**0.09**	**0.00**	**0.01**	**5.51**	**0.01**	**0.01**	**0.01**	**0.02**	**0.03**	**0.03**	**0.39**	**0.23**	**0.00**	**97.54**
	JM/05	**Turquoise**	**26-11-2013**	**Std. Dev.**	**0.51**	**0.28**	**0.10**	**0.19**	**0.07**	**0.04**	**0.04**	**0.01**	**0.00**	**0.03**	**0.38**	**0.01**	**0.02**	**0.01**	**0.02**	**0.03**	**0.02**	**0.07**	**0.03**	**0.00**	

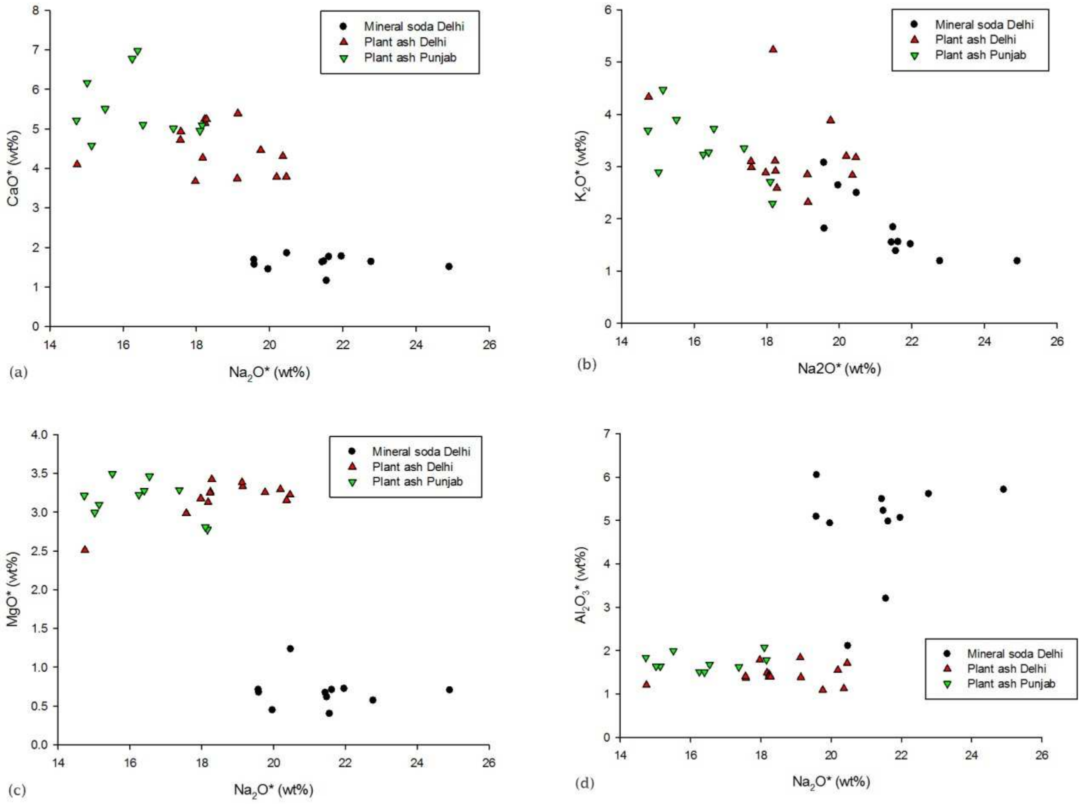
Appendix 6.9 Chemical compositions of the tile glazes from Lodhi buildings at Punjab determined through EPMA-WDS analyses. All results are in wt%.

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
1	BT/01	Turquoise	12-12-2013	I	62.83	15.03	4.26	3.11	2.81	1.57	0.60	0.03	0.00	0.05	3.37	0.00	0.07	0.00	0.04	0.05	0.03	0.41	0.23	0.00	94.47
	BT/01	Turquoise	12-12-2013	II	62.94	16.04	4.76	3.08	2.99	1.28	0.51	0.05	0.00	0.03	4.52	0.00	0.09	0.00	0.03	0.00	0.00	0.60	0.21	0.00	97.13
	BT/01	Turquoise	12-12-2013	III	62.84	16.46	4.85	2.99	3.17	1.57	0.57	0.07	0.00	0.05	4.45	0.00	0.13	0.00	0.02	0.08	0.04	0.58	0.18	0.00	98.02
	BT/01	Turquoise	12-12-2013	IV	61.67	15.99	4.36	3.05	2.92	1.49	0.50	0.04	0.00	0.03	4.06	0.00	0.07	0.00	0.04	0.05	0.04	0.56	0.21	0.00	95.07
	BT/01	Turquoise	12-12-2013	V	63.01	15.70	4.63	3.07	3.11	1.50	0.52	0.05	0.00	0.03	4.14	0.00	0.06	0.00	0.03	0.02	0.00	0.55	0.15	0.00	96.56
	BT/01	**Turquoise**	**12-12-2013**	**Average**	**62.66**	**15.84**	**4.57**	**3.06**	**3.00**	**1.48**	**0.54**	**0.05**	**0.00**	**0.04**	**4.11**	**0.00**	**0.08**	**0.00**	**0.03**	**0.04**	**0.02**	**0.54**	**0.20**	**0.00**	**96.25**
	BT/01	**Turquoise**	**12-12-2013**	**Std. Dev.**	**0.56**	**0.53**	**0.26**	**0.05**	**0.15**	**0.12**	**0.04**	**0.01**	**0.00**	**0.01**	**0.45**	**0.00**	**0.03**	**0.00**	**0.01**	**0.03**	**0.02**	**0.07**	**0.03**	**0.00**	
2	BT/02	Turquoise	12-12-2013	I	65.85	14.09	5.81	2.92	2.95	1.71	0.58	0.02	0.00	0.03	3.76	0.01	0.12	0.00	0.00	0.21	0.06	0.70	0.21	0.00	99.02
	BT/02	Turquoise	12-12-2013	II	61.40	16.20	6.90	2.85	3.30	1.45	0.54	0.09	0.00	0.02	4.86	0.00	0.11	0.04	0.05	0.12	0.04	0.64	0.19	0.00	98.78
	BT/02	Turquoise	12-12-2013	III	66.68	14.05	5.67	3.19	2.66	1.20	0.46	0.04	0.00	0.05	3.69	0.00	0.12	0.00	0.00	0.00	0.00	0.51	0.15	0.00	98.46
	BT/02	Turquoise	12-12-2013	IV	61.55	16.14	6.91	3.00	3.24	1.26	0.55	0.08	0.07	0.05	4.61	0.00	0.21	0.01	0.03	0.13	0.05	0.69	0.23	0.00	98.81
	BT/02	Turquoise	12-12-2013	V	63.44	15.30	6.29	3.12	2.90	1.45	0.45	0.07	0.00	0.06	4.38	0.00	0.09	0.00	0.00	0.05	0.03	0.68	0.15	0.00	98.45
	BT/02	**Turquoise**	**12-12-2013**	**Average**	**63.78**	**15.16**	**6.32**	**3.02**	**3.01**	**1.41**	**0.52**	**0.06**	**0.01**	**0.04**	**4.26**	**0.00**	**0.13**	**0.01**	**0.02**	**0.10**	**0.04**	**0.64**	**0.19**	**0.00**	**98.70**
	BT/02	**Turquoise**	**12-12-2013**	**Std. Dev.**	**2.42**	**1.05**	**0.58**	**0.14**	**0.26**	**0.20**	**0.06**	**0.03**	**0.03**	**0.01**	**0.52**	**0.00**	**0.04**	**0.02**	**0.02**	**0.08**	**0.02**	**0.08**	**0.04**	**0.00**	
3	BT/03	Turquoise	12-12-2013	I	61.89	15.96	6.33	2.95	2.95	1.21	0.44	0.04	0.00	0.08	4.20	0.00	0.08	0.00	0.06	0.05	0.03	0.69	0.23	0.00	97.18
	BT/03	Turquoise	12-12-2013	II	62.71	15.58	6.14	3.05	2.88	1.41	0.46	0.07	0.00	0.03	4.26	0.00	0.13	0.02	0.03	0.00	0.03	0.73	0.18	0.00	97.71
	BT/03	Turquoise	12-12-2013	III	61.89	15.63	6.91	2.89	3.16	1.47	0.62	0.04	0.10	0.07	4.30	0.00	0.09	0.00	0.00	0.01	0.00	0.89	0.32	0.00	98.39
	BT/03	Turquoise	12-12-2013	IV	63.21	15.11	6.74	3.16	3.31	1.50	0.50	0.04	0.03	0.04	3.70	0.00	0.11	0.05	0.02	0.18	0.03	0.78	0.26	0.00	98.74
	BT/03	Turquoise	12-12-2013	V	64.58	13.53	6.16	3.10	2.84	1.35	0.51	0.07	0.00	0.03	3.71	0.00	0.07	0.00	0.03	0.08	0.07	0.56	0.22	0.00	96.90
	BT/03	**Turquoise**	**12-12-2013**	**Average**	**62.86**	**15.16**	**6.45**	**3.03**	**3.03**	**1.39**	**0.51**	**0.05**	**0.02**	**0.05**	**4.03**	**0.00**	**0.10**	**0.01**	**0.03**	**0.06**	**0.03**	**0.73**	**0.24**	**0.00**	**97.78**
	BT/03	**Turquoise**	**12-12-2013**	**Std. Dev.**	**1.11**	**0.96**	**0.35**	**0.11**	**0.20**	**0.12**	**0.07**	**0.02**	**0.04**	**0.02**	**0.30**	**0.00**	**0.02**	**0.02**	**0.02**	**0.07**	**0.02**	**0.12**	**0.05**	**0.00**	
4	BT/04	Turquoise	12-12-2013	I	64.86	14.48	4.26	4.34	2.90	1.72	0.60	0.07	0.00	0.05	3.77	0.00	0.14	0.00	0.00	0.00	0.04	0.49	0.24	0.00	97.95
	BT/04	Turquoise	12-12-2013	II	66.02	14.15	4.22	4.45	2.97	1.53	0.43	0.04	0.00	0.03	2.91	0.01	0.06	0.00	0.03	0.02	0.00	0.45	0.24	0.00	97.53
	BT/04	Turquoise	12-12-2013	III	67.19	13.37	3.89	4.05	2.68	1.47	0.51	0.05	0.05	0.05	3.20	0.01	0.12	0.00	0.00	0.00	0.01	0.41	0.22	0.00	97.26
	BT/04	Turquoise	12-12-2013	IV	65.77	15.03	5.06	3.86	3.29	1.36	0.57	0.07	0.00	0.00	3.44	0.01	0.24	0.02	0.12	0.00	0.03	0.56	0.29	0.00	99.71
	BT/04	Turquoise	12-12-2013	V	66.22	13.91	4.04	4.25	2.68	1.63	0.49	0.09	0.00	0.01	3.62	0.00	0.07	0.00	0.00	0.06	0.00	0.49	0.23	0.00	97.78
	BT/04	**Turquoise**	**12-12-2013**	**Average**	**66.01**	**14.19**	**4.29**	**4.19**	**2.90**	**1.54**	**0.52**	**0.06**	**0.01**	**0.03**	**3.39**	**0.01**	**0.13**	**0.00**	**0.03**	**0.02**	**0.02**	**0.48**	**0.24**	**0.00**	**98.05**
	BT/04	**Turquoise**	**12-12-2013**	**Std. Dev.**	**0.84**	**0.62**	**0.45**	**0.24**	**0.25**	**0.14**	**0.07**	**0.02**	**0.02**	**0.02**	**0.34**	**0.00**	**0.07**	**0.01**	**0.05**	**0.03**	**0.02**	**0.06**	**0.03**	**0.00**	
5	BT/05	Turquoise	12-12-2013	I	64.16	15.46	4.58	3.57	3.12	1.56	0.56	0.04	0.00	0.05	3.55	0.00	0.13	0.01	0.03	0.04	0.07	0.49	0.23	0.00	97.65
	BT/05	Turquoise	12-12-2013	II	64.00	15.66	5.08	3.52	3.31	1.56	0.53	0.10	0.00	0.04	3.32	0.00	0.10	0.00	0.02	0.00	0.00	0.56	0.27	0.00	98.06
	BT/05	Turquoise	12-12-2013	III	63.65	15.70	4.81	3.44	3.22	1.46	0.54	0.04	0.00	0.05	3.57	0.00	0.14	0.03	0.02	0.06	0.00	0.49	0.29	0.00	97.50
	BT/05	Turquoise	12-12-2013	IV	64.68	15.36	4.52	3.50	3.21	1.59	0.74	0.09	0.00	0.03	2.97	0.00	0.10	0.00	0.02	0.02	0.01	0.46	0.32	0.00	97.60
	BT/05	Turquoise	12-12-2013	V	65.34	15.26	4.92	3.42	3.34	1.70	0.65	0.08	0.00	0.04	2.66	0.00	0.09	0.00	0.00	0.03	0.04	0.54	0.24	0.00	98.35
	BT/05	**Turquoise**	**12-12-2013**	**Average**	**64.37**	**15.49**	**4.78**	**3.49**	**3.24**	**1.57**	**0.60**	**0.07**	**0.00**	**0.04**	**3.21**	**0.00**	**0.11**	**0.01**	**0.02**	**0.03**	**0.02**	**0.51**	**0.27**	**0.00**	**97.83**
	BT/05	**Turquoise**	**12-12-2013**	**Std. Dev.**	**0.66**	**0.19**	**0.23**	**0.06**	**0.09**	**0.09**	**0.09**	**0.03**	**0.00**	**0.01**	**0.39**	**0.00**	**0.02**	**0.01**	**0.01**	**0.02**	**0.03**	**0.04**	**0.04**	**0.00**	
6	BT/06	Turquoise	13-12-2013	I	65.50	14.35	5.68	2.72	2.77	1.79	0.54	0.07	0.00	0.10	3.24	0.01	0.03	0.08	0.01	0.00	0.04	0.64	0.20	0.00	97.77
	BT/06	Turquoise	13-12-2013	II	64.20	14.55	6.11	2.67	3.30	1.77	0.52	0.09	0.00	0.12	3.19	0.00	0.07	0.00	0.08	0.01	0.00	0.68	0.20	0.00	97.55
	BT/06	Turquoise	13-12-2013	III	66.33	13.83	5.48	2.74	2.70	1.41	0.95	0.04	0.04	0.08	2.92	0.00	0.04	0.04	0.05	0.00	0.01	0.50	0.17	0.00	97.32
	BT/06	Turquoise	13-12-2013	IV	66.96	14.55	6.30	2.74	2.93	1.69	0.47	0.12	0.00	0.09	3.12	0.00	0.11	0.10	0.01	0.26	0.02	0.07	0.38	0.00	99.89
	BT/06	Turquoise	13-12-2013	V	70.08	13.63	5.56	2.80	2.45	1.08	0.57	0.11	0.00	0.09	2.73	0.00	0.00	0.00	0.00	0.08	0.00	0.46	0.28	0.00	99.93
	BT/06	**Turquoise**	**13-12-2013**	**Average**	**66.61**	**14.18**	**5.82**	**2.73**	**2.83**	**1.55**	**0.61**	**0.09**	**0.01**	**0.09**	**3.04**	**0.00**	**0.05**	**0.04**	**0.03**	**0.07**	**0.01**	**0.47**	**0.24**	**0.00**	**98.49**
	BT/06	**Turquoise**	**13-12-2013**	**Std. Dev.**	**2.20**	**0.42**	**0.36**	**0.05**	**0.32**	**0.30**	**0.19**	**0.03**	**0.02**	**0.02**	**0.21**	**0.00**	**0.04**	**0.04**	**0.04**	**0.11**	**0.02**	**0.24**	**0.09**	**0.00**	
7	HM/01	Turquoise	13-12-2014	I	64.02	17.46	4.93	2.14	2.70	1.64	0.49	0.08	0.00	0.04	4.75	0.00	0.05	0.02	0.01	0.00	0.00	0.43	0.16	0.01	98.94
	HM/01	Turquoise	13-12-2014	II	63.21	17.61	5.20	2.12	2.76	1.78	0.53	0.08	0.00	0.05	4.98	0.00	0.06	0.02	0.01	0.00	0.00	0.43	0.16	0.01	99.00

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	HM/01	Turquoise	13-12-2014	III	67.49	15.97	4.18	2.19	2.34	1.61	0.47	0.08	0.00	0.04	3.93	0.00	0.04	0.01	0.01	0.00	0.00	0.43	0.14	0.00	98.92
	HM/01	**Turquoise**	**13-12-2014**	**Average**	**64.91**	**17.01**	**4.77**	**2.15**	**2.60**	**1.68**	**0.50**	**0.08**	**0.00**	**0.04**	**4.55**	**0.00**	**0.05**	**0.02**	**0.01**	**0.00**	**0.00**	**0.43**	**0.15**	**0.01**	**98.95**
	HM/01	**Turquoise**	**13-12-2014**	**Std. Dev.**	**2.27**	**0.91**	**0.53**	**0.04**	**0.23**	**0.09**	**0.03**	**0.00**	**0.00**	**0.00**	**0.55**	**0.00**	**0.01**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	
8	HM/02	Turquoise	13-12-2014	I	65.49	17.02	4.47	2.49	2.53	1.69	0.55	0.10	0.00	0.03	2.63	0.00	0.03	0.04	0.00	0.01	0.00	0.61	0.76	0.00	98.47
	HM/02	Turquoise	13-12-2014	II	65.06	17.59	4.67	2.50	2.90	1.77	0.51	0.08	0.00	0.04	2.63	0.00	0.17	0.04	0.00	0.03	0.00	0.52	0.14	0.00	98.65
	HM/02	Turquoise	13-12-2014	III	65.35	16.99	4.98	2.74	2.58	2.47	0.51	0.08	0.00	0.04	2.35	0.00	0.02	0.04	0.00	0.02	0.00	0.47	0.14	0.00	98.78
	HM/02	**Turquoise**	**13-12-2014**	**Average**	**65.30**	**17.20**	**4.71**	**2.57**	**2.67**	**1.98**	**0.52**	**0.09**	**0.00**	**0.04**	**2.54**	**0.00**	**0.07**	**0.04**	**0.00**	**0.02**	**0.00**	**0.53**	**0.35**	**0.00**	**98.63**
	HM/02	**Turquoise**	**13-12-2014**	**Std. Dev.**	**0.22**	**0.34**	**0.26**	**0.14**	**0.20**	**0.43**	**0.02**	**0.01**	**0.00**	**0.00**	**0.16**	**0.00**	**0.08**	**0.00**	**0.00**	**0.01**	**0.00**	**0.07**	**0.36**	**0.00**	
9	HM/03	Turquoise	13-12-2014	I	63.92	14.52	5.27	3.62	3.21	1.81	0.61	0.15	0.00	0.03	4.56	0.00	0.00	0.02	0.01	0.01	0.00	0.73	0.24	0.01	98.73
	HM/03	Turquoise	13-12-2014	II	63.78	14.28	5.28	3.57	3.17	2.02	0.82	0.11	0.00	0.04	4.40	0.00	0.00	0.07	0.01	0.02	0.00	0.25	0.23	0.02	98.08
	HM/03	Turquoise	13-12-2014	III	64.05	14.49	4.82	3.69	3.37	1.74	0.69	0.10	0.00	0.04	4.61	0.00	0.00	0.04	0.02	0.02	0.00	0.24	0.24	0.01	98.17
	HM/03	**Turquoise**	**13-12-2014**	**Average**	**63.92**	**14.43**	**5.12**	**3.63**	**3.25**	**1.86**	**0.71**	**0.12**	**0.00**	**0.04**	**4.52**	**0.00**	**0.00**	**0.04**	**0.01**	**0.02**	**0.00**	**0.41**	**0.24**	**0.01**	**98.33**
	HM/03	**Turquoise**	**13-12-2014**	**Std. Dev.**	**0.14**	**0.13**	**0.26**	**0.06**	**0.11**	**0.15**	**0.11**	**0.03**	**0.00**	**0.01**	**0.11**	**0.00**	**0.00**	**0.02**	**0.01**	**0.01**	**0.00**	**0.28**	**0.01**	**0.01**	
10	HM/04	Turquoise	13-12-2014	I	65.18	13.49	4.64	3.45	2.92	1.73	0.51	0.11	0.00	0.06	4.09	0.00	0.00	0.04	0.02	0.03	0.00	0.34	0.26	0.01	96.88
	HM/04	Turquoise	13-12-2014	II	64.79	13.76	4.82	3.33	2.91	1.65	0.58	0.11	0.00	0.05	4.11	0.00	0.00	0.04	0.02	0.03	0.00	0.42	0.28	0.01	96.92
	HM/04	Turquoise	13-12-2014	III	64.55	13.33	4.91	3.39	3.02	1.70	0.54	0.10	0.00	0.06	4.31	0.00	0.00	0.05	0.02	0.03	0.00	0.50	0.27	0.01	96.79
	HM/04	**Turquoise**	**13-12-2014**	**Average**	**64.84**	**13.53**	**4.79**	**3.39**	**2.95**	**1.69**	**0.54**	**0.11**	**0.00**	**0.05**	**4.17**	**0.00**	**0.00**	**0.04**	**0.02**	**0.03**	**0.00**	**0.42**	**0.27**	**0.01**	**96.86**
	HM/04	**Turquoise**	**13-12-2014**	**Std. Dev.**	**0.32**	**0.22**	**0.14**	**0.06**	**0.06**	**0.04**	**0.04**	**0.01**	**0.00**	**0.00**	**0.12**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.08**	**0.01**	**0.00**	



Appendix 6.10 Scatter plots of (a) alumina versus iron oxide, (b) alumina versus titanium oxide, (c) lime versus magnesia, (d) alumina versus potash, (e) alumina versus magnesia, and (f) alumina versus silica contents of the Lodhi tile glazes. '*' indicates reduced composition.



Appendix 6.11 Scatter plots of (a) soda versus lime (b) soda versus potash (c) soda versus magnesia and (d) soda versus alumina contents of the Lodhi tile glazes. '*' indicates reduced composition.

Appendix 6.12 Chemical compositions of individual copper-containing particles found in the Lodhi turquoise coloured glazes. All results are in wt% from SEM-EDS analyses, and normalised to 100%. '-' indicates ‘not detected’ or 'below detection limit’.

Sample	Particle	Na_2O	MgO	Al_2O_3	SiO_2	SO_3	K_2O	CaO	Fe_2O_3	CuO	ZnO	Ag_2O	SnO_2	PbO	Total
BAG/01	I	-	-	-	1.9	-	-	0.9	-	97.2	-	-		-	100.0
BAG/01	II	6.5	-	3.3	10.4	-	-	2.8	0.5	76.6	-	-		-	100.0
BAG/02	I	3.7	0.5	-	6.0	-	-	-	-	87.7	-	-	2.2	-	100.0
BAG/02	II	-	-	-	7.2	-	-	0.9	-	91.9	-	-	-	-	100.0
SG/03	I	-	-	-	0.4	-	-	-	-	99.6	-	-	-	-	100.0
SG/03	II	-	-	-	1.4	-	-	0.9	-	97.7	-	-	-	-	100.0
SG/04	I	-	-	-	0.7	36.2	-	-	-	62.6	-	0.5	-	-	100.0
SG/04	II	-	-	-	0.6	45.9	-	-	-	53.5	-	-	-	-	100.0
SL/05	I	-	-	-	0.8	-	-	-	0.8	59.2	37.5	-	-	1.7	100.0
BT/01	I	1.3	-	-	4.2	2.6	-	-	-	91.9	-	-	-	-	100.0
BT/05	I	-	-	-	2.8	30.2	0.3	0.3	-	66.0	-	0.5	-	-	100.0

Appendix 6.13 Chemical compositions of individual cobalt-containing particles found in the Lodhi dark-blue coloured glazes. All results are in wt% from SEM-EDS analyses, and normalised to 100%. '-' indicates ‘not detected’ or 'below detection limit’.

Sample	Particle	Na_2O	MgO	Al_2O_3	SiO_2	CaO	Fe_2O_3	CoO	NiO	Total
SG/05	I	-	-	2.7	3.7	0.5	56.3	9.2	27.6	100.0
SG/05	II	-	-	1.2	3.5	0.4	60.7	18.6	15.6	100.0
SG/06	I	-	-	1.0	2.6	0.4	61.7	29.4	5.0	100.0
SG/09	I	1.8	1.6	-	7.2	1.0	64.2	17.1	7.1	100.0
SG/10	I	1.1	-	1.2	3.6	0.5	55.0	27.1	11.6	100.0
SG/10	II	9.7	1.4	-	38.7	2.6	38.9	8.8	-	100.0

Appendix 7.1 List of tile-embellished buildings of the Mughal era at Delhi, Punjab, and other locations alongside the Badshahi Sadak. Buildings taken up for a detailed study are highlighted in bold. The buildings are listed by region, and within the region in their most probable chronological order.

No.	Building	Region	Date/Period	Typology
1	Tomb of Jamali-Kamali	Delhi	1528-1529 CE	Tomb
2	Tomb of Yusuf Qattal	Delhi	c. 1530 CE	Tomb
3	**Humayun Darwaza**	**Delhi**	**16th century**	**Fort gateway**
4	Talaqi Darwaza	Delhi	16th century	Fort gateway
5	Bada Darwaza (Sur period)	Delhi	16th century	Fort gateway
6	Lal Darwaza (Sur period)	Delhi	16th century	Gateway
7	Sher Mandal (Sur period)	Delhi	16th century	Watch tower
8	**Tomb of Isa Khan** (Sur period)	**Delhi**	**1547-1548 CE**	**Tomb**
9	**Arab-ki Sarai**	**Delhi**	**c. 1560 CE**	**Sarai gateway**
10	**Khairul Manzil Masjid**	**Delhi**	**1561-1562 CE**	**Mosque**
11	Tomb of Humayun	Delhi	1565-1566 CE	Tomb
12	Nili Chhatri	Delhi	1566 CE	Tomb
13	**Tomb of Atgah Khan**	**Delhi**	**1566-1567 CE**	**Tomb**
14	Mosque at Delhi Gate	Delhi	1575 CE	Mosque
15	**Sabz Burj**	**Delhi**	**16th century**	**Tomb**
16	Chini-ka Burj	Delhi	16th century	Watch tower
17	Nai-ka Gumbad	Delhi	1590-1591 CE	Tomb
18	Mihir Banu Gate	Delhi	17th century	Sarai gateway
19	**Nila Gumbad**	**Delhi**	**c. 1625 CE**	**Tomb**
20	**Tomb of Quli Khan**	**Delhi**	**17th century**	**Tomb**
21	Dargah of Qutbuddin Md. Kaki	Delhi	17th century	Shrine
22	Roshanara Bagh	Delhi	17th century	Garden gateway
23	Humayun's Mosque	Agra	16th century	Mosque
24	Jehangiri Mahal	Agra	16th century	Royal apartment
25	Tomb of Akbar	Agra	17th century	Tomb
26	**Kanch Mahal**	**Agra**	**17th century**	**Royal apartment**
27	Amar Singh Gate	Agra	17th century	Fort gateway
28	**Naubat Khana**	**Agra**	**17th century**	**Fort building**
29	Tomb of Firoz Khan	Agra	17th century	Tomb
30	**Chini-ka Rauza**	**Agra**	**c. 1639 CE**	**Tomb**
31	Chini-wali Masjid	Haryana	1565-1566 CE	Mosque
32	Tomb of Sheikh Chillie	Haryana	17th century	Tomb
33	**Doraha Sarai**	**Punjab**	**17th century**	**Sarai gateway**
34	**Fatehabad Sarai**	**Punjab**	**17th century**	**Sarai gateway**
35	**Tomb of Ustad**	**Punjab**	**1612 CE**	**Tomb**
36	**Sheesh Mahal**	**Punjab**	**c. 1634 CE**	**Royal apartment**
37	**Dakhini Sarai**	**Punjab**	**17th century**	**Sarai gateway and mosque**
38	Sarai Amanat Khan	Punjab	17th century	Sarai gateway and mosque
39	Mosque at Raja Taal	Punjab	17th century	Mosque
40	**Tomb of Shagird**	**Punjab**	**1657 CE**	**Tomb**
41	Tomb of Shaikh Ahmad Sirhindi	Punjab	17th century	Tomb
42	Tomb at Shaikhpura	Punjab	17th century	Tomb
43	Tomb of Khwaja Muhammad Masum	Punjab	17th century	Tomb
44	Mosque near Rauza Sharif	Punjab	17th century	Mosque

Appendix 7.2 Average chemical compositions of the tile bodies from Mughal buildings at Delhi determined through SEM-EDS analyses. All results are in wt%. Results below the detection limit of the instrument are provided for comparative purposes only.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
1	IK/02	White	Tomb of Isa Khan	97.0	1.1	0.3	0.3	0.1	0.7	0.5	100.0
2	IK/04	Dark-Blue	Tomb of Isa Khan	94.8	2.1	0.4	0.5	0.3	1.3	0.6	100.0
3	IK/05	Dark-Blue	Tomb of Isa Khan	95.4	1.5	0.4	0.4	0.3	1.4	0.6	100.0
4	AS/01	Green	Arab-ki Sarai	95.2	1.5	0.6	0.5	0.4	1.2	0.5	100.0
5	AS/02	Dark-Blue	Arab-ki Sarai	94.6	2.0	0.5	0.5	0.3	1.5	0.7	100.0
6	AS/03	Dark-Blue	Arab-ki Sarai	95.1	2.1	0.5	0.5	0.3	1.0	0.5	100.0
7	AS/04	Yellow	Arab-ki Sarai	94.6	1.9	0.6	0.5	0.4	1.5	0.5	100.0
8	AK/01	Yellow	Tomb of Atgah Khan	94.3	2.0	0.4	0.6	0.2	1.8	0.6	100.0
9	AK/02	Turquoise	Tomb of Atgah Khan	95.4	1.6	0.5	0.4	0.3	1.3	0.5	100.0
10	AK/03	Turquoise	Tomb of Atgah Khan	94.7	1.8	0.5	0.4	0.3	1.7	0.6	100.0
11	SB/01	Dark-Blue	Sabz Burj	96.6	1.0	0.3	0.4	0.3	1.1	0.4	100.0
12	NG/01	White	Nila Gumbad	95.2	2.1	0.3	0.6	0.3	1.0	0.5	100.0
13	NG/02	Yellow	Nila Gumbad	96.4	1.3	0.3	0.5	0.2	1.0	0.3	100.0
14	NG/04	Turquoise	Nila Gumbad	95.6	1.4	0.3	0.6	0.2	1.3	0.6	100.0
15	NG/05	Green	Nila Gumbad	94.8	1.6	0.6	0.6	0.4	1.3	0.7	100.0
16	NG/07	Yellow	Nila Gumbad	96.6	1.2	0.6	0.4	0.3	0.6	0.3	100.0
17	NG/08	Dark-Blue	Nila Gumbad	95.3	1.9	0.5	0.6	0.2	1.0	0.4	100.0
18	NG/09	Dark-Blue	Nila Gumbad	94.9	1.7	0.4	0.5	0.3	1.4	0.8	100.0
19	NG/11	Turquoise	Nila Gumbad	94.0	2.3	0.8	0.6	0.5	1.3	0.6	100.0
20	NG/14	Turquoise	Nila Gumbad	95.3	1.9	0.5	0.5	0.1	1.1	0.5	100.0
21	NG/15	Dark-Blue	Nila Gumbad	95.0	1.8	0.4	0.4	0.4	1.3	0.7	100.0
22	NG/16	White	Nila Gumbad	96.4	1.1	0.3	0.5	0.4	0.9	0.3	100.0
23	NG/17	Green	Nila Gumbad	94.7	1.9	0.4	0.6	0.3	1.6	0.5	100.0
24	QK/02	Dark-Blue	Tomb of Quli Khan	95.2	1.3	0.4	0.5	0.4	1.6	0.6	100.0

Appendix 7.3 Average chemical compositions of the tile bodies from Mughal buildings at Agra determined through SEM-EDS analyses. All results are in wt%. Results below the detection limit of the instrument are provided for comparative purposes only. '-' indicates ‘not detected’.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
1	CR/01	Purple	Chini-ka Rauza	95.8	1.2	0.4	0.6	0.2	1.4	0.4	100.0
2	CR/02	Purple	Chini-ka Rauza	95.2	1.3	0.4	0.7	0.3	1.6	0.4	100.0
3	CR/03	Yellow	Chini-ka Rauza	96.7	0.7	0.4	0.5	0.2	1.1	0.4	100.0
4	CR/04	Yellow	Chini-ka Rauza	95.5	1.4	0.3	0.5	0.2	1.7	0.3	100.0
5	CR/05	Green	Chini-ka Rauza	96.4	1.0	0.3	0.5	0.2	1.2	0.3	100.0
6	CR/06	Green	Chini-ka Rauza	96.7	0.6	0.3	0.6	0.2	1.1	0.3	100.0
7	CR/08	Dark-Blue	Chini-ka Rauza	96.9	0.9	0.5	0.4	0.2	0.9	0.3	100.0
8	CR/09	Dark-Blue	Chini-ka Rauza	96.4	0.9	0.4	0.6	0.2	1.1	0.3	100.0
9	CR/13	Turquoise	Chini-ka Rauza	96.8	0.9	0.3	0.5	0.2	1.0	0.3	100.0
10	CR/14	Turquoise	Chini-ka Rauza	90.9	3.0	1.0	0.9	0.4	3.4	0.3	100.0
11	CR/15	Turquoise	Chini-ka Rauza	96.5	0.9	0.3	0.5	0.2	1.2	0.4	100.0
12	CR/16	White	Chini-ka Rauza	96.2	1.0	0.4	0.5	0.2	1.2	0.5	100.0
13	CR/18	Dark-Blue	Chini-ka Rauza	95.0	1.0	0.7	0.7	0.3	1.7	0.6	100.0
14	CR/19	Turquoise	Chini-ka Rauza	94.8	1.2	0.5	0.7	0.3	1.9	0.5	100.0

Appendix 7.4 Average chemical compositions of the tile bodies from Mughal buildings at Punjab determined through SEM-EDS analyses. All results are in wt%. Results below the detection limit of the instrument are provided for comparative purposes only. '-' indicates 'not detected'.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	PbO	Total
1	DS/01	Yellow	Doraha Sarai	94.5	1.0	0.8	0.9	0.3	1.9	0.5	-	100.0
2	DS/02	Turquoise	Doraha Sarai	93.0	1.5	0.6	1.0	0.4	2.8	0.6	-	100.0
3	DS/03	Yellow	Doraha Sarai	94.2	0.7	0.6	0.9	0.4	2.5	0.7	-	100.0
4	DS/04	Turquoise	Doraha Sarai	94.3	1.0	0.7	0.8	0.4	2.2	0.6	-	100.0
5	DS/07	Dark-Blue	Doraha Sarai	94.1	1.3	0.5	0.8	0.3	2.5	0.5	-	100.0
6	DS/10	Dark-Blue	Doraha Sarai	96.7	1.1	0.4	0.4	0.2	0.8	0.4	-	100.0
7	FS/01	Yellow	Fatehabad Sarai	94.2	1.3	1.1	0.8	0.4	1.8	0.4	-	100.0
8	FS/02	Dark-Blue	Fatehabad Sarai	95.0	1.2	0.5	0.7	0.4	1.6	0.6	-	100.0
9	TU/01	Dark-Blue	Tomb of Ustad	94.4	1.3	0.6	0.7	0.6	1.9	0.6	-	100.0
10	TU/02	Dark-Blue	Tomb of Ustad	94.8	1.2	0.5	0.7	0.3	1.7	0.7	-	100.0
11	TU/03	Dark-Blue	Tomb of Ustad	94.2	1.3	0.6	0.9	0.4	2.0	0.5	-	100.0
12	SM/01	Purple	Sheesh Mahal	96.5	1.0	0.4	0.5	0.2	0.9	0.4	-	100.0
13	SM/02	Yellow	Sheesh Mahal	96.2	0.3	2.8	-	0.2	0.3	0.2	-	100.0
14	SM/03	DarkBlue	Sheesh Mahal	96.1	1.0	0.4	0.6	0.2	1.3	0.5	-	100.0
15	SM/04	Orange	Sheesh Mahal	96.1	1.0	0.3	0.7	0.3	1.2	0.4	-	100.0
16	SM/05	Green	Sheesh Mahal	95.3	1.0	0.9	0.7	0.3	1.3	0.5	-	100.0
17	SM/06	White	Sheesh Mahal	96.8	0.8	0.3	0.6	0.2	0.9	0.4	-	100.0
18	SM/08	Purple	Sheesh Mahal	95.8	1.0	0.6	0.7	0.2	1.3	0.5	-	100.0
19	SM/11	Orange	Sheesh Mahal	95.8	1.0	0.3	0.6	0.2	1.5	0.6	-	100.0
20	DKS/01	Turquoise	Dakhini Sarai	95.8	1.2	0.4	0.6	0.2	1.5	0.4	-	100.0
21	DKS/02	Orange	Dakhini Sarai	95.6	0.9	0.3	0.7	0.2	1.7	0.5	-	100.0
22	DKS/03	Orange	Dakhini Sarai	96.5	1.0	0.2	0.5	0.2	1.3	0.3	-	100.0
23	DKS/04	Green	Dakhini Sarai	95.4	1.1	0.5	0.7	0.3	1.6	0.4	-	100.0
24	TS/01	Purple	Tomb of Shagird	96.3	0.9	0.5	0.6	0.2	1.1	0.4	-	100.0
25	TS/02	Yellow	Tomb of Shagird	95.6	0.8	0.5	0.7	0.4	1.3	0.6	-	100.0
26	TS/03	DarkBlue	Tomb of Shagird	96.6	0.9	0.3	0.7	0.2	0.9	0.5	-	100.0
27	TS/04	Orange	Tomb of Shagird	96.8	0.8	0.2	0.6	0.2	1.0	0.4	-	100.0
28	TS/05	Purple	Tomb of Shagird	95.5	1.5	0.5	0.8	0.1	0.9	0.3	0.2	100.0
29	TS/06	Green	Tomb of Shagird	95.6	0.9	0.4	0.8	0.3	1.5	0.6	-	100.0
30	TS/07	Green	Tomb of Shagird	96.4	0.7	0.5	0.6	0.3	0.8	0.3	0.5	100.0
31	TS/08	Yellow	Tomb of Shagird	96.6	0.7	0.3	0.5	0.3	1.2	0.4	-	100.0
32	TS/09	Yellow	Tomb of Shagird	95.1	0.9	0.5	0.8	0.3	1.7	0.7	-	100.0
33	TS/10	Dark-Blue	Tomb of Shagird	96.7	0.9	0.4	0.6	0.2	0.9	0.3	-	100.0
34	TS/11	Dark-Blue	Tomb of Shagird	94.2	1.8	0.7	0.9	0.4	1.6	0.4	-	100.0
35	TS/12	Green	Tomb of Shagird	96.0	0.8	0.6	0.6	0.2	0.9	0.3	0.5	100.0
36	TS/13	Orange	Tomb of Shagird	96.6	0.9	0.2	0.5	0.1	1.3	0.3	-	100.0

Appendix 7.5 Chemical compositions of the tile bodies from Mughal buildings at Delhi determined through SEM-EDS analyses. All results are in wt%, and normalised to 100 %.

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
1	IK/02	White	Tomb of Isa Khan	14-01-2015	I	98.7	0.7	0.2	0.1	0.1	0.1	0.2	100.0
	IK/02	White	Tomb of Isa Khan	14-01-2015	II	95.4	1.5	0.4	0.4	0.2	1.3	0.7	100.0
	IK/02	White	Tomb of Isa Khan	14-01-2015	III	95.8	1.6	0.3	0.4	0.2	1.1	0.7	100.0
	IK/02	White	Tomb of Isa Khan	14-01-2015	IV	98.2	0.8	0.2	0.1	0.1	0.3	0.3	100.0
	IK/02	**White**	**Tomb of Isa Khan**	**14-01-2015**	**Average**	**97.0**	**1.1**	**0.3**	**0.3**	**0.1**	**0.7**	**0.5**	**100.0**
	IK/02	**White**	**Tomb of Isa Khan**	**14-01-2015**	**Std. Dev.**	**1.7**	**0.5**	**0.1**	**0.2**	**0.1**	**0.6**	**0.3**	
2	IK/04	Dark-Blue	Tomb of Isa Khan	21-01-2014	I	94.6	2.3	0.4	0.6	0.3	1.3	0.6	100.0
	IK/04	Dark-Blue	Tomb of Isa Khan	21-01-2014	II	94.9	2.0	0.4	0.5	0.3	1.2	0.6	100.0
	IK/04	Dark-Blue	Tomb of Isa Khan	21-01-2014	III	94.8	2.0	0.4	0.5	0.3	1.4	0.6	100.0
	IK/04	Dark-Blue	Tomb of Isa Khan	21-01-2014	IV	95.1	2.1	0.4	0.5	0.2	1.2	0.5	100.0
	IK/04	Dark-Blue	Tomb of Isa Khan	21-01-2014	V	94.8	2.0	0.4	0.6	0.3	1.4	0.5	100.0
	IK/04	**Dark-Blue**	**Tomb of Isa Khan**	**21-01-2014**	**Average**	**94.8**	**2.1**	**0.4**	**0.5**	**0.3**	**1.3**	**0.6**	**100.0**
	IK/04	**Dark-Blue**	**Tomb of Isa Khan**	**21-01-2014**	**Std. Dev.**	**0.2**	**0.1**	**0.0**	**0.1**	**0.0**	**0.1**	**0.0**	
3	IK/05	Dark-Blue	Tomb of Isa Khan	21-01-2014	I	95.7	1.3	0.4	0.4	0.3	1.3	0.6	100.0
	IK/05	Dark-Blue	Tomb of Isa Khan	21-01-2014	II	95.3	1.6	0.4	0.5	0.3	1.4	0.5	100.0
	IK/05	Dark-Blue	Tomb of Isa Khan	21-01-2014	III	95.3	1.6	0.4	0.4	0.3	1.4	0.7	100.0
	IK/05	Dark-Blue	Tomb of Isa Khan	21-01-2014	IV	95.3	1.5	0.4	0.5	0.3	1.3	0.7	100.0
	IK/05	Dark-Blue	Tomb of Isa Khan	21-01-2014	V	95.3	1.4	0.4	0.5	0.3	1.5	0.6	100.0
	IK/05	**Dark-Blue**	**Tomb of Isa Khan**	**21-01-2014**	**Average**	**95.4**	**1.5**	**0.4**	**0.4**	**0.3**	**1.4**	**0.6**	**100.0**
	IK/05	**Dark-Blue**	**Tomb of Isa Khan**	**21-01-2014**	**Std. Dev.**	**0.2**	**0.1**	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	
4	AS/01	Green	Arab-ki Sarai	14-01-2015	I	95.7	1.5	0.6	0.4	0.2	1.0	0.6	100.0
	AS/01	Green	Arab-ki Sarai	14-01-2015	II	95.9	1.5	0.6	0.4	0.4	1.0	0.4	100.0
	AS/01	Green	Arab-ki Sarai	14-01-2015	III	94.5	1.6	0.8	0.8	0.5	1.3	0.5	100.0
	AS/01	Green	Arab-ki Sarai	14-01-2015	IV	94.9	1.5	0.6	0.6	0.5	1.4	0.7	100.0
	AS/01	**Green**	**Arab-ki Sarai**	**14-01-2015**	**Average**	**95.2**	**1.5**	**0.6**	**0.5**	**0.4**	**1.2**	**0.5**	**100.0**
	AS/01	**Green**	**Arab-ki Sarai**	**14-01-2015**	**Std. Dev.**	**0.7**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.1**	
5	AS/02	Dark-Blue	Arab-ki Sarai	14-01-2015	I	93.9	2.2	0.5	0.5	0.3	1.9	0.8	100.0
	AS/02	Dark-Blue	Arab-ki Sarai	14-01-2015	II	95.1	1.9	0.4	0.4	0.2	1.3	0.6	100.0
	AS/02	Dark-Blue	Arab-ki Sarai	14-01-2015	III	94.8	2.0	0.5	0.5	0.3	1.3	0.7	100.0
	AS/02	**Dark-Blue**	**Arab-ki Sarai**	**14-01-2015**	**Average**	**94.6**	**2.0**	**0.5**	**0.5**	**0.3**	**1.5**	**0.7**	**100.0**
	AS/02	**Dark-Blue**	**Arab-ki Sarai**	**14-01-2015**	**Std. Dev.**	**0.7**	**0.2**	**0.0**	**0.0**	**0.1**	**0.3**	**0.1**	
6	AS/03	Dark-Blue	Arab-ki Sarai	14-01-2015	I	95.1	2.2	0.5	0.5	0.4	1.0	0.5	100.0
	AS/03	Dark-Blue	Arab-ki Sarai	14-01-2015	II	94.4	2.3	0.6	0.5	0.4	1.3	0.6	100.0
	AS/03	Dark-Blue	Arab-ki Sarai	14-01-2015	III	96.9	1.2	0.5	0.3	0.2	0.6	0.3	100.0
	AS/03	Dark-Blue	Arab-ki Sarai	14-01-2015	IV	94.2	2.7	0.6	0.6	0.3	1.3	0.5	100.0
	AS/03	**Dark-Blue**	**Arab-ki Sarai**	**14-01-2015**	**Average**	**95.1**	**2.1**	**0.5**	**0.5**	**0.3**	**1.0**	**0.5**	**100.0**
	AS/03	**Dark-Blue**	**Arab-ki Sarai**	**14-01-2015**	**Std. Dev.**	**1.2**	**0.6**	**0.1**	**0.1**	**0.1**	**0.3**	**0.1**	
7	AS/04	Yellow	Arab-ki Sarai	01-02-2015	I	94.5	2.0	0.6	0.5	0.4	1.5	0.5	100.0
	AS/04	Yellow	Arab-ki Sarai	01-02-2015	II	94.9	1.8	0.6	0.5	0.3	1.5	0.4	100.0
	AS/04	Yellow	Arab-ki Sarai	01-02-2015	III	95.3	1.6	0.5	0.4	0.4	1.3	0.5	100.0
	AS/04	Yellow	Arab-ki Sarai	01-02-2015	IV	93.9	2.1	0.6	0.6	0.5	1.8	0.6	100.0
	AS/04	**Yellow**	**Arab-ki Sarai**	**01-02-2015**	**Average**	**94.6**	**1.9**	**0.6**	**0.5**	**0.4**	**1.5**	**0.5**	**100.0**
	AS/04	**Yellow**	**Arab-ki Sarai**	**01-02-2015**	**Std. Dev.**	**0.6**	**0.2**	**0.0**	**0.1**	**0.1**	**0.2**	**0.1**	
8	AK/01	Yellow	Tomb of Atgah Khan	29-01-2015	I	94.8	1.9	0.4	0.6	0.2	1.6	0.6	100.0
	AK/01	Yellow	Tomb of Atgah Khan	29-01-2015	II	94.2	2.1	0.4	0.6	0.3	1.8	0.7	100.0
	AK/01	Yellow	Tomb of Atgah Khan	29-01-2015	III	93.4	2.3	0.5	0.7	0.3	2.1	0.8	100.0
	AK/01	Yellow	Tomb of Atgah Khan	29-01-2015	IV	94.8	1.7	0.4	0.6	0.2	1.7	0.6	100.0
	AK/01	**Yellow**	**Tomb of Atgah Khan**	**29-01-2015**	**Average**	**94.3**	**2.0**	**0.4**	**0.6**	**0.2**	**1.8**	**0.6**	**100.0**
	AK/01	**Yellow**	**Tomb of Atgah Khan**	**29-01-2015**	**Std. Dev.**	**0.7**	**0.3**	**0.0**	**0.0**	**0.0**	**0.2**	**0.1**	
9	AK/02	Turquoise	Tomb of Atgah Khan	29-01-2015	I	94.7	1.9	0.4	0.4	0.3	1.8	0.6	100.0
	AK/02	Turquoise	Tomb of Atgah Khan	29-01-2015	II	95.5	1.5	0.5	0.4	0.2	1.2	0.6	100.0
	AK/02	Turquoise	Tomb of Atgah Khan	29-01-2015	III	95.8	1.5	0.6	0.4	0.3	1.1	0.4	100.0
	AK/02	Turquoise	Tomb of Atgah Khan	29-01-2015	IV	95.8	1.6	0.4	0.3	0.2	1.3	0.5	100.0
	AK/02	**Turquoise**	**Tomb of Atgah Khan**	**29-01-2015**	**Average**	**95.4**	**1.6**	**0.5**	**0.4**	**0.3**	**1.3**	**0.5**	**100.0**

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
	AK/02	Turquoise	Tomb of Atgah Khan	29-01-2015	Std. Dev.	0.5	0.2	0.1	0.0	0.0	0.3	0.1	
10	AK/03	Turquoise	Tomb of Atgah Khan	01-02-2015	I	94.4	1.9	0.5	0.4	0.3	1.7	0.7	100.0
	AK/03	Turquoise	Tomb of Atgah Khan	01-02-2015	II	94.5	1.9	0.6	0.4	0.4	1.7	0.6	100.0
	AK/03	Turquoise	Tomb of Atgah Khan	01-02-2015	III	94.7	1.8	0.5	0.5	0.3	1.7	0.6	100.0
	AK/03	Turquoise	Tomb of Atgah Khan	01-02-2015	IV	95.1	1.6	0.5	0.5	0.2	1.5	0.6	100.0
	AK/03	Turquoise	Tomb of Atgah Khan	01-02-2015	Average	94.7	1.8	0.5	0.4	0.3	1.7	0.6	100.0
	AK/03	Turquoise	Tomb of Atgah Khan	01-02-2015	Std. Dev.	0.3	0.1	0.1	0.0	0.1	0.1	0.1	
11	SB/01	Dark-Blue	Sabz Burj	13-06-2013	I	97.2	0.9	0.3	0.3	0.2	0.6	0.5	100.0
	SB/01	Dark-Blue	Sabz Burj	13-06-2013	II	97.4	0.8	0.3	0.3	0.3	0.5	0.4	100.0
	SB/01	Dark-Blue	Sabz Burj	13-06-2013	III	95.2	1.1	0.3	0.4	0.4	2.0	0.6	100.0
	SB/01	Dark-Blue	Sabz Burj	13-06-2013	IV	96.6	1.1	0.3	0.4	0.3	1.0	0.3	100.0
	SB/01	Dark-Blue	Sabz Burj	13-06-2013	Average	96.6	1.0	0.3	0.4	0.3	1.1	0.4	100.0
	SB/01	Dark-Blue	Sabz Burj	13-06-2013	Std. Dev.	1.0	0.1	0.0	0.1	0.1	0.7	0.2	
12	NG/01	White	Nila Gumbad	14-05-2012	I	94.9	2.4	0.4	0.6	0.3	1.0	0.4	100.0
	NG/01	White	Nila Gumbad	14-05-2012	II	95.1	2.0	0.3	0.6	0.3	1.2	0.6	100.0
	NG/01	White	Nila Gumbad	14-05-2012	III	95.5	2.0	0.2	0.5	0.4	0.8	0.6	100.0
	NG/01	White	Nila Gumbad	14-05-2012	Average	95.2	2.1	0.3	0.6	0.3	1.0	0.5	100.0
	NG/01	White	Nila Gumbad	14-05-2012	Std. Dev.	0.3	0.2	0.1	0.0	0.1	0.2	0.1	
13	NG/02	Yellow	Nila Gumbad	14-05-2012	I	96.1	1.3	0.4	0.5	0.2	1.1	0.3	100.0
	NG/02	Yellow	Nila Gumbad	14-05-2012	II	96.9	1.1	0.2	0.4	0.2	0.8	0.4	100.0
	NG/02	Yellow	Nila Gumbad	14-05-2012	III	96.1	1.5	0.4	0.5	0.2	1.1	0.3	100.0
	NG/02	Yellow	Nila Gumbad	14-05-2012	Average	96.4	1.3	0.3	0.5	0.2	1.0	0.3	100.0
	NG/02	Yellow	Nila Gumbad	14-05-2012	Std. Dev.	0.4	0.2	0.1	0.0	0.0	0.2	0.0	
14	NG/04	Turquoise	Nila Gumbad	14-05-2012	I	95.6	1.6	0.2	0.4	0.3	1.4	0.5	100.0
	NG/04	Turquoise	Nila Gumbad	14-05-2012	II	95.6	1.2	0.5	0.5	0.2	1.2	0.7	100.0
	NG/04	Turquoise	Nila Gumbad	14-05-2012	III	95.5	1.3	0.3	0.9	0.2	1.2	0.6	100.0
	NG/04	Turquoise	Nila Gumbad	14-05-2012	Average	95.6	1.4	0.3	0.6	0.2	1.3	0.6	100.0
	NG/04	Turquoise	Nila Gumbad	14-05-2012	Std. Dev.	0.1	0.2	0.2	0.3	0.0	0.1	0.1	
15	NG/05	Green	Nila Gumbad	14-05-2012	I	95.2	1.6	0.5	0.4	0.3	1.2	0.8	100.0
	NG/05	Green	Nila Gumbad	14-05-2012	II	94.7	1.7	0.7	0.7	0.3	1.4	0.6	100.0
	NG/05	Green	Nila Gumbad	14-05-2012	III	94.7	1.6	0.6	0.7	0.6	1.2	0.6	100.0
	NG/05	Green	Nila Gumbad	14-05-2012	Average	94.8	1.6	0.6	0.6	0.4	1.3	0.7	100.0
	NG/05	Green	Nila Gumbad	14-05-2012	Std. Dev.	0.3	0.1	0.1	0.2	0.2	0.1	0.1	
16	NG/07	Yellow	Nila Gumbad	25-04-2012	I	96.7	1.1	0.6	0.4	0.3	0.6	0.2	100.0
	NG/07	Yellow	Nila Gumbad	25-04-2012	II	96.7	1.2	0.6	0.5	0.2	0.7	0.1	100.0
	NG/07	Yellow	Nila Gumbad	25-04-2012	III	96.3	1.3	0.5	0.4	0.3	0.6	0.5	100.0
	NG/07	Yellow	Nila Gumbad	25-04-2012	Average	96.6	1.2	0.6	0.4	0.3	0.6	0.3	100.0
	NG/07	Yellow	Nila Gumbad	25-04-2012	Std. Dev.	0.2	0.1	0.1	0.1	0.0	0.1	0.2	
17	NG/08	Dark-Blue	Nila Gumbad	25-04-2012	I	95.4	1.7	0.6	0.6	0.3	1.0	0.4	100.0
	NG/08	Dark-Blue	Nila Gumbad	25-04-2012	II	94.3	2.2	0.8	0.7	0.2	1.2	0.4	100.0
	NG/08	Dark-Blue	Nila Gumbad	25-04-2012	III	96.1	1.6	0.2	0.6	0.2	0.8	0.4	100.0
	NG/08	Dark-Blue	Nila Gumbad	25-04-2012	Average	95.3	1.9	0.5	0.6	0.2	1.0	0.4	100.0
	NG/08	Dark-Blue	Nila Gumbad	25-04-2012	Std. Dev.	0.9	0.3	0.3	0.1	0.1	0.2	0.0	
18	NG/09	Dark-Blue	Nila Gumbad	25-04-2012	I	94.9	1.6	0.3	0.5	0.3	1.3	1.1	100.0
	NG/09	Dark-Blue	Nila Gumbad	25-04-2012	II	95.7	1.4	0.5	0.5	0.3	1.0	0.7	100.0
	NG/09	Dark-Blue	Nila Gumbad	25-04-2012	III	90.9	2.2	0.4	0.7	0.3	2.0	3.6	100.0
	NG/09	Dark-Blue	Nila Gumbad	25-04-2012	Average	94.9	1.7	0.4	0.5	0.3	1.4	0.8	100.0
	NG/09	Dark-Blue	Nila Gumbad	25-04-2012	Std. Dev.	0.9	0.4	0.1	0.1	0.0	0.5	0.3	
19	NG/11	Turquoise	Nila Gumbad	25-06-2012	I	93.4	2.5	0.8	0.7	0.4	1.6	0.6	100.0
	NG/11	Turquoise	Nila Gumbad	25-06-2012	II	94.3	2.4	0.7	0.7	0.4	1.1	0.4	100.0
	NG/11	Turquoise	Nila Gumbad	25-06-2012	III	94.4	2.0	0.7	0.5	0.6	1.2	0.6	100.0
	NG/11	Turquoise	Nila Gumbad	25-06-2012	Average	94.0	2.3	0.8	0.6	0.5	1.3	0.6	100.0
	NG/11	Turquoise	Nila Gumbad	25-06-2012	Std. Dev.	0.5	0.3	0.1	0.1	0.1	0.3	0.1	
20	NG/14	Turquoise	Nila Gumbad	08-06-2012	I	95.7	1.7	0.6	0.3	0.1	1.2	0.6	100.0
	NG/14	Turquoise	Nila Gumbad	08-06-2012	II	95.1	1.9	0.7	0.5	0.1	1.2	0.5	100.0
	NG/14	Turquoise	Nila Gumbad	08-06-2012	III	95.2	2.1	0.4	0.6	0.2	1.1	0.4	100.0
	NG/14	Turquoise	Nila Gumbad	08-06-2012	Average	95.3	1.9	0.5	0.5	0.1	1.1	0.5	100.0
	NG/14	Turquoise	Nila Gumbad	08-06-2012	Std. Dev.	0.3	0.2	0.1	0.2	0.1	0.0	0.1	

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
21	NG/15	Dark-Blue	Nila Gumbad	08-06-2012	I	95.8	1.5	0.4	0.3	0.3	1.0	0.7	100.0
	NG/15	Dark-Blue	Nila Gumbad	08-06-2012	II	95.2	1.8	0.4	0.4	0.5	1.2	0.4	100.0
	NG/15	Dark-Blue	Nila Gumbad	08-06-2012	III	94.1	2.0	0.4	0.5	0.3	1.8	0.9	100.0
	NG/15	**Dark-Blue**	**Nila Gumbad**	**08-06-2012**	**Average**	**95.0**	**1.8**	**0.4**	**0.4**	**0.4**	**1.3**	**0.7**	**100.0**
	NG/15	**Dark-Blue**	**Nila Gumbad**	**08-06-2012**	**Std. Dev.**	**0.9**	**0.2**	**0.0**	**0.1**	**0.1**	**0.4**	**0.2**	
22	NG/16	White	Nila Gumbad	03-10-2012	I	96.4	1.2	0.3	0.7	0.3	1.1	0.1	100.0
	NG/16	White	Nila Gumbad	03-10-2012	II	96.4	1.1	0.2	0.5	0.4	1.0	0.5	100.0
	NG/16	White	Nila Gumbad	03-10-2012	III	96.6	1.1	0.4	0.5	0.5	0.7	0.3	100.0
	NG/16	**White**	**Nila Gumbad**	**03-10-2012**	**Average**	**96.4**	**1.1**	**0.3**	**0.5**	**0.4**	**0.9**	**0.3**	**100.0**
	NG/16	**White**	**Nila Gumbad**	**03-10-2012**	**Std. Dev.**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	
23	NG/17	Green	Nila Gumbad	03-10-2012	I	93.0	2.3	0.6	0.8	0.4	2.2	0.6	100.0
	NG/17	Green	Nila Gumbad	03-10-2012	II	96.4	1.4	0.3	0.4	0.1	0.9	0.4	100.0
	NG/17	Green	Nila Gumbad	03-10-2012	III	94.5	1.9	0.3	0.6	0.5	1.6	0.6	100.0
	NG/17	**Green**	**Nila Gumbad**	**03-10-2012**	**Average**	**94.7**	**1.9**	**0.4**	**0.6**	**0.3**	**1.6**	**0.5**	**100.0**
	NG/17	**Green**	**Nila Gumbad**	**03-10-2012**	**Std. Dev.**	**1.7**	**0.4**	**0.2**	**0.2**	**0.2**	**0.7**	**0.1**	
24	QK/02	Dark-Blue	Tomb of Quli Khan	09-02-2014	I	94.9	1.4	0.4	0.6	0.4	1.7	0.6	100.0
	QK/02	Dark-Blue	Tomb of Quli Khan	09-02-2014	II	95.2	1.4	0.4	0.5	0.4	1.5	0.6	100.0
	QK/02	Dark-Blue	Tomb of Quli Khan	09-02-2014	III	95.8	1.3	0.4	0.4	0.4	1.4	0.5	100.0
	QK/02	Dark-Blue	Tomb of Quli Khan	09-02-2014	IV	94.8	1.3	0.4	0.5	0.4	1.7	0.8	100.0
	QK/02	**Dark-Blue**	**Tomb of Quli Khan**	**09-02-2014**	**Average**	**95.2**	**1.3**	**0.4**	**0.5**	**0.4**	**1.6**	**0.6**	**100.0**
	QK/02	**Dark-Blue**	**Tomb of Quli Khan**	**09-02-2014**	**Std. Dev.**	**0.5**	**0.1**	**0.0**	**0.1**	**0.0**	**0.2**	**0.1**	

Appendix 7.6 Chemical compositions of the tile bodies from Mughal buildings at Agra determined through SEM-EDS analyses. All results are in wt%, and normalised to 100 %.

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
1	CR/01	Purple	Chini-ka Rauza	15-04-2015	I	95.0	1.5	0.4	0.6	0.3	1.8	0.5	100.0
	CR/01	Purple	Chini-ka Rauza	15-04-2015	II	96.7	1.0	0.4	0.5	0.2	1.0	0.4	100.0
	CR/01	Purple	Chini-ka Rauza	15-04-2015	III	95.9	1.2	0.3	0.6	0.2	1.4	0.4	100.0
	CR/01	**Purple**	**Chini-ka Rauza**	**15-04-2015**	**Average**	**95.8**	**1.2**	**0.4**	**0.6**	**0.2**	**1.4**	**0.4**	**100.0**
	CR/01	**Purple**	**Chini-ka Rauza**	**15-04-2015**	**Std. Dev.**	**0.9**	**0.3**	**0.0**	**0.1**	**0.1**	**0.4**	**0.0**	
2	CR/02	Purple	Chini-ka Rauza	15-04-2015	I	95.0	1.3	0.5	0.7	0.3	1.8	0.5	100.0
	CR/02	Purple	Chini-ka Rauza	15-04-2015	II	95.0	1.5	0.4	0.7	0.3	1.8	0.4	100.0
	CR/02	Purple	Chini-ka Rauza	15-04-2015	III	95.7	1.2	0.4	0.7	0.2	1.3	0.4	100.0
	CR/02	**Purple**	**Chini-ka Rauza**	**15-04-2015**	**Average**	**95.2**	**1.3**	**0.4**	**0.7**	**0.3**	**1.6**	**0.4**	**100.0**
	CR/02	**Purple**	**Chini-ka Rauza**	**15-04-2015**	**Std. Dev.**	**0.4**	**0.1**	**0.1**	**0.0**	**0.0**	**0.3**	**0.0**	
3	CR/03	Yellow	Chini-ka Rauza	22-04-2015	I	96.9	0.7	0.3	0.5	0.2	1.0	0.4	100.0
	CR/03	Yellow	Chini-ka Rauza	22-04-2015	II	96.0	0.6	0.6	0.6	0.3	1.4	0.4	100.0
	CR/03	Yellow	Chini-ka Rauza	22-04-2015	III	97.3	0.7	0.2	0.4	0.1	1.0	0.3	100.0
	CR/03	**Yellow**	**Chini-ka Rauza**	**22-04-2015**	**Average**	**96.7**	**0.7**	**0.4**	**0.5**	**0.2**	**1.1**	**0.4**	**100.0**
	CR/03	**Yellow**	**Chini-ka Rauza**	**22-04-2015**	**Std. Dev.**	**0.6**	**0.1**	**0.2**	**0.1**	**0.1**	**0.2**	**0.0**	
4	CR/04	Yellow	Chini-ka Rauza	22-04-2015	I	96.2	1.0	0.3	0.6	0.3	1.3	0.3	100.0
	CR/04	Yellow	Chini-ka Rauza	22-04-2015	II	95.4	1.5	0.4	0.5	0.2	1.7	0.3	100.0
	CR/04	Yellow	Chini-ka Rauza	22-04-2015	III	94.9	1.8	0.3	0.5	0.2	2.0	0.3	100.0
	CR/04	**Yellow**	**Chini-ka Rauza**	**22-04-2015**	**Average**	**95.5**	**1.4**	**0.3**	**0.5**	**0.2**	**1.7**	**0.3**	**100.0**
	CR/04	**Yellow**	**Chini-ka Rauza**	**22-04-2015**	**Std. Dev.**	**0.7**	**0.4**	**0.0**	**0.1**	**0.0**	**0.4**	**0.0**	
5	CR/05	Green	Chini-ka Rauza	25-03-2014	I	96.9	0.9	0.3	0.5	0.2	0.9	0.3	100.0
	CR/05	Green	Chini-ka Rauza	25-03-2014	II	96.3	0.9	0.4	0.6	0.2	1.2	0.3	100.0
	CR/05	Green	Chini-ka Rauza	25-03-2014	III	95.8	1.1	0.3	0.6	0.3	1.5	0.4	100.0
	CR/05	Green	Chini-ka Rauza	25-03-2014	IV	96.4	1.1	0.3	0.5	0.2	1.3	0.2	100.0
	CR/05	**Green**	**Chini-ka Rauza**	**25-03-2014**	**Average**	**96.4**	**1.0**	**0.3**	**0.5**	**0.2**	**1.2**	**0.3**	**100.0**
	CR/05	**Green**	**Chini-ka Rauza**	**25-03-2014**	**Std. Dev.**	**0.5**	**0.1**	**0.0**	**0.1**	**0.0**	**0.3**	**0.1**	
6	CR/06	Green	Chini-ka Rauza	25-03-2014	I	96.9	0.6	0.3	0.6	0.2	1.0	0.4	100.0
	CR/06	Green	Chini-ka Rauza	25-03-2014	II	97.1	0.6	0.3	0.6	0.2	0.9	0.3	100.0
	CR/06	Green	Chini-ka Rauza	25-03-2014	III	95.7	0.8	0.4	0.8	0.2	1.6	0.5	100.0
	CR/06	Green	Chini-ka Rauza	25-03-2014	IV	97.3	0.5	0.2	0.6	0.3	0.9	0.3	100.0
	CR/06	**Green**	**Chini-ka Rauza**	**25-03-2014**	**Average**	**96.7**	**0.6**	**0.3**	**0.6**	**0.2**	**1.1**	**0.3**	**100.0**
	CR/06	**Green**	**Chini-ka Rauza**	**25-03-2014**	**Std. Dev.**	**0.7**	**0.1**	**0.1**	**0.1**	**0.0**	**0.3**	**0.1**	
7	CR/08	Dark-Blue	Chini-ka Rauza	22-04-2015	I	96.3	0.9	0.6	0.5	0.2	1.1	0.4	100.0
	CR/08	Dark-Blue	Chini-ka Rauza	22-04-2015	II	97.2	0.8	0.4	0.4	0.2	0.7	0.3	100.0
	CR/08	Dark-Blue	Chini-ka Rauza	22-04-2015	III	97.1	0.9	0.4	0.4	0.2	0.8	0.3	100.0
	CR/08	**Dark-Blue**	**Chini-ka Rauza**	**22-04-2015**	**Average**	**96.9**	**0.9**	**0.5**	**0.4**	**0.2**	**0.9**	**0.3**	**100.0**
	CR/08	**Dark-Blue**	**Chini-ka Rauza**	**22-04-2015**	**Std. Dev.**	**0.5**	**0.1**	**0.1**	**0.1**	**0.0**	**0.2**	**0.0**	
8	CR/09	Dark-Blue	Chini-ka Rauza	22-04-2015	I	96.5	0.8	0.5	0.5	0.2	1.2	0.3	100.0
	CR/09	Dark-Blue	Chini-ka Rauza	22-04-2015	II	96.7	0.9	0.4	0.5	0.2	1.0	0.4	100.0
	CR/09	Dark-Blue	Chini-ka Rauza	22-04-2015	III	96.1	1.0	0.4	0.8	0.2	1.1	0.4	100.0
	CR/09	**Dark-Blue**	**Chini-ka Rauza**	**22-04-2015**	**Average**	**96.4**	**0.9**	**0.4**	**0.6**	**0.2**	**1.1**	**0.3**	**100.0**
	CR/09	**Dark-Blue**	**Chini-ka Rauza**	**22-04-2015**	**Std. Dev.**	**0.3**	**0.1**	**0.1**	**0.2**	**0.0**	**0.1**	**0.1**	
9	CR/13	Turquoise	Chini-ka Rauza	08-04-2015	I	96.8	0.9	0.4	0.5	0.2	1.0	0.3	100.0
	CR/13	Turquoise	Chini-ka Rauza	08-04-2015	II	97.0	0.9	0.3	0.6	0.2	0.9	0.3	100.0
	CR/13	Turquoise	Chini-ka Rauza	08-04-2015	III	96.7	0.9	0.3	0.5	0.2	1.0	0.4	100.0
	CR/13	**Turquoise**	**Chini-ka Rauza**	**08-04-2015**	**Average**	**96.8**	**0.9**	**0.3**	**0.5**	**0.2**	**1.0**	**0.3**	**100.0**
	CR/13	**Turquoise**	**Chini-ka Rauza**	**08-04-2015**	**Std. Dev.**	**0.1**	**0.0**	**0.0**	**0.1**	**0.0**	**0.1**	**0.1**	
10	CR/14	Turquoise	Chini-ka Rauza	08-04-2015	I	91.5	2.8	0.9	0.9	0.4	3.2	0.3	100.0
	CR/14	Turquoise	Chini-ka Rauza	08-04-2015	II	90.7	3.1	1.1	0.9	0.5	3.5	0.3	100.0
	CR/14	Turquoise	Chini-ka Rauza	08-04-2015	III	90.3	3.1	1.0	1.0	0.5	3.7	0.4	100.0
	CR/14	**Turquoise**	**Chini-ka Rauza**	**08-04-2015**	**Average**	**90.9**	**3.0**	**1.0**	**0.9**	**0.4**	**3.4**	**0.3**	**100.0**
	CR/14	**Turquoise**	**Chini-ka Rauza**	**08-04-2015**	**Std. Dev.**	**0.6**	**0.2**	**0.1**	**0.1**	**0.1**	**0.2**	**0.1**	
11	CR/15	Turquoise	Chini-ka Rauza	08-04-2015	I	96.9	0.9	0.3	0.5	0.2	1.1	0.3	100.0
	CR/15	Turquoise	Chini-ka Rauza	08-04-2015	II	96.4	0.9	0.4	0.5	0.2	1.2	0.4	100.0

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
	CR/15	Turquoise	Chini-ka Rauza	08-04-2015	III	96.2	1.0	0.4	0.5	0.3	1.2	0.4	100.0
	CR/15	**Turquoise**	**Chini-ka Rauza**	**08-04-2015**	**Average**	**96.5**	**0.9**	**0.3**	**0.5**	**0.2**	**1.2**	**0.4**	**100.0**
	CR/15	**Turquoise**	**Chini-ka Rauza**	**08-04-2015**	**Std. Dev.**	**0.3**	**0.1**	**0.1**	**0.0**	**0.1**	**0.1**	**0.1**	
12	CR/16	White	Chini-ka Rauza	15-04-2015	I	95.9	1.1	0.4	0.6	0.3	1.3	0.5	100.0
	CR/16	White	Chini-ka Rauza	15-04-2015	II	96.4	1.1	0.4	0.5	0.2	1.0	0.4	100.0
	CR/16	White	Chini-ka Rauza	15-04-2015	III	96.2	1.0	0.5	0.5	0.2	1.1	0.4	100.0
	CR/16	**White**	**Chini-ka Rauza**	**15-04-2015**	**Average**	**96.2**	**1.0**	**0.4**	**0.5**	**0.2**	**1.2**	**0.5**	**100.0**
	CR/16	**White**	**Chini-ka Rauza**	**15-04-2015**	**Std. Dev.**	**0.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.2**	**0.1**	
13	CR/18	Dark-Blue	Chini-ka Rauza	29-01-2014	I	94.9	0.9	0.7	0.6	0.4	1.9	0.6	100.0
	CR/18	Dark-Blue	Chini-ka Rauza	29-01-2014	II	96.0	1.0	0.4	0.6	0.2	1.3	0.4	100.0
	CR/18	Dark-Blue	Chini-ka Rauza	29-01-2014	III	94.6	1.0	0.7	0.8	0.3	1.9	0.7	100.0
	CR/18	Dark-Blue	Chini-ka Rauza	29-01-2014	IV	94.5	1.2	0.9	0.7	0.4	1.9	0.6	100.0
	CR/18	**Dark-Blue**	**Chini-ka Rauza**	**29-01-2014**	**Average**	**95.0**	**1.0**	**0.7**	**0.7**	**0.3**	**1.7**	**0.6**	**100.0**
	CR/18	**Dark-Blue**	**Chini-ka Rauza**	**29-01-2014**	**Std. Dev.**	**0.7**	**0.1**	**0.2**	**0.1**	**0.1**	**0.3**	**0.1**	
14	CR/19	Turquoise	Chini-ka Rauza	29-01-2014	I	94.3	1.2	0.8	0.8	0.3	2.0	0.6	100.0
	CR/19	Turquoise	Chini-ka Rauza	29-01-2014	II	94.2	1.4	0.5	0.7	0.4	2.2	0.7	100.0
	CR/19	Turquoise	Chini-ka Rauza	29-01-2014	III	94.9	1.2	0.4	0.7	0.3	1.9	0.7	100.0
	CR/19	Turquoise	Chini-ka Rauza	29-01-2014	IV	96.0	1.2	0.3	0.7	0.2	1.4	0.3	100.0
	CR/19	**Turquoise**	**Chini-ka Rauza**	**29-01-2014**	**Average**	**94.8**	**1.2**	**0.5**	**0.7**	**0.3**	**1.9**	**0.5**	**100.0**
	CR/19	**Turquoise**	**Chini-ka Rauza**	**29-01-2014**	**Std. Dev.**	**0.8**	**0.1**	**0.2**	**0.1**	**0.1**	**0.3**	**0.2**	

Appendix 7.7 Chemical compositions of the tile bodies from Mughal buildings at Punjab determined through SEM-EDS analyses. All results are in wt%, and normalised to 100 %. '-' indicates 'not detected'.

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	PbO	Total
1	DS/01	Yellow	Doraha Sarai	17-02-2015	I	95.4	0.8	0.9	0.8	0.3	1.4	0.4	-	100.0
	DS/01	Yellow	Doraha Sarai	17-02-2015	II	92.5	1.4	0.9	1.2	0.4	2.9	0.7	-	100.0
	DS/01	Yellow	Doraha Sarai	17-02-2015	III	95.4	0.8	0.6	0.8	0.3	1.6	0.5	-	100.0
	DS/01	**Yellow**	**Doraha Sarai**	**17-02-2015**	**Average**	**94.5**	**1.0**	**0.8**	**0.9**	**0.3**	**1.9**	**0.5**	**-**	**100.0**
	DS/01	**Yellow**	**Doraha Sarai**	**17-02-2015**	**Std. Dev.**	**1.7**	**0.4**	**0.2**	**0.2**	**0.1**	**0.8**	**0.2**	**-**	
2	DS/02	Turquoise	Doraha Sarai	03-02-2015	I	94.1	1.3	0.6	0.8	0.4	2.3	0.6	-	100.0
	DS/02	Turquoise	Doraha Sarai	03-02-2015	II	92.9	1.6	0.6	0.9	0.4	3.0	0.7	-	100.0
	DS/02	Turquoise	Doraha Sarai	03-02-2015	III	93.3	1.6	0.5	1.1	0.3	2.7	0.5	-	100.0
	DS/02	Turquoise	Doraha Sarai	03-02-2015	IV	92.0	1.6	0.8	1.4	0.5	3.2	0.7	-	100.0
	DS/02	**Turquoise**	**Doraha Sarai**	**03-02-2015**	**Average**	**93.0**	**1.5**	**0.6**	**1.0**	**0.4**	**2.8**	**0.6**	**-**	**100.0**
	DS/02	**Turquoise**	**Doraha Sarai**	**03-02-2015**	**Std. Dev.**	**0.9**	**0.2**	**0.1**	**0.3**	**0.1**	**0.4**	**0.1**	**-**	
3	DS/03	Yellow	Doraha Sarai	19-02-2015	I	93.4	0.8	0.7	1.1	0.5	2.8	0.8	-	100.0
	DS/03	Yellow	Doraha Sarai	19-02-2015	II	94.2	0.8	0.5	0.9	0.3	2.6	0.7	-	100.0
	DS/03	Yellow	Doraha Sarai	19-02-2015	III	95.1	0.5	0.6	0.8	0.3	2.1	0.6	-	100.0
	DS/03	**Yellow**	**Doraha Sarai**	**19-02-2015**	**Average**	**94.2**	**0.7**	**0.6**	**0.9**	**0.4**	**2.5**	**0.7**	**-**	**100.0**
	DS/03	**Yellow**	**Doraha Sarai**	**19-02-2015**	**Std. Dev.**	**0.9**	**0.1**	**0.1**	**0.2**	**0.1**	**0.3**	**0.1**	**-**	
4	DS/04	Turquoise	Doraha Sarai	03-02-2015	I	95.2	1.0	0.5	0.7	0.3	1.8	0.5	-	100.0
	DS/04	Turquoise	Doraha Sarai	03-02-2015	II	92.7	1.1	0.9	1.2	0.5	2.9	0.7	-	100.0
	DS/04	Turquoise	Doraha Sarai	03-02-2015	III	95.1	0.9	0.6	0.6	0.3	2.0	0.6	-	100.0
	DS/04	**Turquoise**	**Doraha Sarai**	**03-02-2015**	**Average**	**94.3**	**1.0**	**0.7**	**0.8**	**0.4**	**2.2**	**0.6**	**-**	**100.0**
	DS/04	**Turquoise**	**Doraha Sarai**	**03-02-2015**	**Std. Dev.**	**1.4**	**0.1**	**0.2**	**0.3**	**0.1**	**0.6**	**0.1**	**-**	
5	DS/07	Dark-Blue	Doraha Sarai	17-02-2015	I	95.0	1.1	0.3	0.8	0.1	2.2	0.4	-	100.0
	DS/07	Dark-Blue	Doraha Sarai	17-02-2015	II	92.3	1.7	0.4	1.0	0.4	3.5	0.6	-	100.0
	DS/07	Dark-Blue	Doraha Sarai	17-02-2015	III	95.0	1.0	0.8	0.7	0.2	1.8	0.5	-	100.0
	DS/07	**Dark-Blue**	**Doraha Sarai**	**17-02-2015**	**Average**	**94.1**	**1.3**	**0.5**	**0.8**	**0.3**	**2.5**	**0.5**	**-**	**100.0**
	DS/07	**Dark-Blue**	**Doraha Sarai**	**17-02-2015**	**Std. Dev.**	**1.6**	**0.4**	**0.2**	**0.2**	**0.2**	**0.9**	**0.1**	**-**	
6	DS/10	Dark-Blue	Doraha Sarai	25-02-2015	I	97.1	1.0	0.4	0.4	0.2	0.7	0.3	-	100.0
	DS/10	Dark-Blue	Doraha Sarai	25-02-2015	II	96.4	1.2	0.5	0.4	0.3	0.8	0.4	-	100.0
	DS/10	Dark-Blue	Doraha Sarai	25-02-2015	III	96.7	1.1	0.5	0.4	0.2	0.7	0.4	-	100.0
	DS/10	Dark-Blue	Doraha Sarai	25-02-2015	IV	96.7	1.0	0.4	0.4	0.2	0.8	0.5	-	100.0
	DS/10	**Dark-Blue**	**Doraha Sarai**	**25-02-2015**	**Average**	**96.7**	**1.1**	**0.4**	**0.4**	**0.2**	**0.8**	**0.4**	**-**	**100.0**
	DS/10	**Dark-Blue**	**Doraha Sarai**	**25-02-2015**	**Std. Dev.**	**0.3**	**0.1**	**0.1**	**0.0**	**0.1**	**0.1**	**0.1**	**-**	
7	FS/01	Yellow	Fatehabad Sarai	22-01-2015	I	95.5	1.1	0.7	0.7	0.2	1.4	0.4	-	100.0
	FS/01	Yellow	Fatehabad Sarai	22-01-2015	II	94.0	1.4	1.0	0.7	0.4	2.0	0.4	-	100.0
	FS/01	Yellow	Fatehabad Sarai	22-01-2015	III	93.0	1.5	1.6	1.1	0.4	1.9	0.5	-	100.0
	FS/01	**Yellow**	**Fatehabad Sarai**	**22-01-2015**	**Average**	**94.2**	**1.3**	**1.1**	**0.8**	**0.4**	**1.8**	**0.4**	**-**	**100.0**
	FS/01	**Yellow**	**Fatehabad Sarai**	**22-01-2015**	**Std. Dev.**	**1.3**	**0.2**	**0.5**	**0.3**	**0.1**	**0.3**	**0.1**	**-**	
8	FS/02	Dark-Blue	Fatehabad Sarai	22-01-2015	I	93.9	1.6	0.7	0.8	0.5	1.8	0.8	-	100.0
	FS/02	Dark-Blue	Fatehabad Sarai	22-01-2015	II	96.0	1.0	0.4	0.6	0.4	1.2	0.5	-	100.0
	FS/02	Dark-Blue	Fatehabad Sarai	22-01-2015	III	94.8	1.0	0.6	0.9	0.4	1.8	0.6	-	100.0
	FS/02	Dark-Blue	Fatehabad Sarai	22-01-2015	IV	95.4	1.0	0.4	0.7	0.3	1.6	0.6	-	100.0
	FS/02	**Dark-Blue**	**Fatehabad Sarai**	**22-01-2015**	**Average**	**95.0**	**1.2**	**0.5**	**0.7**	**0.4**	**1.6**	**0.6**	**-**	**100.0**
	FS/02	**Dark-Blue**	**Fatehabad Sarai**	**22-01-2015**	**Std. Dev.**	**0.9**	**0.3**	**0.1**	**0.1**	**0.1**	**0.3**	**0.1**	**-**	
9	TU/01	Dark-Blue	Tomb of Ustad	26-09-2013	I	95.5	1.2	0.4	0.7	0.3	1.4	0.5	-	100.0
	TU/01	Dark-Blue	Tomb of Ustad	26-09-2013	II	95.0	1.2	0.5	0.6	0.4	1.7	0.5	-	100.0
	TU/01	Dark-Blue	Tomb of Ustad	26-09-2013	III	93.9	1.3	0.6	0.8	0.4	2.2	0.8	-	100.0
	TU/01	Dark-Blue	Tomb of Ustad	26-09-2013	IV	93.1	1.4	0.8	0.7	1.2	2.1	0.6	-	100.0
	TU/01	**Dark-Blue**	**Tomb of Ustad**	**26-09-2013**	**Average**	**94.4**	**1.3**	**0.6**	**0.7**	**0.6**	**1.9**	**0.6**	**-**	**100.0**
	TU/01	**Dark-Blue**	**Tomb of Ustad**	**26-09-2013**	**Std. Dev.**	**1.1**	**0.1**	**0.2**	**0.1**	**0.4**	**0.4**	**0.1**	**-**	
10	TU/02	Dark-Blue	Tomb of Ustad	26-09-2013	I	95.3	1.1	0.6	0.6	0.3	1.5	0.6	-	100.0
	TU/02	Dark-Blue	Tomb of Ustad	26-09-2013	II	95.4	1.1	0.4	0.6	0.3	1.6	0.7	-	100.0
	TU/02	Dark-Blue	Tomb of Ustad	26-09-2013	III	94.7	1.1	0.5	0.8	0.4	1.8	0.8	-	100.0
	TU/02	Dark-Blue	Tomb of Ustad	26-09-2013	IV	94.1	1.4	0.4	0.8	0.3	2.1	0.9	-	100.0
	TU/02	**Dark-Blue**	**Tomb of Ustad**	**26-09-2013**	**Average**	**94.8**	**1.2**	**0.5**	**0.7**	**0.3**	**1.7**	**0.7**	**-**	**100.0**

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	PbO	Total
	TU/02	Dark-Blue	Tomb of Ustad	26-09-2013	Std. Dev.	0.6	0.2	0.1	0.1	0.0	0.3	0.1	-	
11	TU/03	Dark-Blue	Tomb of Ustad	26-09-2013	I	93.5	1.5	0.6	1.1	0.4	2.5	0.5	-	100.0
	TU/03	Dark-Blue	Tomb of Ustad	26-09-2013	II	94.3	1.5	0.7	0.8	0.6	1.8	0.4	-	100.0
	TU/03	Dark-Blue	Tomb of Ustad	26-09-2013	III	94.9	1.0	0.8	0.7	0.3	1.7	0.6	-	100.0
	TU/03	Dark-Blue	Tomb of Ustad	26-09-2013	IV	94.2	1.4	0.4	1.0	0.4	2.1	0.5	-	100.0
	TU/03	Dark-Blue	Tomb of Ustad	26-09-2013	Average	94.2	1.3	0.6	0.9	0.4	2.0	0.5	-	100.0
	TU/03	Dark-Blue	Tomb of Ustad	26-09-2013	Std. Dev.	0.6	0.2	0.2	0.2	0.1	0.4	0.1	-	
12	SM/01	Purple	Sheesh Mahal	13-03-2012	I	96.6	1.1	0.4	0.5	0.2	0.9	0.3	-	100.0
	SM/01	Purple	Sheesh Mahal	13-03-2012	II	96.6	1.0	0.5	0.4	0.3	0.7	0.5	-	100.0
	SM/01	Purple	Sheesh Mahal	13-03-2012	III	96.4	1.0	0.3	0.7	0.1	1.0	0.4	-	100.0
	SM/01	Purple	Sheesh Mahal	13-03-2012	Average	96.5	1.0	0.4	0.5	0.2	0.9	0.4	-	100.0
	SM/01	Purple	Sheesh Mahal	13-03-2012	Std. Dev.	0.1	0.1	0.1	0.1	0.1	0.2	0.1	-	
13	SM/02	Yellow	Sheesh Mahal	27-01-2012	I	98.4	0.2	1.1	0.1	0.1	0.1	-	-	100.0
	SM/02	Yellow	Sheesh Mahal	27-01-2012	II	94.3	0.4	4.2	-	0.3	0.5	0.4	-	100.0
	SM/02	Yellow	Sheesh Mahal	27-01-2012	III	95.8	0.3	3.3	-	0.2	0.3	0.1	-	100.0
	SM/02	Yellow	Sheesh Mahal	27-01-2012	Average	96.2	0.3	2.8	0.0	0.2	0.3	0.2	-	100.0
	SM/02	Yellow	Sheesh Mahal	27-01-2012	Std. Dev.	2.1	0.1	1.6	0.1	0.1	0.2	0.2	-	
14	SM/03	DarkBlue	Sheesh Mahal	13-01-2012	I	96.0	1.1	0.4	0.5	0.2	1.4	0.5	-	100.0
	SM/03	DarkBlue	Sheesh Mahal	13-01-2012	II	96.4	1.0	0.3	0.5	0.1	1.3	0.4	-	100.0
	SM/03	DarkBlue	Sheesh Mahal	13-01-2012	III	95.8	1.0	0.4	0.7	0.2	1.3	0.6	-	100.0
	SM/03	DarkBlue	Sheesh Mahal	13-01-2012	Average	96.1	1.0	0.4	0.6	0.2	1.3	0.5	-	100.0
	SM/03	DarkBlue	Sheesh Mahal	13-01-2012	Std. Dev.	0.3	0.1	0.1	0.1	0.1	0.1	0.1	-	
15	SM/04	Orange	Sheesh Mahal	25-01-2012	I	95.8	1.2	0.4	0.8	0.2	1.1	0.4	-	100.0
	SM/04	Orange	Sheesh Mahal	25-01-2012	II	96.2	0.8	0.3	0.6	0.3	1.3	0.5	-	100.0
	SM/04	Orange	Sheesh Mahal	25-01-2012	III	96.3	1.0	0.3	0.7	0.3	1.2	0.3	-	100.0
	SM/04	Orange	Sheesh Mahal	25-01-2012	Average	96.1	1.0	0.3	0.7	0.3	1.2	0.4	-	100.0
	SM/04	Orange	Sheesh Mahal	25-01-2012	Std. Dev.	0.3	0.2	0.1	0.1	0.0	0.1	0.1	-	
16	SM/05	Green	Sheesh Mahal	27-01-2012	I	94.6	1.1	0.8	0.8	0.4	1.7	0.6	-	100.0
	SM/05	Green	Sheesh Mahal	27-01-2012	II	95.5	0.9	1.0	0.7	0.2	1.1	0.5	-	100.0
	SM/05	Green	Sheesh Mahal	27-01-2012	III	95.8	1.0	0.9	0.7	0.3	1.0	0.3	-	100.0
	SM/05	Green	Sheesh Mahal	27-01-2012	Average	95.3	1.0	0.9	0.7	0.3	1.3	0.5	-	100.0
	SM/05	Green	Sheesh Mahal	27-01-2012	Std. Dev.	0.6	0.1	0.1	0.1	0.1	0.4	0.1	-	
17	SM/06	White	Sheesh Mahal	12-12-2011	I	97.0	0.7	0.2	0.6	0.3	0.7	0.5	-	100.0
	SM/06	White	Sheesh Mahal	12-12-2011	II	97.1	0.9	0.2	0.5	0.2	0.8	0.3	-	100.0
	SM/06	White	Sheesh Mahal	12-12-2011	III	96.3	0.8	0.3	0.7	0.2	1.3	0.4	-	100.0
	SM/06	White	Sheesh Mahal	12-12-2011	IV	96.7	0.9	0.4	0.5	0.2	1.0	0.4	-	100.0
	SM/06	White	Sheesh Mahal	12-12-2011	Average	96.8	0.8	0.3	0.6	0.2	0.9	0.4	-	100.0
	SM/06	White	Sheesh Mahal	12-12-2011	Std. Dev.	0.3	0.1	0.1	0.1	0.0	0.3	0.1	-	
18	SM/08	Purple	Sheesh Mahal	22-01-2015	I	95.2	1.2	0.6	0.8	0.2	1.6	0.5	-	100.0
	SM/08	Purple	Sheesh Mahal	22-01-2015	II	96.2	0.9	0.5	0.6	0.2	1.0	0.6	-	100.0
	SM/08	Purple	Sheesh Mahal	22-01-2015	III	95.9	0.9	0.7	0.6	0.2	1.2	0.5	-	100.0
	SM/08	Purple	Sheesh Mahal	22-01-2015	Average	95.8	1.0	0.6	0.7	0.2	1.3	0.5	-	100.0
	SM/08	Purple	Sheesh Mahal	22-01-2015	Std. Dev.	0.5	0.2	0.1	0.1	0.0	0.3	0.1	-	
19	SM/11	Orange	Sheesh Mahal	22-01-2015	I	94.9	1.1	0.4	0.8	0.2	1.8	0.9	-	100.0
	SM/11	Orange	Sheesh Mahal	22-01-2015	II	96.2	1.0	0.3	0.5	0.3	1.3	0.5	-	100.0
	SM/11	Orange	Sheesh Mahal	22-01-2015	III	96.3	0.9	0.3	0.6	0.2	1.4	0.4	-	100.0
	SM/11	Orange	Sheesh Mahal	22-01-2015	Average	95.8	1.0	0.3	0.6	0.2	1.5	0.6	-	100.0
	SM/11	Orange	Sheesh Mahal	22-01-2015	Std. Dev.	0.8	0.1	0.1	0.1	0.0	0.2	0.3	-	
20	DKS/01	Turquoise	Dakhini Sarai	02-10-2013	I	95.7	1.2	0.4	0.7	0.1	1.5	0.4	-	100.0
	DKS/01	Turquoise	Dakhini Sarai	02-10-2013	II	95.9	1.1	0.5	0.6	0.3	1.3	0.3	-	100.0
	DKS/01	Turquoise	Dakhini Sarai	02-10-2013	III	95.9	1.1	0.5	0.5	0.3	1.4	0.4	-	100.0
	DKS/01	Turquoise	Dakhini Sarai	02-10-2013	IV	95.7	1.2	0.4	0.5	0.2	1.6	0.4	-	100.0
	DKS/01	Turquoise	Dakhini Sarai	02-10-2013	Average	95.8	1.2	0.4	0.6	0.2	1.5	0.4	-	100.0
	DKS/01	Turquoise	Dakhini Sarai	02-10-2013	Std. Dev.	0.1	0.0	0.1	0.1	0.1	0.1	0.0	-	
21	DKS/02	Orange	Dakhini Sarai	02-10-2013	I	95.4	0.9	0.3	0.7	0.3	1.8	0.6	-	100.0
	DKS/02	Orange	Dakhini Sarai	02-10-2013	II	94.7	1.1	0.5	1.0	0.3	1.9	0.6	-	100.0
	DKS/02	Orange	Dakhini Sarai	02-10-2013	III	96.2	0.9	0.3	0.6	0.2	1.4	0.5	-	100.0
	DKS/02	Orange	Dakhini Sarai	02-10-2013	IV	96.2	0.7	0.3	0.7	0.2	1.6	0.3	-	100.0

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	PbO	Total
	DKS/02	Orange	Dakhini Sarai	02-10-2013	Average	95.6	0.9	0.3	0.7	0.2	1.7	0.5	-	100.0
	DKS/02	Orange	Dakhini Sarai	02-10-2013	Std. Dev.	0.7	0.1	0.1	0.2	0.1	0.2	0.1	-	
22	DKS/03	Orange	Dakhini Sarai	07-10-2013	I	96.2	1.0	0.4	0.6	0.3	1.5	0.1	-	100.0
	DKS/03	Orange	Dakhini Sarai	07-10-2013	II	97.0	1.0	0.1	0.4	0.2	1.1	0.3	-	100.0
	DKS/03	Orange	Dakhini Sarai	07-10-2013	III	96.2	1.0	0.3	0.6	0.2	1.5	0.3	-	100.0
	DKS/03	Orange	Dakhini Sarai	07-10-2013	IV	96.6	1.0	0.2	0.5	0.2	1.2	0.3	-	100.0
	DKS/03	Orange	Dakhini Sarai	07-10-2013	Average	96.5	1.0	0.2	0.5	0.2	1.3	0.3	-	100.0
	DKS/03	Orange	Dakhini Sarai	07-10-2013	Std. Dev.	0.4	0.0	0.1	0.1	0.0	0.2	0.1	-	
23	DKS/04	Green	Dakhini Sarai	07-10-2013	I	95.8	1.1	0.4	0.6	0.2	1.6	0.3	-	100.0
	DKS/04	Green	Dakhini Sarai	07-10-2013	II	95.3	1.1	0.4	0.8	0.4	1.6	0.5	-	100.0
	DKS/04	Green	Dakhini Sarai	07-10-2013	III	95.6	1.0	0.5	0.7	0.2	1.6	0.4	-	100.0
	DKS/04	Green	Dakhini Sarai	07-10-2013	IV	94.9	1.3	0.6	0.6	0.4	1.6	0.6	-	100.0
	DKS/04	Green	Dakhini Sarai	07-10-2013	Average	95.4	1.1	0.5	0.7	0.3	1.6	0.4	-	100.0
	DKS/04	Green	Dakhini Sarai	07-10-2013	Std. Dev.	0.4	0.1	0.1	0.1	0.1	0.0	0.1	-	
24	TS/01	Purple	Tomb of Shagird	27-01-2012	I	95.7	1.2	0.5	0.8	0.1	1.2	0.5	-	100.0
	TS/01	Purple	Tomb of Shagird	27-01-2012	II	96.8	0.9	0.4	0.6	0.2	0.8	0.3	-	100.0
	TS/01	Purple	Tomb of Shagird	27-01-2012	III	96.2	0.7	0.7	0.6	0.3	1.1	0.4	-	100.0
	TS/01	Purple	Tomb of Shagird	27-01-2012	IV	96.5	0.9	0.3	0.5	0.2	1.2	0.5	-	100.0
	TS/01	Purple	Tomb of Shagird	27-01-2012	Average	96.3	0.9	0.5	0.6	0.2	1.1	0.4	-	100.0
	TS/01	Purple	Tomb of Shagird	27-01-2012	Std. Dev.	0.5	0.2	0.2	0.1	0.1	0.2	0.1	-	
25	TS/02	Yellow	Tomb of Shagird	17-01-2012	I	95.2	0.9	0.5	0.8	0.6	1.3	0.7	-	100.0
	TS/02	Yellow	Tomb of Shagird	17-01-2012	II	95.4	0.9	0.5	0.8	0.4	1.3	0.7	-	100.0
	TS/02	Yellow	Tomb of Shagird	17-01-2012	III	95.7	0.8	0.5	0.7	0.3	1.5	0.6	-	100.0
	TS/02	Yellow	Tomb of Shagird	17-01-2012	IV	96.1	0.8	0.5	0.6	0.3	1.1	0.5	-	100.0
	TS/02	Yellow	Tomb of Shagird	17-01-2012	Average	95.6	0.8	0.5	0.7	0.4	1.3	0.6	-	100.0
	TS/02	Yellow	Tomb of Shagird	17-01-2012	Std. Dev.	0.4	0.1	0.0	0.1	0.1	0.1	0.1	-	
26	TS/03	DarkBlue	Tomb of Shagird	16-12-2011	I	97.0	0.8	0.2	0.6	0.2	0.7	0.4	-	100.0
	TS/03	DarkBlue	Tomb of Shagird	16-12-2011	II	96.0	1.0	0.3	0.8	0.2	1.3	0.4	-	100.0
	TS/03	DarkBlue	Tomb of Shagird	16-12-2011	III	96.7	0.8	0.4	0.6	0.2	0.8	0.5	-	100.0
	TS/03	DarkBlue	Tomb of Shagird	16-12-2011	Average	96.6	0.9	0.3	0.7	0.2	0.9	0.5	-	100.0
	TS/03	DarkBlue	Tomb of Shagird	16-12-2011	Std. Dev.	0.5	0.1	0.1	0.1	0.0	0.3	0.1	-	
27	TS/04	Orange	Tomb of Shagird	13-01-2014	I	97.2	0.7	0.2	0.5	0.2	0.8	0.3	-	100.0
	TS/04	Orange	Tomb of Shagird	13-01-2014	II	96.3	0.9	0.3	0.7	0.1	1.2	0.5	-	100.0
	TS/04	Orange	Tomb of Shagird	13-01-2014	III	96.9	0.8	0.2	0.6	0.2	0.9	0.4	-	100.0
	TS/04	Orange	Tomb of Shagird	13-01-2014	Average	96.8	0.8	0.2	0.6	0.2	1.0	0.4	-	100.0
	TS/04	Orange	Tomb of Shagird	13-01-2014	Std. Dev.	0.4	0.1	0.1	0.1	0.1	0.2	0.1	-	
28	TS/05	Purple	Tomb of Shagird	25-01-2012	I	95.6	1.6	0.3	0.7	0.3	0.9	0.4	0.1	100.0
	TS/05	Purple	Tomb of Shagird	25-01-2012	II	95.2	1.8	0.4	0.9	0.2	0.8	0.3	0.3	100.0
	TS/05	Purple	Tomb of Shagird	25-01-2012	III	95.9	1.4	1.0	0.7	0.1	0.5	0.4	-	100.0
	TS/05	Purple	Tomb of Shagird	25-01-2012	IV	95.3	1.2	0.5	1.0	-	1.4	0.3	0.3	100.0
	TS/05	Purple	Tomb of Shagird	25-01-2012	Average	95.5	1.5	0.5	0.8	0.1	0.9	0.3	0.2	100.0
	TS/05	Purple	Tomb of Shagird	25-01-2012	Std. Dev.	0.3	0.2	0.3	0.1	0.1	0.4	0.0	0.1	
29	TS/06	Green	Tomb of Shagird	12-12-2011	I	95.4	0.7	0.5	1.0	0.2	1.5	0.7	-	100.0
	TS/06	Green	Tomb of Shagird	12-12-2011	II	96.0	0.9	0.3	0.7	0.2	1.4	0.5	-	100.0
	TS/06	Green	Tomb of Shagird	12-12-2011	III	95.3	1.0	0.5	0.8	0.4	1.5	0.6	-	100.0
	TS/06	Green	Tomb of Shagird	12-12-2011	Average	95.6	0.9	0.4	0.8	0.3	1.5	0.6	-	100.0
	TS/06	Green	Tomb of Shagird	12-12-2011	Std. Dev.	0.4	0.2	0.1	0.2	0.1	0.0	0.1	-	
30	TS/07	Green	Tomb of Shagird	31-01-2012	I	95.7	0.9	0.7	0.5	0.5	0.7	0.3	0.7	100.0
	TS/07	Green	Tomb of Shagird	31-01-2012	II	96.2	0.5	0.5	0.7	0.4	1.1	0.3	0.3	100.0
	TS/07	Green	Tomb of Shagird	31-01-2012	III	97.8	0.5	0.3	0.4	0.1	0.5	0.2	0.3	100.0
	TS/07	Green	Tomb of Shagird	31-01-2012	IV	95.8	0.8	0.7	0.8	0.3	0.8	0.3	0.5	100.0
	TS/07	Green	Tomb of Shagird	31-01-2012	Average	96.4	0.7	0.5	0.6	0.3	0.8	0.3	0.5	100.0
	TS/07	Green	Tomb of Shagird	31-01-2012	Std. Dev.	1.0	0.2	0.2	0.2	0.2	0.2	0.0	0.2	
31	TS/08	Yellow	Tomb of Shagird	25-06-2012	I	97.3	0.5	0.4	0.4	0.2	1.0	0.1	-	100.0
	TS/08	Yellow	Tomb of Shagird	25-06-2012	II	96.6	0.8	0.2	0.5	0.2	1.1	0.5	-	100.0
	TS/08	Yellow	Tomb of Shagird	25-06-2012	III	95.9	0.7	0.2	0.6	0.5	1.5	0.6	-	100.0
	TS/08	Yellow	Tomb of Shagird	25-06-2012	Average	96.6	0.7	0.3	0.5	0.3	1.2	0.4	-	100.0
	TS/08	Yellow	Tomb of Shagird	25-06-2012	Std. Dev.	0.73	0.14	0.11	0.08	0.16	0.27	0.25	-	

No.	Sample	Colour	Building	Date	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	PbO	Total
32	TS/09	Yellow	Tomb of Shagird	25-06-2012	I	94.3	1.3	0.5	0.7	0.3	2.1	0.8	-	100.0
	TS/09	Yellow	Tomb of Shagird	25-06-2012	II	95.5	0.8	0.4	0.9	0.3	1.6	0.6	-	100.0
	TS/09	Yellow	Tomb of Shagird	25-06-2012	III	95.5	0.6	0.5	0.8	0.4	1.5	0.7	-	100.0
	TS/09	**Yellow**	**Tomb of Shagird**	**25-06-2012**	**Average**	**95.1**	**0.9**	**0.5**	**0.8**	**0.3**	**1.7**	**0.7**	**-**	**100.0**
	TS/09	**Yellow**	**Tomb of Shagird**	**25-06-2012**	**Std. Dev.**	**0.7**	**0.4**	**0.1**	**0.1**	**0.1**	**0.3**	**0.1**	**-**	
33	TS/10	Dark-Blue	Tomb of Shagird	25-06-2012	I	97.2	0.7	0.4	0.5	0.4	0.5	0.5	-	100.0
	TS/10	Dark-Blue	Tomb of Shagird	25-06-2012	II	96.1	1.3	0.4	0.7	0.1	1.1	0.4	-	100.0
	TS/10	Dark-Blue	Tomb of Shagird	25-06-2012	III	96.9	0.7	0.3	0.7	0.2	1.0	0.1	-	100.0
	TS/10	**Dark-Blue**	**Tomb of Shagird**	**25-06-2012**	**Average**	**96.7**	**0.9**	**0.4**	**0.6**	**0.2**	**0.9**	**0.3**	**-**	**100.0**
	TS/10	**Dark-Blue**	**Tomb of Shagird**	**25-06-2012**	**Std. Dev.**	**0.6**	**0.3**	**0.1**	**0.1**	**0.1**	**0.3**	**0.2**	**-**	
34	TS/11	Dark-Blue	Tomb of Shagird	25-06-2012	I	94.6	1.8	0.7	0.8	0.5	1.4	0.3	-	100.0
	TS/11	Dark-Blue	Tomb of Shagird	25-06-2012	II	93.9	2.0	0.6	1.0	0.3	1.7	0.6	-	100.0
	TS/11	Dark-Blue	Tomb of Shagird	25-06-2012	III	94.1	1.8	0.7	0.9	0.4	1.6	0.5	-	100.0
	TS/11	**Dark-Blue**	**Tomb of Shagird**	**25-06-2012**	**Average**	**94.2**	**1.8**	**0.7**	**0.9**	**0.4**	**1.6**	**0.4**	**-**	**100.0**
	TS/11	**Dark-Blue**	**Tomb of Shagird**	**25-06-2012**	**Std. Dev.**	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**-**	
35	TS/12	Green	Tomb of Shagird	25-06-2012	I	96.0	0.6	0.7	0.8	0.3	1.1	0.6	-	100.0
	TS/12	Green	Tomb of Shagird	25-06-2012	II	96.7	1.0	0.5	0.6	0.3	0.8	0.1	-	100.0
	TS/12	Green	Tomb of Shagird	25-06-2012	III	95.3	0.8	0.5	0.6	0.2	0.8	0.3	1.6	100.0
	TS/12	**Green**	**Tomb of Shagird**	**25-06-2012**	**Average**	**96.0**	**0.8**	**0.6**	**0.6**	**0.2**	**0.9**	**0.3**	**0.5**	**100.0**
	TS/12	**Green**	**Tomb of Shagird**	**25-06-2012**	**Std. Dev.**	**0.7**	**0.2**	**0.1**	**0.1**	**0.1**	**0.2**	**0.3**	**0.9**	
36	TS/13	Orange	Tomb of Shagird	25-06-2012	I	97.2	0.8	0.1	0.4	0.1	1.0	0.4	-	100.0
	TS/13	Orange	Tomb of Shagird	25-06-2012	II	97.0	0.8	0.3	0.6	0.1	1.0	0.3	-	100.0
	TS/13	Orange	Tomb of Shagird	25-06-2012	III	95.6	1.1	0.3	0.7	0.1	1.9	0.4	-	100.0
	TS/13	**Orange**	**Tomb of Shagird**	**25-06-2012**	**Average**	**96.6**	**0.9**	**0.2**	**0.5**	**0.1**	**1.3**	**0.3**	**-**	**100.0**
	TS/13	**Orange**	**Tomb of Shagird**	**25-06-2012**	**Std. Dev.**	**0.9**	**0.2**	**0.1**	**0.1**	**0.0**	**0.5**	**0.1**	**-**	

Appendix 7.8 Chemical compositions of the slip layer on tile bodies from Mughal buildings at Punjab and Agra determined through SEM-EDS analyses. All results are in wt%, and normalised to 100 %.

No.	Sample	Colour	Building	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
1	DS/01	Yellow	Doraha Sarai	I	93.4	1.1	0.4	1.2	0.3	2.9	0.6	100.0
	DS/01	Yellow	Doraha Sarai	II	95.1	1.0	0.4	0.8	0.3	2.0	0.4	100.0
	DS/01	Yellow	Doraha Sarai	III	95.5	0.9	0.4	0.8	0.3	1.8	0.4	100.0
	DS/01	**Yellow**	**Doraha Sarai**	**Average**	**94.7**	**1.0**	**0.4**	**0.9**	**0.3**	**2.2**	**0.5**	**100.0**
2	DS/03	Yellow	Doraha Sarai	I	93.7	1.3	0.5	0.9	0.3	2.8	0.5	100.0
	DS/03	Yellow	Doraha Sarai	II	94.9	1.0	0.6	0.7	0.3	2.1	0.5	100.0
	DS/03	Yellow	Doraha Sarai	III	94.4	1.2	0.5	0.7	0.3	2.5	0.5	100.0
	DS/03	**Yellow**	**Doraha Sarai**	**Average**	**94.3**	**1.1**	**0.5**	**0.8**	**0.3**	**2.5**	**0.5**	**100.0**
3	DS/07	Dark-Blue	Doraha Sarai	I	92.8	1.2	0.7	1.1	0.5	2.8	0.9	100.0
	DS/07	Dark-Blue	Doraha Sarai	II	92.1	1.5	1.0	1.1	0.6	3.0	0.9	100.0
	DS/07	Dark-Blue	Doraha Sarai	III	93.3	1.3	0.8	1.0	0.4	2.4	0.9	100.0
	DS/07	**Dark-Blue**	**Doraha Sarai**	**Average**	**92.7**	**1.3**	**0.8**	**1.0**	**0.5**	**2.7**	**0.9**	**100.0**
4	DS/11	Dark-Blue	Doraha Sarai	I	92.9	0.9	0.7	0.9	0.5	2.9	1.2	100.0
	DS/11	Dark-Blue	Doraha Sarai	II	93.8	1.0	0.6	1.2	0.3	2.5	0.6	100.0
	DS/11	Dark-Blue	Doraha Sarai	III	92.5	1.4	0.8	1.1	0.5	2.8	0.9	100.0
	DS/11	**Dark-Blue**	**Doraha Sarai**	**Average**	**93.1**	**1.1**	**0.7**	**1.1**	**0.4**	**2.7**	**0.9**	**100.0**
5	CR/03	Yellow	Chini-ka Rauza	I	97.7	0.6	0.2	0.4	0.1	0.6	0.4	100.0
	CR/03	Yellow	Chini-ka Rauza	II	97.6	0.6	0.2	0.4	0.1	0.7	0.4	100.0
	CR/03	Yellow	Chini-ka Rauza	III	96.9	0.7	0.4	0.4	0.3	0.8	0.5	100.0
	CR/03	**Yellow**	**Chini-ka Rauza**	**Average**	**97.4**	**0.7**	**0.2**	**0.4**	**0.2**	**0.7**	**0.5**	**100.0**
6	CR/05	Green	Chini-ka Rauza	I	95.9	1.0	0.3	0.8	0.2	1.4	0.5	100.0
	CR/05	Green	Chini-ka Rauza	II	96.9	0.7	0.4	0.6	0.1	0.9	0.5	100.0
	CR/05	Green	Chini-ka Rauza	III	96.9	0.7	0.2	0.8	0.1	0.9	0.4	100.0
	CR/05	**Green**	**Chini-ka Rauza**	**Average**	**96.5**	**0.8**	**0.3**	**0.7**	**0.1**	**1.1**	**0.5**	**100.0**
7	CR/15	Turquoise	Chini-ka Rauza	I	96.1	1.1	0.3	0.6	0.1	1.2	0.6	100.0
	CR/15	Turquoise	Chini-ka Rauza	II	97.2	0.7	0.3	0.4	0.1	0.6	0.7	100.0
	CR/15	Turquoise	Chini-ka Rauza	III	96.8	0.9	0.3	0.4	0.1	1.1	0.5	100.0
	CR/15	**Turquoise**	**Chini-ka Rauza**	**Average**	**96.7**	**0.9**	**0.3**	**0.4**	**0.1**	**1.0**	**0.6**	**100.0**
8	CR/16	White	Chini-ka Rauza	I	96.6	0.8	0.3	0.4	0.3	1.1	0.6	100.0
	CR/16	White	Chini-ka Rauza	II	96.9	0.7	0.1	0.4	0.2	1.1	0.6	100.0
	CR/16	White	Chini-ka Rauza	III	96.7	0.7	0.2	0.4	0.3	1.1	0.6	100.0
	CR/16	**White**	**Chini-ka Rauza**	**Average**	**96.8**	**0.7**	**0.2**	**0.4**	**0.2**	**1.1**	**0.6**	**100.0**
9	SM/03	Dark-Blue	Sheesh Mahal	I	94.3	1.5	0.7	0.8	0.5	1.8	0.6	100.0
	SM/03	Dark-Blue	Sheesh Mahal	II	94.5	1.5	0.5	0.7	0.4	1.7	0.6	100.0
	SM/03	Dark-Blue	Sheesh Mahal	III	95.7	1.0	0.5	0.6	0.4	1.2	0.5	100.0
	SM/03	**Dark-Blue**	**Sheesh Mahal**	**Average**	**94.8**	**1.3**	**0.6**	**0.7**	**0.4**	**1.6**	**0.6**	**100.0**
10	SM/11	Orange	Sheesh Mahal	I	94.8	1.0	0.4	1.0	0.3	1.8	0.7	100.0
	SM/11	Orange	Sheesh Mahal	II	95.3	0.9	0.5	0.9	0.2	1.5	0.7	100.0
	SM/11	Orange	Sheesh Mahal	III	95.1	1.0	0.5	0.8	0.2	1.8	0.6	100.0
	SM/11	**Orange**	**Sheesh Mahal**	**Average**	**95.1**	**1.0**	**0.5**	**0.9**	**0.2**	**1.7**	**0.7**	**100.0**
11	TS/02	Yellow	Tomb of Shagird	I	93.3	1.3	0.7	1.4	0.3	2.3	0.6	100.0
	TS/02	Yellow	Tomb of Shagird	II	95.8	0.9	0.3	0.8	0.3	1.3	0.7	100.0
	TS/02	Yellow	Tomb of Shagird	III	95.4	1.1	0.4	0.7	0.2	1.6	0.6	100.0
	TS/02	**Yellow**	**Tomb of Shagird**	**Average**	**94.8**	**1.1**	**0.5**	**1.0**	**0.3**	**1.7**	**0.6**	**100.0**
12	TS/04	Orange	Tomb of Shagird	I	97.6	0.6	0.3	0.4	0.1	0.6	0.4	100.0
	TS/04	Orange	Tomb of Shagird	II	97.1	0.8	0.2	0.6	0.0	0.7	0.6	100.0
	TS/04	Orange	Tomb of Shagird	III	96.7	0.8	0.4	0.6	0.0	0.9	0.6	100.0
	TS/04	**Orange**	**Tomb of Shagird**	**Average**	**97.1**	**0.7**	**0.3**	**0.5**	**0.1**	**0.7**	**0.5**	**100.0**
13	TS/06	Green	Tomb of Shagird	I	97.1	0.7	0.1	0.7	0.1	0.8	0.6	100.0
	TS/06	Green	Tomb of Shagird	II	95.5	0.7	0.3	0.9	0.2	1.2	1.1	100.0
	TS/06	Green	Tomb of Shagird	III	95.5	0.9	0.2	1.1	0.3	1.3	0.7	100.0
	TS/06	**Green**	**Tomb of Shagird**	**Average**	**96.0**	**0.8**	**0.2**	**0.9**	**0.2**	**1.1**	**0.8**	**100.0**

Appendix 7.9 Chemical composition of interparticle glass in the bodies of tiles from Mughal buildings at Delhi. All results are in wt% from SEM-EDS analyses, and normalised to 100 %.

No.	Sample	Colour	Building	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
1	IK/02	White	Tomb of Isa Khan	I	71.8	16.0	1.8	2.5	0.7	5.9	1.3	100.0
	IK/02	White	Tomb of Isa Khan	II	73.4	15.4	1.9	2.5	0.6	5.1	1.2	100.0
	IK/02	White	Tomb of Isa Khan	III	71.6	15.0	2.8	2.5	0.7	6.0	1.4	100.0
	IK/02	**White**	**Tomb of Isa Khan**	**Average**	**72.3**	**15.5**	**2.1**	**2.5**	**0.7**	**5.7**	**1.3**	**100.0**
	IK/02	**White**	**Tomb of Isa Khan**	**Std. Dev.**	**1.0**	**0.5**	**0.6**	**0.0**	**0.1**	**0.5**	**0.1**	
2	IK/04	DarkBlue	Tomb of Isa Khan	I	73.1	12.6	2.4	3.2	1.0	6.1	1.6	100.0
	IK/04	DarkBlue	Tomb of Isa Khan	II	72.6	12.6	2.2	3.3	1.1	6.5	1.8	100.0
	IK/04	DarkBlue	Tomb of Isa Khan	III	72.5	11.6	2.0	3.6	1.4	6.6	2.2	100.0
	IK/04	DarkBlue	Tomb of Isa Khan	IV	72.4	11.4	1.8	3.2	1.2	5.1	4.9	100.0
	IK/04	DarkBlue	Tomb of Isa Khan	V	73.8	12.4	2.3	3.0	1.7	5.0	1.9	100.0
	IK/04	**DarkBlue**	**Tomb of Isa Khan**	**Average**	**72.9**	**12.1**	**2.1**	**3.3**	**1.3**	**5.9**	**2.5**	**100.0**
	IK/04	**DarkBlue**	**Tomb of Isa Khan**	**Std. Dev.**	**0.6**	**0.6**	**0.2**	**0.2**	**0.3**	**0.8**	**1.4**	
3	IK/05	DarkBlue	Tomb of Isa Khan	I	72.2	12.6	2.6	3.2	1.0	6.9	1.5	100.0
	IK/05	DarkBlue	Tomb of Isa Khan	II	71.8	10.6	1.6	3.1	1.4	7.7	3.8	100.0
	IK/05	DarkBlue	Tomb of Isa Khan	III	72.8	10.5	3.2	2.9	1.3	6.0	3.3	100.0
	IK/05	DarkBlue	Tomb of Isa Khan	IV	72.3	11.5	1.7	3.6	2.0	5.0	4.0	100.0
	IK/05	**DarkBlue**	**Tomb of Isa Khan**	**Average**	**72.2**	**11.3**	**2.3**	**3.2**	**1.4**	**6.4**	**3.2**	**100.0**
	IK/05	**DarkBlue**	**Tomb of Isa Khan**	**Std. Dev.**	**0.4**	**1.0**	**0.8**	**0.3**	**0.4**	**1.2**	**1.1**	
4	AS/01	Green	Arab-ki Sarai	I	72.5	12.0	2.3	3.8	1.7	5.5	2.2	100.0
	AS/01	Green	Arab-ki Sarai	II	71.6	12.2	2.6	3.8	2.3	5.5	2.0	100.0
	AS/01	Green	Arab-ki Sarai	III	70.2	12.9	2.1	3.4	1.9	7.2	2.4	100.0
	AS/01	**Green**	**Arab-ki Sarai**	**Average**	**71.4**	**12.4**	**2.4**	**3.7**	**1.9**	**6.1**	**2.2**	**100.0**
	AS/01	**Green**	**Arab-ki Sarai**	**Std. Dev.**	**1.1**	**0.5**	**0.3**	**0.3**	**0.3**	**1.0**	**0.2**	
5	AS/02	DarkBlue	Arab-ki Sarai	I	72.4	11.8	2.1	3.2	1.6	4.9	4.1	100.0
	AS/02	DarkBlue	Arab-ki Sarai	II	73.6	12.4	2.1	2.6	1.5	4.5	3.4	100.0
	AS/02	DarkBlue	Arab-ki Sarai	III	72.5	12.7	2.2	2.5	2.0	5.7	2.4	100.0
	AS/02	**DarkBlue**	**Arab-ki Sarai**	**Average**	**72.8**	**12.3**	**2.1**	**2.7**	**1.7**	**5.0**	**3.3**	**100.0**
	AS/02	**DarkBlue**	**Arab-ki Sarai**	**Std. Dev.**	**0.7**	**0.5**	**0.0**	**0.4**	**0.3**	**0.6**	**0.8**	
6	AS/03	DarkBlue	Arab-ki Sarai	I	72.5	14.2	2.7	2.7	1.9	4.4	1.7	100.0
	AS/03	DarkBlue	Arab-ki Sarai	II	72.9	13.2	2.2	2.9	2.1	5.3	1.6	100.0
	AS/03	DarkBlue	Arab-ki Sarai	III	72.6	13.5	2.1	2.8	1.9	5.0	2.1	100.0
	AS/03	DarkBlue	Arab-ki Sarai	IV	73.5	13.9	2.4	2.4	2.5	4.3	1.0	100.0
	AS/03	**DarkBlue**	**Arab-ki Sarai**	**Average**	**72.9**	**13.7**	**2.3**	**2.7**	**2.1**	**4.7**	**1.6**	**100.0**
	AS/03	**DarkBlue**	**Arab-ki Sarai**	**Std. Dev.**	**0.5**	**0.4**	**0.3**	**0.2**	**0.3**	**0.5**	**0.5**	
7	AS/04	Yellow	Arab-ki Sarai	I	71.7	13.4	1.3	2.9	0.8	7.8	2.1	100.0
	AS/04	Yellow	Arab-ki Sarai	II	72.4	12.6	2.0	3.1	1.2	6.6	2.0	100.0
	AS/04	Yellow	Arab-ki Sarai	III	71.8	13.0	1.9	3.1	1.8	6.7	1.8	100.0
	AS/04	**Yellow**	**Arab-ki Sarai**	**Average**	**72.0**	**13.0**	**1.7**	**3.1**	**1.3**	**7.0**	**2.0**	**100.0**
	AS/04	**Yellow**	**Arab-ki Sarai**	**Std. Dev.**	**0.4**	**0.4**	**0.4**	**0.1**	**0.5**	**0.7**	**0.1**	
8	AK/01	Yellow	Tomb of Atgah Khan	I	69.6	11.6	2.0	3.8	1.3	8.7	3.0	100.0
	AK/01	Yellow	Tomb of Atgah Khan	II	72.7	10.9	1.5	3.5	1.0	7.9	2.6	100.0
	AK/01	Yellow	Tomb of Atgah Khan	III	71.8	12.0	2.3	3.4	1.0	7.2	2.2	100.0
	AK/01	**Yellow**	**Tomb of Atgah Khan**	**Average**	**71.4**	**11.5**	**1.9**	**3.6**	**1.1**	**8.0**	**2.6**	**100.0**
	AK/01	**Yellow**	**Tomb of Atgah Khan**	**Std. Dev.**	**1.6**	**0.6**	**0.4**	**0.2**	**0.1**	**0.8**	**0.4**	
9	AK/02	Turquoise	Tomb of Atgah Khan	I	71.7	11.7	1.5	2.3	1.4	8.8	2.5	100.0
	AK/02	Turquoise	Tomb of Atgah Khan	II	74.5	11.1	1.9	2.2	1.7	6.3	2.4	100.0
	AK/02	Turquoise	Tomb of Atgah Khan	III	68.6	11.3	0.8	3.0	1.0	12.3	3.0	100.0
	AK/02	**Turquoise**	**Tomb of Atgah Khan**	**Average**	**71.6**	**11.4**	**1.4**	**2.5**	**1.4**	**9.1**	**2.7**	**100.0**
	AK/02	**Turquoise**	**Tomb of Atgah Khan**	**Std. Dev.**	**2.9**	**0.3**	**0.5**	**0.5**	**0.4**	**3.0**	**0.3**	
10	AK/03	Turquoise	Tomb of Atgah Khan	I	67.5	9.7	3.6	2.1	3.2	10.6	3.2	100.0
	AK/03	Turquoise	Tomb of Atgah Khan	II	70.3	11.7	2.0	3.2	1.2	9.3	2.5	100.0
	AK/03	Turquoise	Tomb of Atgah Khan	III	71.5	11.4	2.3	3.4	1.3	8.4	1.8	100.0
	AK/03	Turquoise	Tomb of Atgah Khan	IV	62.7	11.7	3.3	2.7	2.1	14.8	2.7	100.0
	AK/03	Turquoise	Tomb of Atgah Khan	V	67.7	11.2	2.3	2.5	1.6	12.0	2.8	100.0

No.	Sample	Colour	Building	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
	AK/03	**Turquoise**	**Tomb of Atgah Khan**	**Average**	**67.9**	**11.1**	**2.7**	**2.8**	**1.9**	**11.0**	**2.6**	**100.0**
	AK/03	**Turquoise**	**Tomb of Atgah Khan**	**Std. Dev.**	**3.4**	**0.8**	**0.7**	**0.5**	**0.8**	**2.5**	**0.5**	
11	SB/01	Dark-Blue	Sabz Burj	I	70.9	12.3	1.7	3.7	1.0	4.7	5.7	100.0
	SB/01	Dark-Blue	Sabz Burj	II	72.0	12.8	3.7	3.5	2.4	4.1	1.4	100.0
	SB/01	**Dark-Blue**	**Sabz Burj**	**Average**	**71.5**	**12.6**	**2.7**	**3.6**	**1.7**	**4.4**	**3.5**	**100.0**
	SB/01	**Dark-Blue**	**Sabz Burj**	**Std. Dev.**	**0.8**	**0.4**	**1.4**	**0.2**	**1.0**	**0.4**	**3.0**	
12	NG/01	White	Nila Gumbad	I	72.5	12.5	1.9	4.0	1.7	5.5	1.9	100.0
	NG/01	White	Nila Gumbad	II	71.3	11.6	1.4	4.4	2.1	6.4	2.8	100.0
	NG/01	White	Nila Gumbad	III	73.5	11.8	2.2	3.9	2.2	4.5	2.0	100.0
	NG/01	**White**	**Nila Gumbad**	**Average**	**72.4**	**12.0**	**1.8**	**4.1**	**2.0**	**5.4**	**2.2**	**100.0**
	NG/01	**White**	**Nila Gumbad**	**Std. Dev.**	**1.1**	**0.5**	**0.4**	**0.3**	**0.3**	**0.9**	**0.5**	
13	NG/02	Yellow	Nila Gumbad	I	76.4	10.4	2.0	3.5	1.1	4.6	2.0	100.0
	NG/02	Yellow	Nila Gumbad	II	73.5	10.9	1.5	3.7	1.0	7.5	1.9	100.0
	NG/02	Yellow	Nila Gumbad	III	72.2	12.5	2.2	3.7	2.0	5.6	1.8	100.0
	NG/02	Yellow	Nila Gumbad	IV	74.0	12.1	2.2	3.3	2.0	4.8	1.6	100.0
	NG/02	Yellow	Nila Gumbad	V	74.3	11.5	2.1	3.5	1.8	5.0	1.7	100.0
	NG/02	**Yellow**	**Nila Gumbad**	**Average**	**74.1**	**11.5**	**2.0**	**3.6**	**1.6**	**5.5**	**1.8**	**100.0**
	NG/02	**Yellow**	**Nila Gumbad**	**Std. Dev.**	**1.5**	**0.9**	**0.3**	**0.2**	**0.5**	**1.2**	**0.1**	
14	NG/04	Turquoise	Nila Gumbad	I	68.4	13.6	1.0	3.0	1.9	9.3	2.8	100.0
	NG/04	Turquoise	Nila Gumbad	II	71.3	14.9	2.2	3.0	2.5	4.5	1.6	100.0
	NG/04	Turquoise	Nila Gumbad	III	70.0	14.7	2.0	3.1	2.2	6.0	2.0	100.0
	NG/04	Turquoise	Nila Gumbad	IV	70.4	15.1	1.7	3.0	1.4	6.8	1.6	100.0
	NG/04	**Turquoise**	**Nila Gumbad**	**Average**	**70.0**	**14.6**	**1.7**	**3.0**	**2.0**	**6.7**	**2.0**	**100.0**
	NG/04	**Turquoise**	**Nila Gumbad**	**Std. Dev.**	**1.2**	**0.7**	**0.5**	**0.1**	**0.4**	**2.0**	**0.6**	
15	NG/07	Yellow	Nila Gumbad	I	70.0	13.0	3.3	3.8	2.4	5.7	1.9	100.0
	NG/07	Yellow	Nila Gumbad	II	76.1	11.6	2.1	3.2	1.4	4.0	1.5	100.0
	NG/07	Yellow	Nila Gumbad	III	71.7	12.7	2.0	4.1	1.4	6.0	2.1	100.0
	NG/07	Yellow	Nila Gumbad	IV	73.3	13.0	3.0	3.4	2.1	3.9	1.3	100.0
	NG/07	**Yellow**	**Nila Gumbad**	**Average**	**72.8**	**12.6**	**2.6**	**3.6**	**1.8**	**4.9**	**1.7**	**100.0**
	NG/07	**Yellow**	**Nila Gumbad**	**Std. Dev.**	**2.6**	**0.6**	**0.6**	**0.4**	**0.5**	**1.1**	**0.3**	
16	NG/09	Dark-Blue	Nila Gumbad	I	72.2	12.0	1.9	3.7	2.3	5.9	1.9	100.0
	NG/09	Dark-Blue	Nila Gumbad	II	70.4	12.4	1.8	4.0	1.5	7.7	2.2	100.0
	NG/09	Dark-Blue	Nila Gumbad	III	72.5	11.4	2.2	3.6	2.0	6.2	2.1	100.0
	NG/09	**Dark-Blue**	**Nila Gumbad**	**Average**	**71.7**	**11.9**	**2.0**	**3.8**	**1.9**	**6.6**	**2.1**	**100.0**
	NG/09	**Dark-Blue**	**Nila Gumbad**	**Std. Dev.**	**1.1**	**0.5**	**0.2**	**0.2**	**0.4**	**0.9**	**0.1**	
17	NG/14	Turquoise	Nila Gumbad	I	70.9	11.5	2.2	4.0	1.3	8.3	2.0	100.0
	NG/14	Turquoise	Nila Gumbad	II	73.0	12.2	3.1	3.5	1.9	4.3	2.0	100.0
	NG/14	Turquoise	Nila Gumbad	III	69.7	11.3	1.3	4.0	0.9	11.1	1.7	100.0
	NG/14	**Turquoise**	**Nila Gumbad**	**Average**	**71.2**	**11.7**	**2.2**	**3.8**	**1.3**	**7.9**	**1.9**	**100.0**
	NG/14	**Turquoise**	**Nila Gumbad**	**Std. Dev.**	**1.7**	**0.5**	**0.9**	**0.3**	**0.5**	**3.4**	**0.2**	
18	NG/15	Dark-Blue	Nila Gumbad	I	69.3	12.5	1.5	3.7	1.0	7.5	4.6	100.0
	NG/15	Dark-Blue	Nila Gumbad	II	67.2	12.7	1.3	3.3	1.1	10.9	3.6	100.0
	NG/15	Dark-Blue	Nila Gumbad	III	71.6	11.4	1.6	3.7	1.8	7.2	2.8	100.0
	NG/15	**Dark-Blue**	**Nila Gumbad**	**Average**	**69.3**	**12.2**	**1.5**	**3.6**	**1.3**	**8.5**	**3.6**	**100.0**
	NG/15	**Dark-Blue**	**Nila Gumbad**	**Std. Dev.**	**2.2**	**0.7**	**0.2**	**0.2**	**0.4**	**2.0**	**0.9**	
19	NG/16	White	Nila Gumbad	I	74.1	11.6	2.6	3.9	1.5	5.0	1.5	100.0
	NG/16	White	Nila Gumbad	II	71.9	12.6	2.4	4.3	2.1	5.2	1.6	100.0
	NG/16	White	Nila Gumbad	III	69.1	11.7	3.0	4.1	3.3	5.9	2.8	100.0
	NG/16	**White**	**Nila Gumbad**	**Average**	**71.7**	**12.0**	**2.6**	**4.1**	**2.3**	**5.4**	**2.0**	**100.0**
	NG/16	**White**	**Nila Gumbad**	**Std. Dev.**	**2.5**	**0.5**	**0.3**	**0.2**	**1.0**	**0.5**	**0.7**	
20	QK/02	Dark-Blue	Tomb of Quli Khan	I	76.6	10.4	1.5	3.5	1.4	4.5	2.2	100.0
	QK/02	Dark-Blue	Tomb of Quli Khan	II	71.7	12.4	2.8	4.1	1.8	5.1	2.0	100.0
	QK/02	Dark-Blue	Tomb of Quli Khan	III	65.7	13.4	1.1	4.9	2.2	9.7	3.0	100.0
	QK/02	Dark-Blue	Tomb of Quli Khan	IV	64.7	12.9	1.0	4.4	1.6	11.5	3.9	100.0
	QK/02	**Dark-Blue**	**Tomb of Quli Khan**	**Average**	**69.7**	**12.3**	**1.6**	**4.2**	**1.8**	**7.7**	**2.8**	**100.0**
	QK/02	**Dark-Blue**	**Tomb of Quli Khan**	**Std. Dev.**	**5.5**	**1.3**	**0.8**	**0.6**	**0.3**	**3.4**	**0.9**	

Appendix 7.10 Chemical composition of interparticle glass in the bodies of tiles from Mughal buildings at Agra. All results are in wt% from SEM-EDS analyses, and normalised to 100 %.

No.	Sample	Colour	Building	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	Total
1	CR/01	Purple	Chini-ka Rauza	I	82.7	6.4	2.0	2.7	1.2	3.6	1.6	100.0
	CR/01	Purple	Chini-ka Rauza	II	86.0	4.5	1.1	2.5	1.5	3.3	1.1	100.0
	CR/01	Purple	Chini-ka Rauza	III	79.4	6.4	1.3	3.9	1.4	5.6	2.1	100.0
	CR/01	**Purple**	**Chini-ka Rauza**	**Average**	**82.7**	**5.8**	**1.4**	**3.0**	**1.3**	**4.1**	**1.6**	**100.0**
	CR/01	**Purple**	**Chini-ka Rauza**	**Std. Dev.**	**3.3**	**1.1**	**0.4**	**0.8**	**0.1**	**1.3**	**0.5**	
2	CR/04	Yellow	Chini-ka Rauza	I	77.1	9.6	2.5	3.2	1.4	3.9	2.4	100.0
	CR/04	Yellow	Chini-ka Rauza	II	75.9	8.7	1.7	4.1	1.2	6.3	2.2	100.0
	CR/04	Yellow	Chini-ka Rauza	III	78.4	8.6	1.4	3.2	1.1	6.3	1.1	100.0
	CR/04	**Yellow**	**Chini-ka Rauza**	**Average**	**77.1**	**9.0**	**1.9**	**3.5**	**1.2**	**5.5**	**1.9**	**100.0**
	CR/04	**Yellow**	**Chini-ka Rauza**	**Std. Dev.**	**1.2**	**0.6**	**0.6**	**0.5**	**0.1**	**1.4**	**0.7**	
3	CR/05	Green	Chini-ka Rauza	I	79.2	7.2	2.2	3.0	1.5	1.6	5.3	100.0
	CR/05	Green	Chini-ka Rauza	II	77.1	6.2	3.9	3.6	3.1	4.4	1.7	100.0
	CR/05	Green	Chini-ka Rauza	III	78.8	7.4	2.5	3.8	1.5	4.4	1.7	100.0
	CR/05	**Green**	**Chini-ka Rauza**	**Average**	**78.4**	**7.0**	**2.8**	**3.5**	**2.0**	**3.5**	**2.9**	**100.0**
	CR/05	**Green**	**Chini-ka Rauza**	**Std. Dev.**	**1.1**	**0.6**	**0.9**	**0.4**	**0.9**	**1.6**	**2.1**	
4	CR/08	Dark-Blue	Chini-ka Rauza	I	74.1	8.9	2.1	3.9	0.7	2.6	7.6	100.0
	CR/08	Dark-Blue	Chini-ka Rauza	II	80.6	6.5	1.5	3.0	0.9	4.1	3.5	100.0
	CR/08	Dark-Blue	Chini-ka Rauza	III	75.2	8.4	4.2	3.7	1.3	5.2	2.1	100.0
	CR/08	**Dark-Blue**	**Chini-ka Rauza**	**Average**	**76.6**	**7.9**	**2.6**	**3.5**	**1.0**	**4.0**	**4.4**	**100.0**
	CR/08	**Dark-Blue**	**Chini-ka Rauza**	**Std. Dev.**	**3.4**	**1.3**	**1.4**	**0.5**	**0.3**	**1.3**	**2.9**	
5	CR/13	Turquoise	Chini-ka Rauza	I	78.6	7.7	2.9	3.7	1.4	3.5	2.3	100.0
	CR/13	Turquoise	Chini-ka Rauza	II	81.2	7.7	2.4	2.6	1.4	3.0	1.7	100.0
	CR/13	Turquoise	Chini-ka Rauza	III	70.6	8.0	0.7	5.0	0.8	13.5	1.4	100.0
	CR/13	**Turquoise**	**Chini-ka Rauza**	**Average**	**76.8**	**7.8**	**2.0**	**3.8**	**1.2**	**6.7**	**1.8**	**100.0**
	CR/13	**Turquoise**	**Chini-ka Rauza**	**Std. Dev.**	**5.5**	**0.2**	**1.2**	**1.2**	**0.4**	**5.9**	**0.4**	
6	CR/14	Turquoise	Chini-ka Rauza	I	75.6	9.3	2.5	3.4	1.2	7.6	0.4	100.0
	CR/14	Turquoise	Chini-ka Rauza	II	67.9	10.9	1.7	4.2	1.0	13.7	0.5	100.0
	CR/14	Turquoise	Chini-ka Rauza	III	71.7	10.5	2.3	3.6	1.3	10.2	0.5	100.0
	CR/14	Turquoise	Chini-ka Rauza	IV	70.4	10.5	2.0	4.1	0.8	11.7	0.4	100.0
	CR/14	**Turquoise**	**Chini-ka Rauza**	**Average**	**71.4**	**10.3**	**2.2**	**3.8**	**1.1**	**10.8**	**0.4**	**100.0**
	CR/14	**Turquoise**	**Chini-ka Rauza**	**Std. Dev.**	**3.2**	**0.7**	**0.3**	**0.4**	**0.2**	**2.6**	**0.1**	
7	CR/18	Dark-Blue	Chini-ka Rauza	I	74.1	12.4	2.9	4.1	1.7	3.2	1.6	100.0
	CR/18	Dark-Blue	Chini-ka Rauza	II	73.5	8.8	3.3	4.3	1.7	3.9	4.5	100.0
	CR/18	Dark-Blue	Chini-ka Rauza	III	73.0	10.2	2.2	4.2	1.6	2.3	6.5	100.0
	CR/18	Dark-Blue	Chini-ka Rauza	IV	73.9	10.9	2.5	4.3	2.8	4.0	1.5	100.0
	CR/18	**Dark-Blue**	**Chini-ka Rauza**	**Average**	**73.6**	**10.6**	**2.7**	**4.2**	**1.9**	**3.4**	**3.6**	**100.0**
	CR/18	**Dark-Blue**	**Chini-ka Rauza**	**Std. Dev.**	**0.5**	**1.5**	**0.5**	**0.1**	**0.6**	**0.8**	**2.4**	

Appendix 7.11 Chemical composition of interparticle glass in the bodies of tiles from Mughal buildings at Punjab. All results are in wt% from SEM-EDS analyses, and normalised to 100 %. '-' indicates 'not detected'.

No.	Sample	Colour	Building	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	PbO	Total
1	DS/04	Turquoise	Doraha Sarai	I	85.2	6.8	0.1	2.9	1.0	2.7	1.3	-	100.0
	DS/04	Turquoise	Doraha Sarai	II	85.1	5.7	2.0	2.4	1.1	1.6	2.1	-	100.0
	DS/04	Turquoise	Doraha Sarai	III	82.4	6.5	1.7	3.5	1.0	3.0	1.9	-	100.0
	DS/04	**Turquoise**	**Doraha Sarai**	**Average**	**84.3**	**6.4**	**1.3**	**2.9**	**1.0**	**2.4**	**1.8**	**-**	**100.0**
	DS/04	**Turquoise**	**Doraha Sarai**	**Std. Dev.**	**1.6**	**0.6**	**1.0**	**0.5**	**0.1**	**0.7**	**0.4**	**-**	
2	DS/07	Dark-Blue	Doraha Sarai	I	89.9	2.6	1.2	2.1	0.9	2.3	1.0	-	100.0
	DS/07	Dark-Blue	Doraha Sarai	II	80.6	6.7	0.8	3.6	1.5	5.1	1.7	-	100.0
	DS/07	Dark-Blue	Doraha Sarai	III	85.0	4.5	0.9	2.5	0.6	3.4	3.0	-	100.0
	DS/07	**Dark-Blue**	**Doraha Sarai**	**Average**	**85.2**	**4.6**	**1.0**	**2.7**	**1.0**	**3.6**	**1.9**	**-**	**100.0**
	DS/07	**Dark-Blue**	**Doraha Sarai**	**Std. Dev.**	**4.7**	**2.1**	**0.2**	**0.8**	**0.5**	**1.4**	**1.0**	**-**	
3	DS/10	Dark-Blue	Doraha Sarai	I	72.9	10.2	2.1	3.8	2.0	5.9	3.1	-	100.0
	DS/10	Dark-Blue	Doraha Sarai	II	74.1	10.5	3.0	3.3	2.5	4.0	2.6	-	100.0
	DS/10	Dark-Blue	Doraha Sarai	III	74.0	10.2	3.1	3.6	2.1	4.2	2.9	-	100.0
	DS/10	**Dark-Blue**	**Doraha Sarai**	**Average**	**73.6**	**10.3**	**2.7**	**3.6**	**2.2**	**4.7**	**2.9**	**-**	**100.0**
	DS/10	**Dark-Blue**	**Doraha Sarai**	**Std. Dev.**	**0.7**	**0.2**	**0.6**	**0.3**	**0.3**	**1.0**	**0.3**	**-**	
4	DS/14	Turquoise	Doraha Sarai	I	73.3	6.3	2.0	4.8	1.8	6.4	5.3	-	100.0
	DS/14	Turquoise	Doraha Sarai	II	70.5	6.2	4.1	4.8	2.1	7.6	4.7	-	100.0
	DS/14	Turquoise	Doraha Sarai	III	81.1	5.6	0.9	3.7	1.2	4.6	3.0	-	100.0
	DS/14	Turquoise	Doraha Sarai	IV	76.8	5.5	1.7	4.2	1.0	5.2	5.6	-	100.0
	DS/14	**Turquoise**	**Doraha Sarai**	**Average**	**75.4**	**5.9**	**2.2**	**4.4**	**1.5**	**6.0**	**4.7**	**-**	**100.0**
	DS/14	**Turquoise**	**Doraha Sarai**	**Std. Dev.**	**4.6**	**0.4**	**1.4**	**0.6**	**0.5**	**1.4**	**1.2**	**-**	
5	FS/01	Yellow	Fatehabad Sarai	I	71.2	11.5	2.9	5.2	1.8	5.8	1.5	-	100.0
	FS/01	Yellow	Fatehabad Sarai	II	71.3	14.4	4.2	4.1	2.7	2.8	0.7	-	100.0
	FS/01	Yellow	Fatehabad Sarai	III	71.9	13.6	3.2	4.4	2.5	3.3	1.1	-	100.0
	FS/01	Yellow	Fatehabad Sarai	IV	72.8	13.9	3.5	3.9	2.6	2.6	0.7	-	100.0
	FS/01	**Yellow**	**Fatehabad Sarai**	**Average**	**71.8**	**13.3**	**3.4**	**4.4**	**2.4**	**3.6**	**1.0**	**-**	**100.0**
	FS/01	**Yellow**	**Fatehabad Sarai**	**Std. Dev.**	**0.8**	**1.2**	**0.6**	**0.6**	**0.4**	**1.5**	**0.4**	**-**	
6	FS/02	Dark-Blue	Fatehabad Sarai	I	71.6	12.9	4.5	4.4	2.8	2.9	0.8	-	100.0
	FS/02	Dark-Blue	Fatehabad Sarai	II	71.1	13.2	4.7	4.3	2.7	3.2	0.9	-	100.0
	FS/02	Dark-Blue	Fatehabad Sarai	III	71.9	11.6	2.6	5.1	1.6	5.1	2.2	-	100.0
	FS/02	**Dark-Blue**	**Fatehabad Sarai**	**Average**	**71.6**	**12.6**	**3.9**	**4.6**	**2.4**	**3.7**	**1.3**	**-**	**100.0**
	FS/02	**Dark-Blue**	**Fatehabad Sarai**	**Std. Dev.**	**0.4**	**0.9**	**1.2**	**0.4**	**0.7**	**1.2**	**0.7**	**-**	
7	TU/01	Dark-Blue	Tomb of Ustad	I	72.8	13.4	4.5	4.0	1.5	2.5	1.3	-	100.0
	TU/01	Dark-Blue	Tomb of Ustad	II	73.8	10.4	3.6	4.5	2.0	4.2	1.6	-	100.0
	TU/01	Dark-Blue	Tomb of Ustad	III	78.3	6.7	3.8	4.0	1.4	2.9	2.9	-	100.0
	TU/01	Dark-Blue	Tomb of Ustad	IV	76.7	7.8	3.1	4.3	1.9	4.4	1.8	-	100.0
	TU/01	**Dark-Blue**	**Tomb of Ustad**	**Average**	**75.4**	**9.6**	**3.8**	**4.2**	**1.7**	**3.5**	**1.9**	**-**	**100.0**
	TU/01	**Dark-Blue**	**Tomb of Ustad**	**Std. Dev.**	**2.5**	**3.0**	**0.6**	**0.3**	**0.3**	**0.9**	**0.7**	**-**	
8	TU/02	Dark-Blue	Tomb of Ustad	I	75.2	8.8	3.5	4.6	2.6	3.0	2.2	-	100.0
	TU/02	Dark-Blue	Tomb of Ustad	II	75.4	8.7	3.4	4.7	2.4	3.6	1.8	-	100.0
	TU/02	Dark-Blue	Tomb of Ustad	III	74.0	9.0	4.3	5.2	3.3	3.2	1.1	-	100.0
	TU/02	**Dark-Blue**	**Tomb of Ustad**	**Average**	**74.9**	**8.9**	**3.7**	**4.9**	**2.8**	**3.2**	**1.7**	**-**	**100.0**
	TU/02	**Dark-Blue**	**Tomb of Ustad**	**Std. Dev.**	**0.8**	**0.1**	**0.5**	**0.3**	**0.5**	**0.3**	**0.6**	**-**	
9	TU/03	Dark-Blue	Tomb of Ustad	I	74.3	8.8	3.3	5.1	2.2	4.4	1.9	-	100.0
	TU/03	Dark-Blue	Tomb of Ustad	II	75.6	7.9	2.6	5.1	2.0	5.0	1.8	-	100.0
	TU/03	Dark-Blue	Tomb of Ustad	III	74.9	8.5	3.3	5.0	2.6	3.6	2.1	-	100.0
	TU/03	**Dark-Blue**	**Tomb of Ustad**	**Average**	**74.9**	**8.4**	**3.1**	**5.1**	**2.3**	**4.4**	**1.9**	**-**	**100.0**
	TU/03	**Dark-Blue**	**Tomb of Ustad**	**Std. Dev.**	**0.7**	**0.5**	**0.4**	**0.0**	**0.3**	**0.7**	**0.1**	**-**	
10	SM/03	Dark-Blue	Sheesh Mahal	I	77.6	6.3	0.9	4.2	0.8	9.3	0.8	-	100.0
	SM/03	Dark-Blue	Sheesh Mahal	II	84.9	4.8	0.9	2.7	0.7	5.3	0.7	-	100.0
	SM/03	Dark-Blue	Sheesh Mahal	III	91.4	2.3	1.0	1.7	0.6	2.4	0.6	-	100.0
	SM/03	**Dark-Blue**	**Sheesh Mahal**	**Average**	**84.6**	**4.5**	**1.0**	**2.9**	**0.7**	**5.7**	**0.7**	**-**	**100.0**
	SM/03	**Dark-Blue**	**Sheesh Mahal**	**Std. Dev.**	**6.9**	**2.0**	**0.1**	**1.3**	**0.1**	**3.5**	**0.1**	**-**	

No.	Sample	Colour	Building	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	PbO	Total
11	SM/05	Green	Sheesh Mahal	I	70.0	5.7	4.3	3.5	2.7	5.6	8.2	-	100.0
	SM/05	Green	Sheesh Mahal	II	76.1	5.1	2.8	4.4	1.3	7.7	2.6	-	100.0
	SM/05	Green	Sheesh Mahal	III	89.3	4.3	2.0	1.2	0.9	1.7	0.6	-	100.0
	SM/05	**Green**	**Sheesh Mahal**	**Average**	**78.5**	**5.0**	**3.0**	**3.0**	**1.6**	**5.0**	**3.8**	**-**	**100.0**
	SM/05	**Green**	**Sheesh Mahal**	**Std. Dev.**	**9.8**	**0.7**	**1.2**	**1.6**	**0.9**	**3.0**	**3.9**	**-**	
12	SM/08	Purple	Sheesh Mahal	I	75.3	7.7	3.7	4.2	2.4	4.5	2.2	-	100.0
	SM/08	Purple	Sheesh Mahal	II	78.1	7.7	3.7	3.3	2.6	3.6	1.1	-	100.0
	SM/08	Purple	Sheesh Mahal	III	57.7	12.5	0.7	4.3	0.3	24.1	0.4	-	100.0
	SM/08	**Purple**	**Sheesh Mahal**	**Average**	**70.4**	**9.3**	**2.7**	**3.9**	**1.8**	**10.8**	**1.2**	**-**	**100.0**
	SM/08	**Purple**	**Sheesh Mahal**	**Std. Dev.**	**11.1**	**2.8**	**1.7**	**0.6**	**1.3**	**11.6**	**0.9**	**-**	
13	SM/11	Orange	Sheesh Mahal	I	73.4	7.8	1.2	4.7	0.9	6.7	5.3	-	100.0
	SM/11	Orange	Sheesh Mahal	II	79.8	6.6	1.7	3.7	1.0	4.6	2.6	-	100.0
	SM/11	Orange	Sheesh Mahal	III	77.0	7.9	2.1	3.8	1.3	3.9	4.2	-	100.0
	SM/11	**Orange**	**Sheesh Mahal**	**Average**	**76.7**	**7.4**	**1.7**	**4.1**	**1.0**	**5.1**	**4.0**	**-**	**100.0**
	SM/11	**Orange**	**Sheesh Mahal**	**Std. Dev.**	**3.2**	**0.7**	**0.4**	**0.6**	**0.2**	**1.5**	**1.3**	**-**	
14	DKS/01	Turquoise	Dakhini Sarai	I	77.3	11.1	1.9	4.3	0.6	3.1	1.8	-	100.0
	DKS/01	Turquoise	Dakhini Sarai	II	76.5	10.0	2.9	3.6	1.6	3.4	2.1	-	100.0
	DKS/01	Turquoise	Dakhini Sarai	III	77.9	8.3	1.8	3.3	1.2	3.4	4.1	-	100.0
	DKS/01	**Turquoise**	**Dakhini Sarai**	**Average**	**77.2**	**9.8**	**2.2**	**3.7**	**1.1**	**3.3**	**2.7**	**-**	**100.0**
	DKS/01	**Turquoise**	**Dakhini Sarai**	**Std. Dev.**	**0.7**	**1.4**	**0.6**	**0.5**	**0.5**	**0.2**	**1.3**	**-**	
15	DKS/02	Orange	Dakhini Sarai	I	74.4	7.4	2.0	4.7	1.4	5.5	4.7	-	100.0
	DKS/02	Orange	Dakhini Sarai	II	80.8	6.6	1.3	3.4	1.3	3.9	2.7	-	100.0
	DKS/02	Orange	Dakhini Sarai	III	81.6	6.3	2.1	3.4	2.0	3.0	1.5	-	100.0
	DKS/02	**Orange**	**Dakhini Sarai**	**Average**	**78.9**	**6.8**	**1.8**	**3.8**	**1.6**	**4.1**	**3.0**	**-**	**100.0**
	DKS/02	**Orange**	**Dakhini Sarai**	**Std. Dev.**	**3.9**	**0.5**	**0.4**	**0.7**	**0.4**	**1.2**	**1.6**	**-**	
16	DKS/04	Green	Dakhini Sarai	I	71.3	11.1	2.3	4.7	1.3	0.7	8.7	-	100.0
	DKS/04	Green	Dakhini Sarai	II	70.8	10.9	3.4	4.7	1.5	6.8	1.9	-	100.0
	DKS/04	Green	Dakhini Sarai	III	81.2	6.9	2.5	3.1	0.9	2.4	3.1	-	100.0
	DKS/04	**Green**	**Dakhini Sarai**	**Average**	**74.4**	**9.6**	**2.7**	**4.2**	**1.3**	**3.3**	**4.5**	**-**	**100.0**
	DKS/04	**Green**	**Dakhini Sarai**	**Std. Dev.**	**5.9**	**2.4**	**0.6**	**0.9**	**0.3**	**3.1**	**3.6**	**-**	
17	TS/01	Purple	Tomb of Shagird	I	68.8	8.4	1.8	4.5	0.9	7.8	7.9	-	100.0
	TS/01	Purple	Tomb of Shagird	II	82.0	5.6	1.4	3.5	1.2	4.5	1.7	-	100.0
	TS/01	Purple	Tomb of Shagird	III	88.5	2.8	1.1	2.7	0.8	3.6	0.6	-	100.0
	TS/01	**Purple**	**Tomb of Shagird**	**Average**	**79.8**	**5.6**	**1.4**	**3.6**	**1.0**	**5.3**	**3.4**	**-**	**100.0**
	TS/01	**Purple**	**Tomb of Shagird**	**Std. Dev.**	**10.0**	**2.8**	**0.4**	**0.9**	**0.2**	**2.2**	**3.9**	**-**	
18	TS/02	Yellow	Tomb of Shagird	I	77.4	8.0	2.3	3.6	2.0	3.9	2.8	-	100.0
	TS/02	Yellow	Tomb of Shagird	II	76.8	8.2	2.2	4.0	2.8	3.3	2.7	-	100.0
	TS/02	Yellow	Tomb of Shagird	III	70.3	9.1	1.9	4.9	2.7	8.8	2.4	-	100.0
	TS/02	**Yellow**	**Tomb of Shagird**	**Average**	**74.8**	**8.5**	**2.1**	**4.2**	**2.5**	**5.3**	**2.7**	**-**	**100.0**
	TS/02	**Yellow**	**Tomb of Shagird**	**Std. Dev.**	**3.9**	**0.6**	**0.2**	**0.6**	**0.4**	**3.0**	**0.2**	**-**	
19	TS/04	Orange	Tomb of Shagird	I	80.1	7.0	1.7	3.6	2.3	3.5	1.7	-	100.0
	TS/04	Orange	Tomb of Shagird	II	80.6	5.3	1.7	3.5	0.7	1.9	6.4	-	100.0
	TS/04	Orange	Tomb of Shagird	III	76.0	7.4	0.1	6.6	0.7	8.1	1.2	-	100.0
	TS/04	**Orange**	**Tomb of Shagird**	**Average**	**78.9**	**6.6**	**1.2**	**4.6**	**1.2**	**4.5**	**3.1**	**-**	**100.0**
	TS/04	**Orange**	**Tomb of Shagird**	**Std. Dev.**	**2.5**	**1.1**	**0.9**	**1.8**	**1.0**	**3.2**	**2.9**	-	
20	TS/05	Purple	Tomb of Shagird	I	74.8	10.5	3.0	3.7	1.7	1.8	1.5	3.0	100.0
	TS/05	Purple	Tomb of Shagird	II	73.6	13.0	2.5	4.2	0.9	1.9	0.5	3.5	100.0
	TS/05	Purple	Tomb of Shagird	III	75.2	10.6	3.3	3.9	1.3	1.1	0.9	3.8	100.0
	TS/05	**Purple**	**Tomb of Shagird**	**Average**	**74.5**	**11.4**	**2.9**	**3.9**	**1.3**	**1.6**	**0.9**	**3.5**	**100.0**
	TS/05	**Purple**	**Tomb of Shagird**	**Std. Dev.**	**0.8**	**1.4**	**0.4**	**0.2**	**0.4**	**0.4**	**0.5**	**0.4**	
21	TS/07	Green	Tomb of Shagird	I	69.8	7.7	3.1	5.6	1.9	2.2	1.3	8.5	100.0
	TS/07	Green	Tomb of Shagird	II	64.4	8.8	4.4	4.8	0.8	3.7	1.1	12.0	100.0
	TS/07	Green	Tomb of Shagird	III	65.9	8.8	3.5	5.5	0.8	5.4	1.4	8.8	100.0
	TS/07	**Green**	**Tomb of Shagird**	**Average**	**66.7**	**8.4**	**3.7**	**5.3**	**1.2**	**3.7**	**1.2**	**9.8**	**100.0**
	TS/07	**Green**	**Tomb of Shagird**	**Std. Dev.**	**2.8**	**0.6**	**0.6**	**0.4**	**0.6**	**1.6**	**0.1**	**1.9**	
22	TS/11	Dark-Blue	Tomb of Shagird	I	79.4	3.8	3.0	4.4	2.5	5.1	1.9	-	100.0
	TS/11	Dark-Blue	Tomb of Shagird	II	78.9	4.5	3.1	4.3	2.3	5.0	1.9	-	100.0
	TS/11	Dark-Blue	Tomb of Shagird	III	78.3	4.5	3.9	4.3	2.5	5.0	1.4	-	100.0

No.	Sample	Colour	Building	Analysis	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	PbO	Total
	TS/11	**Dark-Blue**	**Tomb of Shagird**	**Average**	**78.9**	**4.3**	**3.3**	**4.4**	**2.4**	**5.0**	**1.7**	**-**	**100.0**
	TS/11	**Dark-Blue**	**Tomb of Shagird**	**Std. Dev.**	**0.5**	**0.4**	**0.5**	**0.0**	**0.1**	**0.0**	**0.3**	**-**	
23	TS/12	Green	Tomb of Shagird	I	64.7	8.4	4.2	4.6	1.6	1.3	0.5	14.8	100.0
	TS/12	Green	Tomb of Shagird	II	67.6	7.8	4.4	5.2	1.8	2.2	0.8	10.3	100.0
	TS/12	Green	Tomb of Shagird	III	66.9	7.7	3.9	5.2	2.6	2.2	0.8	10.6	100.0
	TS/12	**Green**	**Tomb of Shagird**	**Average**	**66.4**	**8.0**	**4.2**	**5.0**	**2.0**	**1.9**	**0.7**	**11.9**	**100.0**
	TS/12	**Green**	**Tomb of Shagird**	**Std. Dev.**	**1.5**	**0.3**	**0.2**	**0.4**	**0.5**	**0.5**	**0.2**	**2.5**	

Appendix 7.12 Average chemical compositions of the tile glazes from the sixteenth century Mughal buildings at Delhi determined through EPMA-WDS analyses. All results are in wt%. '-' indicates 'not detected' or 'below detection limit'.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	MnO	CuO	NiO	SnO_2	PbO	ZnO	CoO	As_2O_5	BaO	P_2O_5	SO_3	Total
1	HD/01	Turquoise	Humayun Darwaza	63.76	19.92	1.27	1.40	0.32	4.71	1.29	0.29	-	3.75	-	-	0.31	-	-	0.11	0.06	0.24	0.16	97.60
2	HD/02	Turquoise	Humayun Darwaza	63.10	20.34	1.25	1.32	0.44	4.44	1.30	0.27	-	3.77	-	-	0.06	-	-	0.13	-	0.19	0.25	96.86
3	HD/03	Turquoise	Humayun Darwaza	63.55	20.97	1.22	1.31	0.30	4.55	1.30	0.23	-	3.71	-	-	0.20	-	-	0.39	-	0.45	0.24	98.42
4	HD/04	Turquoise	Humayun Darwaza	62.73	21.76	1.30	1.30	0.43	4.72	1.28	0.28	-	3.66	-	-	0.62	-	-	-	-	0.25	0.22	98.55
5	HD/05	Turquoise	Humayun Darwaza	63.78	20.99	1.19	1.34	0.48	4.63	1.26	0.27	-	3.62	-	-	0.66	-	-	-	-	0.27	0.27	98.78
6	IK/01	Dark-Blue	Tomb of Isa Khan	66.99	18.69	1.67	1.45	0.53	5.90	1.42	0.29	-	0.06	0.06	-	-	-	0.45	1.22	-	-	0.21	98.94
7	IK/02	White	Tomb of Isa Khan	67.29	15.95	1.64	2.02	0.64	6.28	1.26	0.27	-	-	-	-	-	-	-	-	-	0.07	0.23	95.65
8	IK/03	Dark-Blue	Tomb of Isa Khan	64.10	17.49	1.65	1.68	0.64	5.65	1.46	0.31	-	-	0.05	-	-	-	0.44	0.92	-	0.06	0.26	94.71
9	IK/04	Dark-Blue	Tomb of Isa Khan	61.70	18.77	2.33	2.05	1.35	7.11	1.74	0.36	-	-	-	-	-	-	0.31	0.90	-	0.23	0.23	97.08
10	IK/05	Dark-Blue	Tomb of Isa Khan	62.47	20.08	1.78	1.85	0.62	6.38	1.45	0.33	0.08	0.06	0.09	-	-	-	0.44	1.06	-	0.10	0.27	97.06
11	AS/01	Green	Arab-ki Sarai	58.35	15.46	2.86	2.15	1.72	4.70	0.87	0.19	0.05	0.82	-	1.97	9.71	-	-	-	-	0.36	0.17	99.38
12	AS/02	Dark-Blue	Arab-ki Sarai	66.11	16.53	2.53	1.95	1.23	8.45	1.55	0.41	-	-	0.05	-	-	-	0.21	0.47	-	0.14	0.16	99.79
13	AS/03	Dark-Blue	Arab-ki Sarai	66.19	16.24	2.38	2.13	1.26	8.29	1.64	0.40	-	-	-	-	-	-	0.18	0.37	-	0.17	0.13	99.37
14	AS/04	Yellow	Arab-ki Sarai	53.43	13.73	1.76	1.21	0.94	6.36	1.39	0.27	-	-	-	1.21	15.77	0.09	-	-	-	0.14	-	96.30
15	KM/01	Dark-Blue	Khairul Manzil Masjid	61.75	18.02	2.56	2.61	0.83	8.17	2.11	0.45	0.05	-	-	-	-	-	0.31	0.50	-	0.11	0.22	97.69
16	KM/02	Dark-Blue	Khairul Manzil Masjid	62.35	18.69	2.31	1.64	0.81	8.15	2.28	0.44	0.06	-	-	-	-	-	0.31	0.74	-	0.06	0.25	98.08
17	KM/03	Green	Khairul Manzil Masjid	54.17	17.20	1.46	1.69	0.60	6.34	1.47	0.31	-	1.89	-	1.21	9.04	-	-	-	0.06	0.08	0.16	95.67
18	KM/04	Dark-Blue	Khairul Manzil Masjid	62.63	15.91	2.82	4.00	1.13	7.74	2.53	0.42	0.05	0.08	0.06	-	-	-	0.48	0.53	-	0.11	0.29	98.77
19	AK/01	Yellow	Tomb of Atgah Khan	53.91	14.08	1.20	1.56	0.79	6.12	1.54	0.36	0.07	-	-	2.75	14.68	0.65	-	-	-	0.18	-	97.89
20	AK/02	Turquoise	Tomb of Atgah Khan	63.15	18.36	1.49	2.07	0.87	8.38	1.96	0.38	0.09	2.18	-	-	-	-	-	-	-	0.33	0.16	99.42
21	AK/03	Turquoise	Tomb of Atgah Khan	63.44	19.03	1.61	1.77	0.82	8.15	1.69	0.36	0.09	1.53	-	-	-	-	-	-	0.05	0.25	0.18	98.96
22	AK/04	Turquoise	Tomb of Atgah Khan	62.84	19.12	1.64	1.80	0.80	8.01	1.73	0.37	0.06	1.36	-	-	-	-	-	-	-	0.25	0.12	98.10
23	AK/05	Turquoise	Tomb of Atgah Khan	62.50	17.33	1.76	3.57	0.80	7.96	1.72	0.37	0.08	2.02	-	-	-	0.06	-	-	-	0.29	0.14	98.60
24	SB/01	Dark-Blue	Sabz Burj	64.24	18.39	2.72	1.78	1.19	6.15	1.59	0.35	0.06	0.06	-	-	-	-	0.18	0.60	0.05	0.25	0.26	97.86
25	SB/02	Dark-Blue	Sabz Burj	68.76	14.87	1.94	2.50	1.09	6.62	1.61	0.39	-	0.05	0.05	-	-	-	0.16	0.46	-	0.19	0.24	98.92
26	SB/03	Dark-Blue	Sabz Burj	67.87	15.45	1.98	2.49	0.97	6.69	1.63	0.40	-	0.06	-	-	-	-	0.21	0.65	-	0.14	0.31	98.85
27	SB/04	Dark-Blue	Sabz Burj	68.44	15.32	2.14	2.00	1.11	6.39	1.61	0.37	-	0.05	-	-	-	-	0.20	0.54	-	0.20	0.26	98.61
28	SB/05	Dark-Blue	Sabz Burj	67.32	15.48	2.03	2.12	0.84	6.75	1.68	0.47	0.05	0.05	-	-	-	-	0.20	0.46	-	0.15	0.33	97.93
29	SB/06	Yellow	Sabz Burj	54.29	14.84	2.12	1.81	1.53	3.92	0.85	0.21	-	0.08	-	2.75	16.81	0.26	-	-	-	0.24	-	99.71
30	SB/07	Yellow	Sabz Burj	55.49	15.08	1.40	1.94	0.78	6.77	1.44	0.34	-	0.05	-	2.00	12.70	0.24	-	-	-	0.15	-	98.38
31	SB/08	Turquoise	Sabz Burj	65.34	17.49	2.02	1.88	1.06	6.05	1.30	0.32	0.05	3.56	-	-	-	-	-	-	-	0.17	0.22	99.47
32	SB/09	Turquoise	Sabz Burj	66.88	17.08	1.85	1.90	0.92	6.22	1.28	0.35	0.05	2.60	-	-	-	-	-	-	-	0.18	0.28	99.59
33	SB/10	Dark-Blue	Sabz Burj	66.78	16.57	2.04	2.59	1.03	6.03	1.64	0.37	0.05	0.08	-	-	0.05	-	0.17	0.43	-	0.20	0.33	98.34

Appendix 7.13 Average chemical compositions of the tile glazes from the seventeenth century (1st Qtr.) Mughal buildings at Delhi determined through EPMA-WDS analyses. All results are in wt%. '-' indicates 'not detected' or 'below detection limit'.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	MnO	CuO	NiO	SnO_2	PbO	ZnO	CoO	As_2O_5	BaO	P_2O_5	SO_3	Total
1	NG/01	White	Nila Gumbad	64.60	18.13	4.55	2.37	3.21	1.87	0.53	0.09	-	-	-	-	-	-	-	-	-	0.40	0.26	96.02
2	NG/02	Yellow	Nila Gumbad	52.73	12.76	1.46	1.51	0.82	5.64	1.30	0.30	-	-	-	1.89	15.29	0.37	-	-	-	0.10	-	94.16
3	NG/03	Dark-Blue	Nila Gumbad	61.70	17.01	2.81	2.47	1.84	4.84	1.29	0.26	0.05	-	0.05	-	-	-	0.24	0.60	-	0.23	0.27	93.65
4	NG/04	Turquoise	Nila Gumbad	62.03	20.88	1.38	1.51	0.57	5.92	1.51	0.32	-	3.22	-	-	-	-	-	-	0.06	0.18	0.25	97.83
5	NG/05	Green	Nila Gumbad	56.65	14.57	1.52	1.57	0.78	6.59	1.61	0.34	-	1.27	-	1.87	11.18	0.34	-	-	0.05	0.12	-	98.45
6	NG/06	Yellow	Nila Gumbad	54.73	13.62	1.73	2.52	1.05	4.76	1.16	0.22	-	0.06	-	3.53	15.56	0.35	-	-	-	0.24	-	99.52
7	NG/07	Yellow	Nila Gumbad	55.62	13.63	1.81	1.69	0.83	5.56	1.36	0.31	-	-	-	2.72	15.38	0.34	-	-	-	0.13	0.14	99.51
8	NG/08	Dark-Blue	Nila Gumbad	64.42	18.21	2.89	2.36	1.76	5.49	1.52	0.30	-	-	-	-	-	-	0.29	0.63	0.05	0.25	0.30	98.46
9	NG/09	Dark-Blue	Nila Gumbad	64.76	17.92	2.61	2.46	1.55	5.91	1.66	0.29	0.06	-	-	-	-	-	0.29	0.63	-	0.26	0.28	98.68
10	NG/10	Turquoise	Nila Gumbad	62.32	21.47	1.36	1.62	0.51	5.75	1.37	0.34	-	3.22	-	-	-	-	-	-	0.05	0.24	0.23	98.47
11	NG/11	Turquoise	Nila Gumbad	63.83	18.03	1.98	2.51	1.03	5.59	1.40	0.31	-	3.09	-	-	-	-	-	-	-	0.15	0.28	98.20
12	NG/12	Dark-Blue	Nila Gumbad	64.46	17.94	2.61	2.46	1.49	5.92	1.64	0.31	-	-	-	-	-	-	0.30	0.63	-	0.23	0.34	98.34
13	NG/13	Turquoise	Nila Gumbad	61.81	20.25	2.44	1.70	1.30	5.86	1.51	0.30	0.05	3.11	-	-	-	-	-	-	-	0.22	0.23	98.77
14	NG/14	Turquoise	Nila Gumbad	62.72	18.32	2.16	1.80	1.06	6.94	1.61	0.37	0.05	2.91	-	-	0.10	-	-	-	-	0.18	0.15	98.38
15	NG/15	Dark-Blue	Nila Gumbad	64.86	16.38	2.53	1.87	1.20	7.26	1.91	0.41	-	-	-	-	-	-	0.34	0.70	-	0.13	0.19	97.78
16	NG/16	White	Nila Gumbad	61.90	18.79	4.18	2.71	3.27	2.22	0.64	0.10	0.05	-	-	-	-	0.05	-	-	-	0.39	0.24	94.55
17	NG/17	Green	Nila Gumbad	54.54	14.43	1.47	1.46	0.84	6.77	1.57	0.31	-	1.36	-	1.27	10.47	0.41	-	-	-	0.11	-	95.01
18	QK/01	Dark-Blue	Tomb of Quli Khan	62.39	18.35	2.62	1.80	0.96	7.69	1.76	0.35	-	-	0.06	-	-	-	0.62	1.25	-	0.19	0.18	98.20
19	QK/02	Dark-Blue	Tomb of Quli Khan	60.89	18.94	2.02	2.68	1.24	8.35	2.10	0.37	0.05	0.05	-	-	-	-	0.23	0.46	-	0.16	0.30	97.83
20	QK/03	Dark-Blue	Tomb of Quli Khan	62.71	18.02	1.97	2.88	0.95	7.99	1.90	0.37	0.07	-	-	-	-	-	0.31	0.53	-	0.16	0.19	98.04
21	QK/04	Dark-Blue	Tomb of Quli Khan	62.58	18.81	2.13	2.81	0.98	7.40	1.77	0.34	0.06	-	-	-	-	-	0.31	0.82	-	0.16	0.21	98.38

Appendix 7.14 Average chemical compositions of the tile glazes from the seventeenth century (1st Qtr.) Mughal buildings at Agra determined through EPMA-WDS analyses. All results are in wt%. '-' indicates 'not detected' or 'below detection limit'.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	MnO	CuO	NiO	SnO_2	PbO	ZnO	CoO	As_2O_5	BaO	P_2O_5	SO_3	Total
1	KMA/01	Turquoise	Kanch Mahal	63.31	17.56	3.38	1.88	2.08	5.08	1.38	0.27	-	4.73	-	-	-	-	-	-	0.06	0.34	0.21	100.29
2	KMA/02	Turquoise	Kanch Mahal	62.39	17.89	3.50	1.94	2.16	5.32	1.48	0.27	-	4.84	-	-	-	-	-	-	-	0.30	0.22	100.31
3	KMA/03	Yellow	Kanch Mahal	52.64	15.44	1.79	1.40	0.90	6.52	1.59	0.34	-	0.06	-	2.37	15.71	0.17	-	-	-	0.10	-	99.03
4	NK/01	Yellow	Naubat Khana	61.97	15.84	1.45	1.87	1.02	8.41	2.42	0.41	-	-	-	0.29	4.99	0.13	-	-	-	0.16	0.11	99.07
5	NK/02	Yellow	Naubat Khana	51.93	13.42	1.43	1.17	0.87	7.12	1.58	0.31	-	-	-	2.49	17.59	0.44	-	-	-	0.17	-	98.51
6	CR/01	Purple	Chini-ka Rauza	68.97	15.70	3.38	2.98	2.59	1.70	0.80	0.07	1.96	-	0.05	-	-	0.08	-	-	-	0.40	0.33	99.00
7	CR/02	Purple	Chini-ka Rauza	68.44	15.43	3.47	3.90	2.82	1.80	0.67	0.09	1.93	0.06	-	-	0.08	0.07	-	-	0.39	0.30	0.40	99.85
8	CR/03	Yellow	Chini-ka Rauza	58.50	14.27	2.63	2.67	2.53	1.21	0.37	-	-	-	-	1.99	12.32	0.11	-	-	-	0.40	-	97.00
9	CR/04	Yellow	Chini-ka Rauza	55.35	12.12	2.05	2.19	2.12	1.73	0.51	0.06	-	0.08	0.08	2.96	14.26	0.33	-	-	-	0.24	-	94.08
10	CR/05	Green	Chini-ka Rauza	57.66	11.66	2.21	4.14	2.08	1.22	0.40	0.06	-	1.84	-	2.71	12.07	0.34	-	-	0.05	0.18	-	96.62
11	CR/06	Green	Chini-ka Rauza	55.99	13.14	2.58	3.12	2.43	1.50	0.41	0.05	-	1.62	-	2.98	15.77	0.25	-	-	-	0.26	-	100.10
12	CR/07	Green	Chini-ka Rauza	55.46	15.40	1.13	2.42	0.65	6.89	1.37	0.32	-	1.54	0.06	2.35	12.76	-	-	-	-	0.27	-	100.62
13	CR/08	Dark-Blue	Chini-ka Rauza	69.13	13.53	3.23	3.15	2.82	2.12	1.52	0.07	0.21	0.18	0.05	-	0.11	-	0.49	0.47	-	0.52	0.35	97.95
14	CR/09	Dark-Blue	Chini-ka Rauza	70.92	13.81	3.09	3.12	2.66	1.55	1.27	-	0.06	0.21	0.07	-	0.08	-	0.49	0.31	-	0.46	0.30	98.42
15	CR/10	Dark-Blue	Chini-ka Rauza	70.08	14.59	3.24	3.64	2.72	1.62	1.33	0.08	-	0.06	0.06	-	-	-	0.43	0.29	-	0.40	0.30	98.84
16	CR/11	Dark-Blue	Chini-ka Rauza	69.79	14.14	3.11	3.01	2.49	1.87	1.71	0.09	-	0.14	-	-	0.11	-	0.34	0.39	-	0.40	0.24	97.84
17	CR/12	Dark-Blue	Chini-ka Rauza	71.47	14.04	3.19	3.47	2.73	1.58	1.17	0.07	-	0.10	-	-	0.08	-	0.42	0.20	-	0.33	0.34	99.20
18	CR/13	Turquoise	Chini-ka Rauza	71.77	14.34	2.89	3.27	2.06	1.61	0.64	0.05	-	3.73	-	-	-	-	-	0.33	-	0.25	-	100.94
19	CR/14	Turquoise	Chini-ka Rauza	62.96	17.60	1.69	2.63	0.79	8.38	1.86	0.39	-	3.81	-	-	0.05	-	-	-	0.05	0.18	0.24	100.63
20	CR/15	Turquoise	Chini-ka Rauza	67.36	16.23	3.15	3.33	3.05	1.43	0.53	0.05	-	3.59	-	-	0.15	-	-	-	-	0.39	0.28	99.54
21	CR/16	White	Chini-ka Rauza	68.36	17.23	3.79	2.86	3.17	1.73	0.49	0.07	-	-	-	-	0.07	-	-	-	-	0.38	0.27	98.42
22	CR/17	White	Chini-ka Rauza	70.99	15.11	3.27	3.64	2.65	1.76	0.54	-	-	-	0.05	-	0.05	-	-	-	-	0.38	0.47	98.90
23	CR/18	Dark-Blue	Chini-ka Rauza	70.59	15.05	3.41	3.66	2.26	1.61	1.56	-	-	0.06	0.07	-	-	-	0.45	0.42	-	0.43	0.45	100.02
24	CR/19	Turquoise	Chini-ka Rauza	68.44	16.46	3.58	3.86	2.35	1.72	0.56	0.05	-	2.87	-	-	-	-	-	-	-	0.23	0.43	100.55
25	CR/20	Turquoise	Chini-ka Rauza	68.88	15.64	2.72	4.20	1.94	1.73	0.63	0.07	-	2.41	-	-	0.05	-	-	-	-	0.27	0.31	98.85

Appendix 7.15 Average chemical compositions of the tile glazes from the seventeenth century (1^{st} Qtr.) Mughal buildings at Punjab determined through EPMA-WDS analyses. All results are in wt%. '-' indicates 'not detected' or 'below detection limit'.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	MnO	CuO	NiO	SnO_2	PbO	ZnO	CoO	As_2O_5	BaO	P_2O_5	SO_3	Total
1	DS/01	Yellow	Doraha Sarai	59.37	13.84	3.03	2.94	2.47	2.79	0.63	0.06	-	0.05	-	2.23	11.67	0.06	-	-	-	0.41	-	99.56
2	DS/02	Turquoise	Doraha Sarai	63.83	16.83	4.55	3.08	3.16	2.48	0.81	0.11	0.05	2.88	-	-	0.14	0.06	-	-	-	0.40	0.29	98.69
3	DS/03	Yellow	Doraha Sarai	56.66	16.29	3.39	2.68	2.64	2.77	0.72	0.09	-	-	-	1.86	11.17	-	-	-	-	0.22	0.05	98.55
4	DS/04	Turquoise	Doraha Sarai	62.20	17.31	3.93	3.57	3.28	2.93	0.86	0.14	0.06	3.24	-	-	0.25	-	-	-	-	0.32	0.26	98.36
5	DS/05	Yellow	Doraha Sarai	54.68	15.29	3.26	2.42	2.41	2.48	0.74	0.10	-	-	0.05	2.66	11.81	-	-	-	-	0.32	-	96.23
6	DS/06	Dark-Blue	Doraha Sarai	69.60	13.55	4.94	3.56	3.46	2.70	1.51	0.10	-	-	-	-	0.12	-	0.20	0.30	-	0.35	-	100.39
7	DS/07	Dark-Blue	Doraha Sarai	62.68	18.33	3.96	3.26	3.13	2.81	1.85	0.13	-	0.11	-	-	-	0.08	0.33	0.46	0.05	0.57	0.05	97.80
8	DS/08	White	Doraha Sarai	64.19	19.49	4.00	2.94	3.34	3.50	0.91	0.15	0.05	-	-	-	-	-	-	-	-	0.40	0.17	99.14
9	DS/09	Green	Doraha Sarai	58.01	14.79	1.83	2.13	1.40	7.90	2.05	0.37	-	0.81	-	0.92	9.04	-	-	-	-	0.23	0.05	99.52
10	DS/10	Dark-Blue	Doraha Sarai	66.38	14.80	3.37	2.52	1.93	6.00	2.82	0.31	0.06	0.25	-	-	-	-	0.79	0.11	-	0.37	0.21	99.92
11	DS/11	Dark-Blue	Doraha Sarai	65.77	16.78	3.85	2.73	2.78	2.77	1.72	0.11	0.06	1.43	-	-	-	-	0.26	0.07	-	0.49	0.34	99.17
12	DS/12	Turquoise	Doraha Sarai	66.18	15.90	3.79	3.52	2.83	2.55	0.69	0.07	-	2.84	-	-	0.10	-	-	-	-	0.33	0.26	99.06
13	DS/13	Turquoise	Doraha Sarai	63.59	16.69	2.60	2.72	1.72	7.08	1.63	0.32	0.05	2.53	-	-	-	-	-	-	-	0.24	0.13	99.29
14	FS/01	Yellow	Fatehabad Sarai	53.20	15.33	3.54	3.20	2.87	2.47	0.84	0.08	-	-	-	2.26	13.17	0.05	-	-	-	0.41	-	97.41
15	FS/02	Dark-Blue	Fatehabad Sarai	63.93	15.74	4.40	3.79	3.36	3.72	1.76	0.22	0.05	0.10	-	-	-	-	0.25	0.62	-	0.40	0.34	98.67
16	TU/01	Dark-Blue	Tomb of Ustad	64.41	15.12	4.51	4.04	3.13	3.59	1.70	0.18	-	0.15	-	-	0.11	-	0.34	0.51	-	0.45	0.40	98.64
17	TU/02	Dark-Blue	Tomb of Ustad	64.97	15.25	4.64	4.22	3.38	3.61	1.76	0.20	-	0.10	0.06	-	0.10	-	0.34	0.67	-	0.42	0.38	100.10
18	TU/03	Dark-Blue	Tomb of Ustad	64.50	15.34	4.30	5.29	3.07	3.75	1.69	0.20	-	0.11	0.05	-	-	-	0.29	0.63	-	0.25	0.28	99.76
19	TU/04	Yellow	Tomb of Ustad	57.55	14.11	2.62	4.73	2.54	2.18	0.66	0.09	-	0.08	-	2.93	11.92	-	-	-	-	0.33	-	99.73

Appendix 7.16 Average chemical compositions of the tile glazes from the seventeenth century (2nd Qtr.) Mughal buildings at Punjab determined through EPMA-WDS analyses. All results are in wt%. '-' indicates 'not detected' or 'below detection limit'.

No.	Sample	Colour	Building	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	MnO	CuO	NiO	SnO_2	PbO	ZnO	CoO	As_2O_5	BaO	P_2O_5	SO_3	Total
1	SM/01	Purple	Sheesh Mahal	63.23	14.52	3.26	3.32	2.23	1.57	0.62	0.08	1.36	0.05	-	-	0.07	-	-	-	-	0.28	0.30	90.89
2	SM/02	Yellow	Sheesh Mahal	53.11	14.99	1.99	1.52	1.08	5.74	1.43	0.30	-	0.06	-	3.20	16.40	0.27	-	-	-	0.16	-	100.24
3	SM/03	Dark-Blue	Sheesh Mahal	66.05	14.87	3.27	3.07	2.31	1.66	1.32	0.08	-	0.06	0.07	-	0.05	-	0.40	0.16	-	0.30	0.41	94.07
4	SM/04	Orange	Sheesh Mahal	56.00	10.80	2.53	2.43	1.96	1.32	0.51	0.07	-	0.05	-	3.63	19.39	1.78	-	-	-	0.23	-	100.71
5	SM/05	Green	Sheesh Mahal	52.20	11.05	1.97	2.54	1.62	1.25	0.49	-	-	3.00	-	4.54	19.52	0.37	-	-	-	0.19	-	98.74
6	SM/06	White	Sheesh Mahal	63.25	13.04	3.09	3.56	2.09	1.47	0.53	0.05	0.05	0.05	-	0.07	0.08	0.07	-	-	-	0.32	0.33	88.04
7	SM/07	Turquoise	Sheesh Mahal	67.86	15.64	3.28	3.23	2.48	1.85	0.61	0.14	-	3.04	-	-	0.10	-	-	-	-	0.32	0.19	98.73
8	SM/08	Purple	Sheesh Mahal	73.51	13.89	3.09	4.50	2.02	1.48	0.61	0.07	1.12	0.05	-	-	0.09	0.07	-	-	-	0.16	0.30	100.96
9	SM/09	Yellow	Sheesh Mahal	52.14	15.00	1.89	2.77	0.88	6.39	1.37	0.28	-	0.06	-	2.53	16.19	0.16	-	-	-	0.15	-	99.82
10	SM/10	Dark-Blue	Sheesh Mahal	72.79	15.25	3.34	3.47	2.33	1.60	1.00	0.07	0.05	0.09	-	-	0.15	-	0.29	0.40	-	0.29	0.13	101.24
11	SM/11	Orange	Sheesh Mahal	52.60	12.28	2.15	3.10	1.81	1.23	0.40	-	-	0.05	-	4.68	20.25	1.58	-	-	-	0.10	-	100.23
12	DKS/01	Turquoise	Dakhini Sarai	70.58	14.64	3.81	2.98	2.41	1.27	0.43	0.05	-	2.70	-	-	0.06	-	-	-	-	0.42	0.31	99.67
13	DKS/02	Orange	Dakhini Sarai	44.39	12.46	2.57	1.75	1.82	1.30	0.56	-	-	0.06	-	4.08	29.06	2.60	-	-	0.05	0.26	-	100.95
14	DKS/03	Orange	Dakhini Sarai	55.93	15.16	2.98	2.66	2.26	1.19	0.49	-	0.05	-	-	1.92	15.34	1.56	-	-	-	0.26	-	99.80
15	DKS/04	Green	Dakhini Sarai	52.64	11.91	3.10	2.89	2.16	1.69	0.59	0.09	-	3.01	-	2.39	16.71	0.27	-	-	0.05	0.46	-	97.96
16	TS/01	Purple	Tomb of Shagird	66.10	17.97	3.96	3.17	2.89	1.57	0.70	0.08	0.85	-	-	-	-	-	-	-	-	0.36	0.38	98.02
17	TS/02	Yellow	Tomb of Shagird	42.96	10.69	2.03	2.50	1.81	1.99	0.64	0.09	-	-	-	4.85	29.39	0.35	-	-	-	0.21	-	97.48
18	TS/03	Dark-Blue	Tomb of Shagird	63.51	19.15	3.84	3.51	2.69	1.73	1.72	0.07	-	0.09	-	-	-	0.05	0.27	0.10	-	0.30	0.53	97.55
19	TS/04	Orange	Tomb of Shagird	51.49	11.84	2.48	3.05	1.97	1.43	0.53	-	0.05	-	-	4.09	18.43	1.93	-	-	-	0.19	-	97.49
20	TS/05	Purple	Tomb of Shagird	62.37	17.39	1.66	2.82	1.05	8.86	2.89	0.45	0.84	-	-	-	0.43	-	-	-	0.07	0.30	0.34	99.46
21	TS/06	Green	Tomb of Shagird	51.41	11.38	2.51	3.40	2.01	1.61	0.59	0.06	-	3.04	-	4.49	18.33	0.36	-	-	-	0.19	-	99.38
22	TS/07	Green	Tomb of Shagird	26.93	2.56	-	0.41	0.16	1.19	0.48	-	-	1.37	-	5.64	60.58	1.59	-	-	0.05	0.06	-	101.03
23	TS/08	Yellow	Tomb of Shagird	51.67	12.74	2.91	2.37	2.16	1.67	0.57	0.05	-	-	0.05	2.99	17.55	0.45	-	-	-	0.35	0.09	95.62
24	TS/09	Yellow	Tomb of Shagird	42.78	12.62	2.16	2.44	1.89	1.72	0.60	0.07	-	0.10	-	3.65	29.61	0.35	-	-	-	0.19	-	98.18
25	TS/10	Dark-Blue	Tomb of Shagird	62.16	17.35	4.05	3.91	2.59	1.72	1.19	-	0.05	0.09	0.05	-	-	-	0.21	0.12	-	0.36	0.56	94.41
26	TS/11	Dark-Blue	Tomb of Shagird	59.34	11.22	3.40	3.61	2.40	1.61	1.33	0.05	-	0.05	-	2.78	1.34	-	0.33	-	-	0.24	0.20	87.89
27	TS/12	Green	Tomb of Shagird	27.65	2.66	0.05	0.48	0.14	1.24	0.47	0.06	-	1.08	-	6.28	57.14	1.25	-	-	0.06	-	-	98.54
28	TS/13	Orange	Tomb of Shagird	49.51	11.36	2.44	2.90	1.93	1.34	0.50	-	-	-	-	3.37	17.61	1.54	-	-	-	0.16	-	92.65

Appendix 7.17 Chemical compositions of the tile glazes from Mughal buildings at Delhi determined through EPMA-WDS analyses. All results are in wt%.

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
1	HD/01	Turquoise	23-02-2014	I	63.71	19.90	1.31	1.41	1.00	4.68	1.38	0.27	0.04	0.02	3.74	0.00	0.00	0.40	0.06	0.00	0.00	0.12	0.09	0.11	98.23
	HD/01	Turquoise	23-02-2014	II	63.46	21.25	1.25	1.43	0.00	4.82	1.22	0.40	0.00	0.04	3.94	0.01	0.00	0.99	0.03	0.04	0.04	0.21	0.32	0.00	99.44
	HD/01	Turquoise	23-02-2014	III	63.61	18.93	1.28	1.33	0.34	4.55	1.37	0.25	0.00	0.02	3.59	0.00	0.02	0.00	0.04	0.03	0.10	0.29	0.08	0.00	95.83
	HD/01	Turquoise	23-02-2014	IV	63.48	21.17	1.22	1.37	0.21	4.21	1.19	0.27	0.00	0.00	3.40	0.00	0.00	0.00	0.04	0.01	0.08	0.17	0.13	0.39	97.34
	HD/01	Turquoise	23-02-2014	V	64.52	18.36	1.30	1.48	0.05	5.28	1.33	0.27	0.00	0.02	4.07	0.00	0.00	0.16	0.02	0.04	0.09	0.42	0.17	0.06	97.62
	HD/01	**Turquoise**	**23-02-2014**	**Average**	**63.76**	**19.92**	**1.27**	**1.40**	**0.32**	**4.71**	**1.29**	**0.29**	**0.01**	**0.02**	**3.75**	**0.00**	**0.00**	**0.31**	**0.04**	**0.02**	**0.06**	**0.24**	**0.16**	**0.11**	**97.69**
	HD/01	**Turquoise**	**23-02-2014**	**Std. Dev.**	**0.44**	**1.30**	**0.04**	**0.06**	**0.40**	**0.39**	**0.09**	**0.06**	**0.02**	**0.01**	**0.27**	**0.01**	**0.01**	**0.41**	**0.02**	**0.02**	**0.04**	**0.12**	**0.10**	**0.16**	
2	HD/02	Turquoise	26-02-2014	I	62.87	20.85	1.24	1.38	0.00	4.29	1.23	0.27	0.00	0.02	3.58	0.01	0.00	0.07	0.00	0.05	0.01	0.00	0.38	0.00	96.26
	HD/02	Turquoise	26-02-2014	II	63.67	19.65	1.25	1.36	0.36	4.88	1.33	0.26	0.00	0.05	3.79	0.00	0.02	0.00	0.03	0.03	0.09	0.45	0.51	0.00	97.73
	HD/02	Turquoise	26-02-2014	III	64.08	19.19	1.22	1.32	0.38	4.05	1.33	0.30	0.00	0.03	3.56	0.00	0.00	0.00	0.05	0.15	0.02	0.19	0.13	0.00	96.00
	HD/02	Turquoise	26-02-2014	IV	60.96	20.91	1.34	1.17	0.56	4.24	1.31	0.26	0.00	0.02	4.14	0.01	0.06	0.00	0.06	0.00	0.00	0.00	0.19	0.00	95.23
	HD/02	Turquoise	26-02-2014	V	64.07	21.03	1.23	1.30	0.51	5.05	1.29	0.24	0.00	0.02	4.01	0.00	0.00	0.00	0.02	0.00	0.08	0.34	0.00	0.41	99.60
	HD/02	Turquoise	26-02-2014	VI	62.93	20.43	1.21	1.41	0.81	4.11	1.31	0.32	0.00	0.03	3.54	0.01	0.09	0.26	0.00	0.00	0.07	0.14	0.31	0.37	97.34
	HD/02	**Turquoise**	**26-02-2014**	**Average**	**63.10**	**20.34**	**1.25**	**1.32**	**0.44**	**4.44**	**1.30**	**0.27**	**0.00**	**0.03**	**3.77**	**0.00**	**0.03**	**0.06**	**0.03**	**0.04**	**0.04**	**0.19**	**0.25**	**0.13**	**97.03**
	HD/02	**Turquoise**	**26-02-2014**	**Std. Dev.**	**1.18**	**0.76**	**0.05**	**0.08**	**0.27**	**0.42**	**0.04**	**0.03**	**0.00**	**0.01**	**0.26**	**0.01**	**0.04**	**0.11**	**0.03**	**0.06**	**0.04**	**0.18**	**0.18**	**0.20**	
3	HD/03	Turquoise	25-02-2014	I	64.11	21.33	1.03	1.19	0.00	3.92	1.20	0.13	0.00	0.04	2.81	0.00	0.00	0.22	0.02	0.00	0.03	0.18	0.25	0.00	96.43
	HD/03	Turquoise	25-02-2014	II	62.51	19.79	1.25	1.43	0.30	4.36	1.16	0.21	0.00	0.03	3.83	0.01	0.00	0.20	0.01	0.00	0.00	0.79	0.37	1.39	97.61
	HD/03	Turquoise	25-02-2014	III	63.80	21.22	1.24	1.37	0.62	5.07	1.41	0.30	0.01	0.06	3.78	0.00	0.11	0.31	0.02	0.00	0.12	0.46	0.14	0.13	100.17
	HD/03	Turquoise	25-02-2014	IV	62.87	21.13	1.31	1.32	0.24	4.58	1.27	0.23	0.00	0.01	4.09	0.00	0.00	0.00	0.01	0.01	0.00	0.14	0.30	0.00	97.52
	HD/03	Turquoise	25-02-2014	V	64.31	21.87	1.26	1.25	0.33	4.24	1.38	0.27	0.00	0.05	3.92	0.00	0.00	0.14	0.01	0.00	0.00	0.45	0.29	0.53	100.30
	HD/03	Turquoise	25-02-2014	VI	63.72	20.49	1.21	1.33	0.30	5.10	1.36	0.25	0.00	0.03	3.84	0.00	0.02	0.34	0.00	0.03	0.00	0.71	0.09	0.27	99.08
	HD/03	**Turquoise**	**25-02-2014**	**Average**	**63.55**	**20.97**	**1.22**	**1.31**	**0.30**	**4.55**	**1.30**	**0.23**	**0.00**	**0.04**	**3.71**	**0.00**	**0.02**	**0.20**	**0.01**	**0.01**	**0.03**	**0.45**	**0.24**	**0.39**	**98.52**
	HD/03	**Turquoise**	**25-02-2014**	**Std. Dev.**	**0.71**	**0.73**	**0.10**	**0.09**	**0.20**	**0.47**	**0.10**	**0.06**	**0.00**	**0.02**	**0.45**	**0.00**	**0.04**	**0.12**	**0.01**	**0.01**	**0.05**	**0.26**	**0.10**	**0.53**	
4	HD/04	Turquoise	03-03-2014	I	63.57	21.79	1.24	1.31	0.50	4.53	1.24	0.26	0.06	0.02	3.28	0.01	0.00	0.58	0.02	0.02	0.01	0.28	0.21	0.00	98.92
	HD/04	Turquoise	03-03-2014	II	61.29	22.10	1.40	1.31	0.33	4.80	1.36	0.30	0.00	0.04	4.15	0.00	0.00	0.68	0.02	0.05	0.05	0.29	0.16	0.00	98.33
	HD/04	Turquoise	03-03-2014	III	63.93	21.36	1.22	1.34	0.43	4.76	1.29	0.28	0.00	0.04	3.06	0.00	0.01	0.53	0.03	0.06	0.00	0.30	0.23	0.00	98.86
	HD/04	Turquoise	03-03-2014	IV	62.75	21.77	1.27	1.25	0.49	4.81	1.28	0.29	0.01	0.03	3.83	0.03	0.00	0.64	0.00	0.04	0.04	0.21	0.23	0.00	98.96
	HD/04	Turquoise	03-03-2014	V	62.38	21.55	1.29	1.32	0.55	4.90	1.30	0.28	0.09	0.05	3.89	0.00	0.00	0.67	0.04	0.07	0.05	0.22	0.22	0.00	98.85
	HD/04	Turquoise	03-03-2014	VI	62.49	22.01	1.36	1.25	0.26	4.52	1.20	0.29	0.00	0.05	3.77	0.02	0.05	0.65	0.01	0.00	0.04	0.22	0.24	0.00	98.42
	HD/04	**Turquoise**	**03-03-2014**	**Average**	**62.73**	**21.76**	**1.30**	**1.30**	**0.43**	**4.72**	**1.28**	**0.28**	**0.03**	**0.04**	**3.66**	**0.01**	**0.01**	**0.62**	**0.02**	**0.04**	**0.03**	**0.25**	**0.22**	**0.00**	**98.72**
	HD/04	**Turquoise**	**03-03-2014**	**Std. Dev.**	**0.94**	**0.28**	**0.07**	**0.04**	**0.11**	**0.16**	**0.05**	**0.01**	**0.04**	**0.01**	**0.41**	**0.01**	**0.02**	**0.06**	**0.01**	**0.03**	**0.02**	**0.04**	**0.03**	**0.00**	
5	HD/05	Turquoise	03-03-2014	I	63.88	21.34	1.27	1.26	0.46	4.53	1.28	0.24	0.00	0.04	3.73	0.00	0.01	0.69	0.00	0.06	0.04	0.29	0.28	0.01	99.40
	HD/05	Turquoise	03-03-2014	II	64.40	20.43	1.17	1.34	0.47	4.72	1.23	0.29	0.06	0.02	3.61	0.00	0.02	0.65	0.03	0.00	0.05	0.26	0.22	0.03	98.98
	HD/05	Turquoise	03-03-2014	III	63.88	21.22	1.17	1.35	0.52	4.47	1.34	0.25	0.03	0.06	3.20	0.00	0.00	0.67	0.07	0.00	0.03	0.22	0.28	0.00	98.75
	HD/05	Turquoise	03-03-2014	IV	61.36	21.42	1.27	1.39	0.47	4.82	1.29	0.30	0.00	0.02	4.02	0.01	0.00	0.74	0.04	0.00	0.01	0.24	0.25	0.00	97.64
	HD/05	Turquoise	03-03-2014	V	64.90	20.84	1.14	1.37	0.49	4.53	1.19	0.24	0.00	0.00	3.36	0.02	0.00	0.66	0.00	0.00	0.05	0.32	0.31	0.02	99.45
	HD/05	Turquoise	03-03-2014	VI	64.29	20.73	1.15	1.36	0.46	4.72	1.25	0.28	0.00	0.05	3.80	0.00	0.00	0.57	0.03	0.01	0.02	0.26	0.27	0.00	99.24
	HD/05	**Turquoise**	**03-03-2014**	**Average**	**63.78**	**20.99**	**1.19**	**1.34**	**0.48**	**4.63**	**1.26**	**0.27**	**0.02**	**0.03**	**3.62**	**0.01**	**0.01**	**0.66**	**0.03**	**0.01**	**0.03**	**0.27**	**0.27**	**0.01**	**98.91**
	HD/05	**Turquoise**	**03-03-2014**	**Std. Dev.**	**1.25**	**0.39**	**0.06**	**0.05**	**0.02**	**0.14**	**0.05**	**0.02**	**0.02**	**0.02**	**0.30**	**0.01**	**0.01**	**0.06**	**0.02**	**0.02**	**0.02**	**0.04**	**0.03**	**0.01**	
6	IK/01	Dark-Blue	22-02-2013	I	65.88	19.28	1.66	1.42	0.44	6.46	1.51	0.32	0.01	0.05	0.07	0.42	0.00	0.07	0.07	0.03	0.00	0.04	0.26	1.41	99.40
	IK/01	Dark-Blue	22-02-2013	II	68.30	18.66	1.56	1.46	0.62	5.22	1.34	0.29	0.01	0.03	0.08	0.46	0.02	0.00	0.11	0.07	0.03	0.05	0.26	1.19	99.74
	IK/01	Dark-Blue	22-02-2013	III	65.42	18.79	1.75	1.42	0.68	5.79	1.48	0.27	0.06	0.04	0.01	0.45	0.01	0.04	0.02	0.00	0.00	0.00	0.21	1.27	97.70
	IK/01	Dark-Blue	22-02-2013	IV	67.45	18.46	1.62	1.51	0.62	6.23	1.37	0.29	0.02	0.04	0.11	0.45	0.00	0.00	0.00	0.00	0.03	0.00	0.15	1.16	99.49

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	IK/01	Dark-Blue	22-02-2013	V	67.90	18.30	1.76	1.44	0.32	5.78	1.40	0.27	0.00	0.04	0.06	0.48	0.00	0.00	0.09	0.03	0.06	0.09	0.17	1.06	99.24
	IK/01	**Dark-Blue**	**22-02-2013**	**Average**	**66.99**	**18.69**	**1.67**	**1.45**	**0.53**	**5.90**	**1.42**	**0.29**	**0.02**	**0.04**	**0.06**	**0.45**	**0.00**	**0.02**	**0.06**	**0.03**	**0.02**	**0.04**	**0.21**	**1.22**	**99.12**
	IK/01	**Dark-Blue**	**22-02-2013**	**Std. Dev.**	**1.27**	**0.37**	**0.09**	**0.04**	**0.15**	**0.48**	**0.07**	**0.02**	**0.02**	**0.01**	**0.04**	**0.02**	**0.01**	**0.03**	**0.05**	**0.03**	**0.02**	**0.04**	**0.05**	**0.13**	
7	IK/02	White	22-02-2013	I	63.83	20.36	1.65	1.61	0.67	6.72	1.28	0.26	0.01	0.04	0.03	0.00	0.00	0.00	0.00	0.08	0.02	0.07	0.21	0.00	96.81
	IK/02	White	22-02-2013	II	64.64	16.94	1.73	1.94	0.73	6.18	1.25	0.29	0.04	0.05	0.04	0.01	0.00	0.00	0.02	0.00	0.01	0.06	0.21	0.00	94.12
	IK/02	White	22-02-2013	III	67.08	15.14	1.66	1.99	0.60	6.07	1.21	0.32	0.00	0.03	0.02	0.02	0.00	0.04	0.00	0.02	0.03	0.09	0.30	0.00	94.63
	IK/02	White	22-02-2013	IV	76.15	12.96	1.60	2.68	0.63	6.38	1.27	0.27	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.04	0.02	0.04	0.22	0.00	102.31
	IK/02	White	22-02-2013	V	66.14	15.06	1.65	2.12	0.75	6.37	1.36	0.28	0.07	0.06	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.03	0.23	0.00	94.13
	IK/02	White	22-02-2013	VI	65.90	15.24	1.57	1.76	0.49	5.96	1.21	0.23	0.04	0.02	0.01	0.02	0.00	0.00	0.05	0.00	0.01	0.12	0.22	0.00	92.83
	IK/02	**White**	**22-02-2013**	**Average**	**67.29**	**15.95**	**1.64**	**2.02**	**0.64**	**6.28**	**1.26**	**0.27**	**0.03**	**0.04**	**0.02**	**0.01**	**0.00**	**0.01**	**0.02**	**0.02**	**0.01**	**0.07**	**0.23**	**0.00**	**95.81**
	IK/02	**White**	**22-02-2013**	**Std. Dev.**	**4.49**	**2.50**	**0.06**	**0.37**	**0.09**	**0.27**	**0.06**	**0.03**	**0.03**	**0.02**	**0.02**	**0.01**	**0.01**	**0.02**	**0.02**	**0.03**	**0.01**	**0.03**	**0.04**	**0.00**	
8	IK/03	Dark-Blue	25-02-2013	I	67.31	17.29	1.75	1.72	0.70	5.42	1.40	0.30	0.04	0.01	0.01	0.48	0.00	0.00	0.09	0.00	0.03	0.04	0.20	0.86	97.64
	IK/03	Dark-Blue	25-02-2013	II	55.85	15.80	1.45	1.45	0.60	4.93	1.25	0.30	0.00	0.01	0.07	0.40	0.00	0.00	0.05	0.04	0.01	0.04	0.28	0.78	83.31
	IK/03	Dark-Blue	25-02-2013	III	66.43	17.71	1.68	1.80	0.47	5.81	1.58	0.33	0.05	0.01	0.05	0.47	0.00	0.07	0.04	0.11	0.02	0.08	0.25	0.87	97.82
	IK/03	Dark-Blue	25-02-2013	IV	65.39	17.94	1.71	1.80	0.73	6.23	1.64	0.36	0.01	0.02	0.04	0.39	0.01	0.01	0.05	0.00	0.05	0.06	0.31	0.90	97.64
	IK/03	Dark-Blue	25-02-2013	V	65.52	18.71	1.66	1.65	0.68	5.86	1.44	0.27	0.02	0.01	0.01	0.46	0.00	0.06	0.03	0.05	0.04	0.05	0.28	1.20	98.00
	IK/03	**Dark-Blue**	**25-02-2013**	**Average**	**64.10**	**17.49**	**1.65**	**1.68**	**0.64**	**5.65**	**1.46**	**0.31**	**0.03**	**0.01**	**0.04**	**0.44**	**0.00**	**0.03**	**0.05**	**0.04**	**0.03**	**0.06**	**0.26**	**0.92**	**94.88**
	IK/03	**Dark-Blue**	**25-02-2013**	**Std. Dev.**	**4.68**	**1.07**	**0.12**	**0.15**	**0.10**	**0.49**	**0.16**	**0.04**	**0.02**	**0.00**	**0.03**	**0.04**	**0.00**	**0.03**	**0.02**	**0.04**	**0.02**	**0.02**	**0.04**	**0.16**	
9	IK/04	Dark-Blue	25-02-2013	I	60.53	18.43	2.28	1.99	1.57	7.06	1.80	0.34	0.00	0.00	0.00	0.26	0.00	0.00	0.02	0.00	0.07	0.30	0.19	0.62	95.46
	IK/04	Dark-Blue	25-02-2013	II	60.24	18.82	2.36	2.02	1.00	7.48	1.70	0.36	0.00	0.10	0.00	0.24	0.00	0.00	0.05	0.01	0.03	0.24	0.18	0.74	95.55
	IK/04	Dark-Blue	25-02-2013	III	62.72	18.87	2.29	2.06	1.37	6.94	1.76	0.35	0.00	0.01	0.00	0.43	0.00	0.00	0.00	0.03	0.01	0.16	0.26	1.22	98.49
	IK/04	Dark-Blue	25-02-2013	IV	62.81	19.12	2.51	2.03	1.45	6.24	1.58	0.35	0.00	0.03	0.00	0.30	0.00	0.00	0.03	0.03	0.00	0.27	0.34	1.26	98.36
	IK/04	Dark-Blue	25-02-2013	V	62.21	18.62	2.21	2.17	1.34	7.83	1.85	0.40	0.00	0.02	0.01	0.33	0.05	0.01	0.03	0.00	0.02	0.21	0.18	0.65	98.13
	IK/04	**Dark-Blue**	**25-02-2013**	**Average**	**61.70**	**18.77**	**2.33**	**2.05**	**1.35**	**7.11**	**1.74**	**0.36**	**0.00**	**0.03**	**0.00**	**0.31**	**0.01**	**0.00**	**0.03**	**0.02**	**0.03**	**0.23**	**0.23**	**0.90**	**97.20**
	IK/04	**Dark-Blue**	**25-02-2013**	**Std. Dev.**	**1.23**	**0.26**	**0.11**	**0.07**	**0.21**	**0.60**	**0.10**	**0.02**	**0.00**	**0.04**	**0.01**	**0.07**	**0.02**	**0.00**	**0.02**	**0.02**	**0.03**	**0.06**	**0.07**	**0.32**	
10	IK/05	Dark-Blue	25-02-2013	I	61.58	22.42	2.05	1.75	0.79	6.52	1.18	0.32	0.00	0.07	0.02	0.35	0.00	0.00	0.09	0.03	0.02	0.10	0.25	0.65	98.18
	IK/05	Dark-Blue	25-02-2013	II	63.00	19.18	1.57	1.89	0.57	6.41	1.48	0.37	0.00	0.10	0.06	0.34	0.01	0.04	0.05	0.00	0.00	0.13	0.24	0.88	96.31
	IK/05	Dark-Blue	25-02-2013	III	61.68	20.82	2.00	1.80	0.80	6.45	1.28	0.30	0.00	0.08	0.17	0.34	0.00	0.00	0.08	0.00	0.00	0.07	0.22	0.74	96.83
	IK/05	Dark-Blue	25-02-2013	IV	60.91	21.41	1.49	1.90	0.69	7.19	1.65	0.37	0.00	0.07	0.01	0.49	0.00	0.02	0.09	0.00	0.01	0.14	0.29	1.23	97.96
	IK/05	Dark-Blue	25-02-2013	V	65.21	16.58	1.78	1.92	0.23	5.31	1.65	0.29	0.05	0.07	0.04	0.67	0.00	0.05	0.12	0.00	0.01	0.08	0.38	1.77	96.20
	IK/05	**Dark-Blue**	**25-02-2013**	**Average**	**62.47**	**20.08**	**1.78**	**1.85**	**0.62**	**6.38**	**1.45**	**0.33**	**0.01**	**0.08**	**0.06**	**0.44**	**0.00**	**0.02**	**0.09**	**0.01**	**0.01**	**0.10**	**0.27**	**1.06**	**97.10**
	IK/05	**Dark-Blue**	**25-02-2013**	**Std. Dev.**	**1.70**	**2.28**	**0.25**	**0.07**	**0.24**	**0.68**	**0.21**	**0.04**	**0.02**	**0.01**	**0.07**	**0.14**	**0.00**	**0.02**	**0.02**	**0.01**	**0.01**	**0.03**	**0.06**	**0.46**	
11	AS/01	Green	21-02-2013	I	55.89	15.55	2.95	2.05	1.80	4.78	0.81	0.18	0.00	0.05	0.86	0.02	3.84	11.52	0.02	0.00	0.03	0.45	0.23	0.00	101.03
	AS/01	Green	21-02-2013	II	60.09	15.25	2.55	2.20	1.48	5.13	0.84	0.22	0.00	0.05	0.95	0.00	1.04	9.13	0.02	0.02	0.00	0.28	0.14	0.00	99.36
	AS/01	Green	21-02-2013	III	59.62	15.59	3.22	2.33	1.83	4.71	0.93	0.18	0.00	0.05	0.80	0.01	0.74	8.92	0.00	0.00	0.04	0.36	0.22	0.00	99.55
	AS/01	Green	21-02-2013	IV	60.30	15.20	2.95	2.19	1.79	4.32	0.90	0.17	0.00	0.03	0.80	0.01	1.57	9.67	0.02	0.00	0.06	0.34	0.11	0.00	100.42
	AS/01	Green	21-02-2013	V	55.86	15.72	2.61	1.97	1.70	4.55	0.89	0.21	0.00	0.05	0.70	0.00	2.68	9.34	0.08	0.05	0.00	0.41	0.14	0.00	96.94
	AS/01	**Green**	**21-02-2013**	**Average**	**58.35**	**15.46**	**2.86**	**2.15**	**1.72**	**4.70**	**0.87**	**0.19**	**0.00**	**0.05**	**0.82**	**0.01**	**1.97**	**9.71**	**0.03**	**0.01**	**0.03**	**0.36**	**0.17**	**0.00**	**99.46**
	AS/01	**Green**	**21-02-2013**	**Std. Dev.**	**2.27**	**0.23**	**0.28**	**0.14**	**0.14**	**0.30**	**0.05**	**0.02**	**0.00**	**0.01**	**0.09**	**0.01**	**1.28**	**1.05**	**0.03**	**0.02**	**0.03**	**0.06**	**0.06**	**0.00**	
12	AS/02	Dark-Blue	21-02-2013	I	65.24	17.61	3.12	1.74	1.70	5.97	1.42	0.43	0.03	0.06	0.11	0.36	0.00	0.06	0.04	0.00	0.00	0.27	0.29	1.12	99.57
	AS/02	Dark-Blue	21-02-2013	II	66.23	16.55	2.26	1.97	1.08	8.83	1.63	0.36	0.00	0.03	0.05	0.24	0.02	0.01	0.05	0.01	0.05	0.07	0.12	0.52	100.08
	AS/02	Dark-Blue	21-02-2013	III	65.57	16.30	2.82	2.01	1.24	8.76	1.46	0.40	0.00	0.02	0.02	0.19	0.00	0.07	0.02	0.00	0.05	0.14	0.16	0.22	99.44
	AS/02	Dark-Blue	21-02-2013	IV	66.70	15.82	2.14	2.08	0.97	9.89	1.63	0.40	0.00	0.00	0.00	0.07	0.00	0.00	0.07	0.00	0.03	0.07	0.10	0.01	99.97
	AS/02	Dark-Blue	21-02-2013	V	66.84	16.35	2.29	1.97	1.18	8.80	1.63	0.43	0.00	0.05	0.00	0.19	0.00	0.07	0.07	0.01	0.00	0.14	0.16	0.46	100.63
	AS/02	**Dark-Blue**	**21-02-2013**	**Average**	**66.11**	**16.53**	**2.53**	**1.95**	**1.23**	**8.45**	**1.55**	**0.41**	**0.01**	**0.03**	**0.04**	**0.21**	**0.00**	**0.04**	**0.05**	**0.00**	**0.03**	**0.14**	**0.16**	**0.47**	**99.94**
	AS/02	**Dark-Blue**	**21-02-2013**	**Std. Dev.**	**0.70**	**0.66**	**0.42**	**0.13**	**0.28**	**1.46**	**0.10**	**0.03**	**0.01**	**0.02**	**0.05**	**0.10**	**0.01**	**0.03**	**0.02**	**0.01**	**0.02**	**0.08**	**0.07**	**0.42**	

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
13	AS/03	Dark-Blue	21-02-2013	I	65.64	16.68	2.65	2.09	1.38	8.19	1.66	0.42	0.00	0.05	0.10	0.29	0.00	0.05	0.08	0.00	0.03	0.17	0.18	0.41	100.04
	AS/03	Dark-Blue	21-02-2013	II	65.09	16.14	2.72	2.02	1.57	7.58	1.26	0.33	0.00	0.02	0.00	0.17	0.00	0.00	0.04	0.05	0.06	0.21	0.11	0.57	97.94
	AS/03	Dark-Blue	21-02-2013	III	66.50	16.24	2.19	2.14	0.99	8.99	1.64	0.41	0.02	0.03	0.02	0.07	0.00	0.05	0.00	0.08	0.02	0.18	0.11	0.14	99.83
	AS/03	Dark-Blue	21-02-2013	IV	66.61	16.17	2.35	2.12	1.36	7.73	1.84	0.41	0.00	0.02	0.05	0.26	0.00	0.03	0.04	0.03	0.03	0.19	0.18	0.61	100.02
	AS/03	Dark-Blue	21-02-2013	V	67.14	15.95	1.96	2.27	0.98	8.96	1.79	0.42	0.00	0.03	0.05	0.12	0.00	0.00	0.05	0.00	0.05	0.12	0.08	0.11	100.07
	AS/03	**Dark-Blue**	**21-02-2013**	**Average**	**66.19**	**16.24**	**2.38**	**2.13**	**1.26**	**8.29**	**1.64**	**0.40**	**0.00**	**0.03**	**0.04**	**0.18**	**0.00**	**0.03**	**0.04**	**0.03**	**0.04**	**0.17**	**0.13**	**0.37**	**99.58**
	AS/03	**Dark-Blue**	**21-02-2013**	**Std. Dev.**	**0.82**	**0.27**	**0.32**	**0.09**	**0.26**	**0.66**	**0.23**	**0.04**	**0.01**	**0.01**	**0.04**	**0.09**	**0.00**	**0.03**	**0.03**	**0.03**	**0.02**	**0.03**	**0.05**	**0.24**	
14	AS/04	Yellow	06-12-2013	I	53.38	14.18	1.71	1.09	0.99	6.07	1.26	0.26	0.00	0.03	0.03	0.00	1.28	19.02	0.00	0.13	0.00	0.15	0.00	0.00	99.58
	AS/04	Yellow	06-12-2013	II	53.52	14.51	1.79	1.31	0.95	6.88	1.69	0.29	0.00	0.04	0.01	0.00	1.10	9.45	0.04	0.14	0.00	0.06	0.00	0.00	91.76
	AS/04	Yellow	06-12-2013	III	53.38	12.50	1.80	1.22	0.89	6.12	1.22	0.27	0.03	0.02	0.01	0.01	1.25	18.84	0.00	0.00	0.03	0.22	0.00	0.00	97.80
	AS/04	**Yellow**	**06-12-2013**	**Average**	**53.43**	**13.73**	**1.76**	**1.21**	**0.94**	**6.36**	**1.39**	**0.27**	**0.01**	**0.03**	**0.02**	**0.00**	**1.21**	**15.77**	**0.01**	**0.09**	**0.01**	**0.14**	**0.00**	**0.00**	**96.38**
	AS/04	**Yellow**	**06-12-2013**	**Std. Dev.**	**0.08**	**1.08**	**0.05**	**0.11**	**0.05**	**0.46**	**0.26**	**0.01**	**0.02**	**0.01**	**0.02**	**0.01**	**0.09**	**5.47**	**0.02**	**0.08**	**0.02**	**0.08**	**0.00**	**0.00**	
15	KM/01	Dark-Blue	20-11-2013	I	60.94	17.79	2.31	2.65	0.56	7.89	2.13	0.42	0.00	0.07	0.02	0.23	0.00	0.11	0.02	0.00	0.00	0.13	0.11	0.16	95.53
	KM/01	Dark-Blue	20-11-2013	II	61.76	18.10	2.28	2.60	0.85	8.33	2.16	0.49	0.00	0.04	0.00	0.37	0.00	0.05	0.02	0.00	0.05	0.16	0.31	0.54	98.10
	KM/01	Dark-Blue	20-11-2013	III	61.66	18.15	2.86	2.78	0.86	8.85	2.08	0.49	0.02	0.05	0.03	0.39	0.00	0.02	0.07	0.04	0.04	0.08	0.27	0.76	99.47
	KM/01	Dark-Blue	20-11-2013	IV	62.68	18.19	2.98	2.65	1.10	8.30	2.15	0.49	0.01	0.05	0.05	0.28	0.00	0.00	0.00	0.09	0.05	0.14	0.19	0.56	99.96
	KM/01	Dark-Blue	20-11-2013	V	61.73	17.89	2.36	2.34	0.79	7.49	2.01	0.36	0.00	0.06	0.06	0.29	0.00	0.03	0.04	0.00	0.03	0.06	0.22	0.49	96.25
	KM/01	**Dark-Blue**	**20-11-2013**	**Average**	**61.75**	**18.02**	**2.56**	**2.61**	**0.83**	**8.17**	**2.11**	**0.45**	**0.01**	**0.05**	**0.03**	**0.31**	**0.00**	**0.04**	**0.03**	**0.03**	**0.03**	**0.11**	**0.22**	**0.50**	**97.86**
	KM/01	**Dark-Blue**	**20-11-2013**	**Std. Dev.**	**0.62**	**0.18**	**0.33**	**0.16**	**0.19**	**0.51**	**0.06**	**0.06**	**0.01**	**0.01**	**0.02**	**0.07**	**0.00**	**0.04**	**0.03**	**0.04**	**0.02**	**0.04**	**0.08**	**0.22**	
16	KM/02	Dark-Blue	20-11-2013	I	61.98	18.56	2.30	1.69	0.77	8.26	2.46	0.48	0.00	0.06	0.00	0.42	0.00	0.00	0.05	0.00	0.00	0.07	0.32	1.14	98.55
	KM/02	Dark-Blue	20-11-2013	II	63.94	17.94	2.35	1.72	0.80	7.94	2.23	0.45	0.00	0.04	0.01	0.26	0.00	0.00	0.02	0.06	0.03	0.09	0.23	0.61	98.70
	KM/02	Dark-Blue	20-11-2013	III	63.32	19.26	2.28	1.63	0.86	8.27	2.29	0.44	0.00	0.09	0.03	0.24	0.00	0.05	0.02	0.00	0.04	0.10	0.24	0.47	99.64
	KM/02	Dark-Blue	20-11-2013	IV	60.86	18.87	2.36	1.52	0.80	8.22	2.03	0.42	0.00	0.07	0.00	0.25	0.00	0.00	0.03	0.02	0.05	0.00	0.17	0.41	96.08
	KM/02	Dark-Blue	20-11-2013	V	61.64	18.80	2.24	1.62	0.85	8.06	2.40	0.40	0.00	0.03	0.02	0.39	0.00	0.00	0.04	0.00	0.03	0.02	0.32	1.06	97.91
	KM/02	**Dark-Blue**	**20-11-2013**	**Average**	**62.35**	**18.69**	**2.31**	**1.64**	**0.81**	**8.15**	**2.28**	**0.44**	**0.00**	**0.06**	**0.01**	**0.31**	**0.00**	**0.01**	**0.03**	**0.02**	**0.03**	**0.06**	**0.25**	**0.74**	**98.18**
	KM/02	**Dark-Blue**	**20-11-2013**	**Std. Dev.**	**1.26**	**0.49**	**0.05**	**0.08**	**0.04**	**0.15**	**0.17**	**0.03**	**0.00**	**0.02**	**0.01**	**0.09**	**0.00**	**0.02**	**0.01**	**0.03**	**0.02**	**0.04**	**0.06**	**0.34**	
17	KM/03	Green	20-11-2013	I	61.66	17.07	1.46	2.34	0.55	7.02	1.48	0.35	0.00	0.02	0.63	0.00	0.29	4.24	0.00	0.00	0.05	0.11	0.01	0.00	97.26
	KM/03	Green	20-11-2013	II	55.34	17.65	1.49	1.84	0.61	5.91	1.37	0.29	0.00	0.04	1.73	0.00	1.84	11.05	0.04	0.00	0.04	0.05	0.15	0.00	99.44
	KM/03	Green	20-11-2013	III	49.13	16.31	1.45	1.62	0.61	6.09	1.56	0.32	0.00	0.04	2.03	0.00	0.91	9.73	0.06	0.00	0.06	0.13	0.21	0.00	90.25
	KM/03	Green	20-11-2013	IV	54.09	18.15	1.49	1.36	0.64	6.57	1.51	0.27	0.00	0.03	2.24	0.02	1.79	11.21	0.00	0.03	0.06	0.09	0.23	0.00	99.77
	KM/03	Green	20-11-2013	V	50.64	16.80	1.39	1.27	0.59	6.11	1.44	0.33	0.00	0.03	2.82	0.00	1.24	8.98	0.00	0.00	0.08	0.05	0.23	0.00	91.99
	KM/03	**Green**	**20-11-2013**	**Average**	**54.17**	**17.20**	**1.46**	**1.69**	**0.60**	**6.34**	**1.47**	**0.31**	**0.00**	**0.03**	**1.89**	**0.00**	**1.21**	**9.04**	**0.02**	**0.01**	**0.06**	**0.08**	**0.16**	**0.00**	**95.74**
	KM/03	**Green**	**20-11-2013**	**Std. Dev.**	**4.88**	**0.72**	**0.04**	**0.43**	**0.03**	**0.45**	**0.07**	**0.03**	**0.00**	**0.01**	**0.81**	**0.01**	**0.65**	**2.84**	**0.03**	**0.01**	**0.01**	**0.04**	**0.09**	**0.00**	
18	KM/04	Dark-Blue	19-01-2014	I	63.72	15.29	2.55	4.46	1.00	8.09	2.55	0.42	0.00	0.07	0.11	0.44	0.00	0.00	0.09	0.03	0.04	0.08	0.25	0.77	99.97
	KM/04	Dark-Blue	19-01-2014	II	60.74	16.17	3.21	4.05	1.14	7.78	2.59	0.43	0.00	0.04	0.11	0.54	0.00	0.04	0.04	0.00	0.06	0.16	0.35	0.21	97.66
	KM/04	Dark-Blue	19-01-2014	III	64.15	16.27	3.08	3.94	0.86	7.18	2.08	0.38	0.00	0.05	0.08	0.46	0.00	0.01	0.06	0.00	0.04	0.11	0.26	0.58	99.56
	KM/04	Dark-Blue	19-01-2014	IV	62.87	15.37	2.47	3.72	1.44	7.52	2.55	0.40	0.00	0.04	0.07	0.45	0.00	0.00	0.07	0.08	0.03	0.09	0.26	0.54	97.97
	KM/04	Dark-Blue	19-01-2014	V	61.67	16.45	2.78	3.85	1.18	8.14	2.85	0.45	0.00	0.04	0.03	0.51	0.00	0.00	0.05	0.00	0.00	0.14	0.35	0.56	99.05
	KM/04	**Dark-Blue**	**19-01-2014**	**Avg**	**62.63**	**15.91**	**2.82**	**4.00**	**1.13**	**7.74**	**2.53**	**0.42**	**0.00**	**0.05**	**0.08**	**0.48**	**0.00**	**0.01**	**0.06**	**0.02**	**0.03**	**0.11**	**0.29**	**0.53**	**98.84**
	KM/04	**Dark-Blue**	**19-01-2014**	**Std. Dev.**	**1.42**	**0.54**	**0.32**	**0.28**	**0.22**	**0.40**	**0.28**	**0.03**	**0.00**	**0.01**	**0.03**	**0.04**	**0.00**	**0.02**	**0.02**	**0.03**	**0.02**	**0.03**	**0.05**	**0.20**	
19	AK/01	Yellow	05-12-2013	I	50.30	12.79	0.81	1.53	0.66	4.70	1.23	0.24	0.04	0.03	0.05	0.01	3.68	16.64	0.02	0.66	0.00	0.17	0.00	0.00	93.55
	AK/01	Yellow	05-12-2013	II	53.57	14.09	1.27	1.49	0.76	6.46	1.34	0.26	0.00	0.03	0.14	0.01	2.35	15.60	0.04	0.79	0.00	0.22	0.00	0.00	98.40
	AK/01	Yellow	05-12-2013	III	45.51	13.97	0.88	1.20	0.71	5.61	1.91	0.61	0.00	0.05	0.00	0.00	6.47	21.32	0.00	1.27	0.00	0.06	0.00	0.00	99.56
	AK/01	Yellow	05-12-2013	IV	59.62	14.62	1.36	1.77	0.87	6.19	1.36	0.31	0.14	0.02	0.00	0.00	1.11	10.93	0.00	0.32	0.06	0.20	0.01	0.00	98.87
	AK/01	Yellow	05-12-2013	V	60.56	14.95	1.66	1.84	0.94	7.66	1.85	0.39	0.00	0.22	0.04	0.02	0.15	8.91	0.00	0.21	0.02	0.22	0.08	0.00	99.71
	AK/01	**Yellow**	**05-12-2013**	**Average**	**53.91**	**14.08**	**1.20**	**1.56**	**0.79**	**6.12**	**1.54**	**0.36**	**0.04**	**0.07**	**0.04**	**0.01**	**2.75**	**14.68**	**0.01**	**0.65**	**0.02**	**0.18**	**0.02**	**0.00**	**98.02**

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	AK/01	**Yellow**	**05-12-2013**	**Std. Dev.**	**6.34**	**0.82**	**0.35**	**0.26**	**0.11**	**1.09**	**0.32**	**0.15**	**0.06**	**0.08**	**0.06**	**0.01**	**2.47**	**4.90**	**0.02**	**0.42**	**0.03**	**0.07**	**0.03**	**0.00**	
20	AK/02	Turquoise	05-12-2013	I	63.03	18.61	1.46	2.21	0.84	8.38	1.96	0.39	0.00	0.13	1.59	0.00	0.00	0.03	0.01	0.00	0.03	0.34	0.17	0.00	99.19
	AK/02	Turquoise	05-12-2013	II	62.97	18.62	1.45	2.09	0.86	8.43	1.96	0.40	0.00	0.03	2.07	0.00	0.00	0.04	0.01	0.03	0.02	0.38	0.18	0.00	99.53
	AK/02	Turquoise	05-12-2013	III	63.17	19.30	1.51	1.93	0.95	8.27	2.03	0.38	0.00	0.04	3.27	0.00	0.04	0.04	0.04	0.03	0.06	0.30	0.18	0.00	101.54
	AK/02	Turquoise	05-12-2013	IV	64.00	16.59	1.54	2.13	0.87	8.70	2.04	0.39	0.00	0.15	1.53	0.01	0.00	0.00	0.03	0.04	0.01	0.41	0.16	0.00	98.58
	AK/02	Turquoise	05-12-2013	V	62.61	18.71	1.49	2.00	0.81	8.13	1.79	0.35	0.00	0.11	2.44	0.02	0.01	0.01	0.01	0.00	0.03	0.23	0.10	0.00	98.82
	AK/02	**Turquoise**	**05-12-2013**	**Average**	**63.15**	**18.36**	**1.49**	**2.07**	**0.87**	**8.38**	**1.96**	**0.38**	**0.00**	**0.09**	**2.18**	**0.01**	**0.01**	**0.02**	**0.02**	**0.02**	**0.03**	**0.33**	**0.16**	**0.00**	**99.53**
	AK/02	**Turquoise**	**05-12-2013**	**Std. Dev.**	**0.51**	**1.03**	**0.04**	**0.11**	**0.05**	**0.21**	**0.10**	**0.02**	**0.00**	**0.05**	**0.71**	**0.01**	**0.02**	**0.02**	**0.01**	**0.02**	**0.02**	**0.07**	**0.03**	**0.00**	
21	AK/03	Turquoise	06-12-2013	I	61.02	20.48	1.39	1.68	0.83	8.09	1.73	0.34	0.00	0.03	2.88	0.00	0.03	0.04	0.03	0.01	0.12	0.19	0.19	0.00	99.09
	AK/03	Turquoise	06-12-2013	II	62.86	19.49	1.50	1.72	0.56	7.82	1.68	0.33	0.00	0.18	2.21	0.00	0.00	0.00	0.05	0.00	0.04	0.25	0.21	0.00	98.92
	AK/03	Turquoise	06-12-2013	III	63.62	18.64	1.50	1.86	0.77	8.54	1.68	0.43	0.00	0.07	0.95	0.00	0.00	0.00	0.00	0.03	0.00	0.34	0.20	0.00	98.62
	AK/03	Turquoise	06-12-2013	IV	65.75	17.79	2.11	1.75	1.03	7.61	1.55	0.33	0.00	0.04	0.62	0.01	0.01	0.00	0.00	0.00	0.06	0.10	0.07	0.00	98.83
	AK/03	Turquoise	06-12-2013	V	63.92	18.74	1.54	1.81	0.91	8.70	1.81	0.39	0.06	0.10	0.98	0.00	0.00	0.00	0.00	0.00	0.02	0.38	0.22	0.00	99.57
	AK/03	**Turquoise**	**06-12-2013**	**Average**	**63.44**	**19.03**	**1.61**	**1.77**	**0.82**	**8.15**	**1.69**	**0.36**	**0.01**	**0.09**	**1.53**	**0.00**	**0.01**	**0.01**	**0.02**	**0.01**	**0.05**	**0.25**	**0.18**	**0.00**	**99.01**
	AK/03	**Turquoise**	**06-12-2013**	**Std. Dev.**	**1.72**	**1.01**	**0.29**	**0.07**	**0.17**	**0.46**	**0.10**	**0.04**	**0.03**	**0.06**	**0.97**	**0.00**	**0.01**	**0.02**	**0.02**	**0.01**	**0.04**	**0.11**	**0.06**	**0.00**	
22	AK/04	Turquoise	05-12-2013	I	62.51	18.92	1.42	1.94	0.83	8.47	1.72	0.39	0.00	0.12	1.44	0.01	0.01	0.01	0.03	0.03	0.02	0.31	0.14	0.00	98.31
	AK/04	Turquoise	05-12-2013	II	61.86	18.91	1.81	1.70	0.94	7.53	1.65	0.34	0.00	0.06	2.78	0.00	0.02	0.00	0.01	0.01	0.08	0.22	0.12	0.00	98.05
	AK/04	Turquoise	05-12-2013	III	61.84	20.27	1.67	1.67	0.50	8.08	1.78	0.37	0.03	0.05	1.08	0.01	0.00	0.08	0.02	0.00	0.04	0.27	0.12	0.00	97.88
	AK/04	Turquoise	05-12-2013	IV	63.75	18.85	1.57	1.86	0.82	8.65	2.04	0.42	0.00	0.03	0.37	0.00	0.00	0.01	0.05	0.02	0.00	0.33	0.16	0.00	98.91
	AK/04	Turquoise	05-12-2013	V	64.22	18.68	1.74	1.82	0.91	7.33	1.45	0.34	0.00	0.02	1.11	0.00	0.00	0.00	0.00	0.04	0.01	0.15	0.06	0.00	97.86
	AK/04	**Turquoise**	**05-12-2013**	**Average**	**62.84**	**19.12**	**1.64**	**1.80**	**0.80**	**8.01**	**1.73**	**0.37**	**0.01**	**0.06**	**1.36**	**0.01**	**0.01**	**0.02**	**0.02**	**0.02**	**0.03**	**0.25**	**0.12**	**0.00**	**98.20**
	AK/04	**Turquoise**	**05-12-2013**	**Std. Dev.**	**1.10**	**0.65**	**0.15**	**0.11**	**0.18**	**0.57**	**0.21**	**0.03**	**0.01**	**0.04**	**0.89**	**0.01**	**0.01**	**0.03**	**0.02**	**0.01**	**0.03**	**0.07**	**0.04**	**0.00**	
23	AK/05	Turquoise	05-12-2013	I	62.36	15.83	1.91	4.62	0.90	8.21	1.82	0.38	0.00	0.15	1.26	0.00	0.00	0.00	0.01	0.00	0.04	0.33	0.09	0.00	97.90
	AK/05	Turquoise	05-12-2013	II	62.02	17.32	1.68	3.69	0.82	8.03	1.65	0.34	0.00	0.11	2.45	0.00	0.00	0.01	0.01	0.09	0.00	0.34	0.13	0.00	98.68
	AK/05	Turquoise	05-12-2013	III	60.98	18.77	1.85	3.11	0.51	7.31	1.63	0.38	0.00	0.05	3.72	0.01	0.07	0.00	0.00	0.05	0.03	0.30	0.19	0.00	98.94
	AK/05	Turquoise	05-12-2013	IV	63.19	17.53	1.48	3.31	0.79	8.82	1.84	0.42	0.00	0.06	0.78	0.01	0.00	0.00	0.00	0.10	0.06	0.36	0.23	0.00	98.98
	AK/05	Turquoise	05-12-2013	V	63.95	17.20	1.86	3.12	0.98	7.46	1.67	0.34	0.00	0.03	1.92	0.01	0.00	0.00	0.05	0.04	0.07	0.11	0.06	0.00	98.87
	AK/05	**Turquoise**	**05-12-2013**	**Average**	**62.50**	**17.33**	**1.76**	**3.57**	**0.80**	**7.96**	**1.72**	**0.37**	**0.00**	**0.08**	**2.02**	**0.01**	**0.01**	**0.00**	**0.01**	**0.06**	**0.04**	**0.29**	**0.14**	**0.00**	**98.67**
	AK/05	**Turquoise**	**05-12-2013**	**Std. Dev.**	**1.14**	**1.05**	**0.18**	**0.63**	**0.18**	**0.61**	**0.10**	**0.03**	**0.00**	**0.05**	**1.14**	**0.00**	**0.03**	**0.00**	**0.02**	**0.04**	**0.03**	**0.10**	**0.07**	**0.00**	
24	SB/01	Dark-Blue	19-02-2013	I	64.36	18.56	2.91	1.78	0.97	5.69	1.69	0.37	0.04	0.07	0.13	0.21	0.00	0.03	0.03	0.02	0.01	0.28	0.27	0.71	98.13
	SB/01	Dark-Blue	19-02-2013	II	64.74	17.52	2.29	1.94	1.22	7.49	1.71	0.41	0.00	0.08	0.01	0.16	0.00	0.05	0.07	0.03	0.06	0.19	0.25	0.51	98.72
	SB/01	Dark-Blue	19-02-2013	III	64.16	18.66	2.82	1.76	1.46	6.03	1.58	0.36	0.00	0.07	0.09	0.18	0.00	0.00	0.01	0.00	0.02	0.25	0.27	0.77	98.50
	SB/01	Dark-Blue	19-02-2013	IV	62.42	18.44	2.65	1.72	1.18	7.49	1.67	0.38	0.00	0.05	0.05	0.18	0.00	0.00	0.00	0.00	0.06	0.17	0.19	0.26	96.89
	SB/01	Dark-Blue	19-02-2013	V	65.54	18.77	2.92	1.70	1.11	4.04	1.31	0.23	0.00	0.06	0.01	0.18	0.01	0.00	0.02	0.00	0.07	0.38	0.29	0.72	97.36
	SB/01	**Dark-Blue**	**19-02-2013**	**Average**	**64.24**	**18.39**	**2.72**	**1.78**	**1.19**	**6.15**	**1.59**	**0.35**	**0.01**	**0.06**	**0.06**	**0.18**	**0.00**	**0.02**	**0.03**	**0.01**	**0.05**	**0.25**	**0.26**	**0.60**	**97.92**
	SB/01	**Dark-Blue**	**19-02-2013**	**Std. Dev.**	**1.15**	**0.50**	**0.27**	**0.10**	**0.18**	**1.44**	**0.17**	**0.07**	**0.02**	**0.01**	**0.05**	**0.02**	**0.00**	**0.02**	**0.03**	**0.01**	**0.03**	**0.08**	**0.04**	**0.21**	
25	SB/02	Dark-Blue	20-02-2013	I	67.91	15.35	2.18	2.36	1.21	6.07	1.59	0.41	0.00	0.06	0.06	0.23	0.00	0.00	0.07	0.02	0.00	0.21	0.26	0.71	98.70
	SB/02	Dark-Blue	20-02-2013	II	70.64	12.89	1.12	3.02	0.87	7.88	1.68	0.46	0.00	0.03	0.06	0.04	0.00	0.00	0.06	0.04	0.04	0.15	0.12	0.09	99.17
	SB/02	Dark-Blue	20-02-2013	III	69.27	14.97	2.12	2.50	1.09	6.47	1.61	0.35	0.00	0.04	0.06	0.09	0.00	0.03	0.01	0.05	0.02	0.19	0.25	0.14	99.24
	SB/02	Dark-Blue	20-02-2013	IV	67.40	15.92	2.22	2.31	1.27	6.48	1.51	0.35	0.01	0.04	0.02	0.21	0.00	0.03	0.04	0.05	0.04	0.19	0.26	0.60	98.95
	SB/02	Dark-Blue	20-02-2013	V	68.59	15.21	2.04	2.34	1.02	6.20	1.64	0.36	0.00	0.02	0.07	0.23	0.00	0.01	0.08	0.00	0.05	0.24	0.33	0.75	99.18
	SB/02	**Dark-Blue**	**20-02-2013**	**Average**	**68.76**	**14.87**	**1.94**	**2.50**	**1.09**	**6.62**	**1.61**	**0.39**	**0.00**	**0.04**	**0.05**	**0.16**	**0.00**	**0.01**	**0.05**	**0.03**	**0.03**	**0.19**	**0.24**	**0.46**	**99.05**
	SB/02	**Dark-Blue**	**20-02-2013**	**Std. Dev.**	**1.26**	**1.16**	**0.46**	**0.30**	**0.16**	**0.73**	**0.06**	**0.05**	**0.00**	**0.01**	**0.02**	**0.09**	**0.00**	**0.01**	**0.03**	**0.02**	**0.02**	**0.03**	**0.08**	**0.32**	
26	SB/03	Dark-Blue	20-02-2013	I	68.27	15.45	2.00	2.54	1.03	6.21	1.59	0.46	0.00	0.05	0.10	0.21	0.00	0.08	0.04	0.07	0.03	0.19	0.27	0.64	99.23
	SB/03	Dark-Blue	20-02-2013	II	67.65	15.72	1.96	2.34	1.22	6.76	1.46	0.36	0.02	0.04	0.12	0.18	0.00	0.00	0.01	0.02	0.05	0.13	0.38	0.64	99.04
	SB/03	Dark-Blue	20-02-2013	III	68.20	15.25	2.01	2.57	1.06	6.53	1.73	0.39	0.00	0.02	0.00	0.24	0.00	0.04	0.06	0.00	0.00	0.22	0.28	0.69	99.29

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	SB/03	Dark-Blue	20-02-2013	IV	67.51	15.48	1.93	2.59	0.60	6.62	1.63	0.37	0.00	0.03	0.00	0.23	0.00	0.00	0.00	0.00	0.02	0.06	0.33	0.59	97.98
	SB/03	Dark-Blue	20-02-2013	V	67.71	15.35	2.00	2.40	0.93	7.35	1.77	0.41	0.01	0.03	0.10	0.22	0.00	0.00	0.00	0.00	0.05	0.10	0.31	0.71	99.43
	SB/03	**Dark-Blue**	**20-02-2013**	**Average**	**67.87**	**15.45**	**1.98**	**2.49**	**0.97**	**6.69**	**1.63**	**0.40**	**0.01**	**0.03**	**0.06**	**0.21**	**0.00**	**0.02**	**0.02**	**0.02**	**0.03**	**0.14**	**0.31**	**0.65**	**98.99**
	SB/03	**Dark-Blue**	**20-02-2013**	**Std. Dev.**	**0.34**	**0.18**	**0.04**	**0.11**	**0.23**	**0.42**	**0.12**	**0.04**	**0.01**	**0.01**	**0.06**	**0.02**	**0.00**	**0.03**	**0.03**	**0.03**	**0.02**	**0.06**	**0.04**	**0.05**	
27	SB/04	Dark-Blue	20-02-2013	I	68.19	15.68	2.57	1.95	1.59	5.41	1.32	0.29	0.06	0.04	0.02	0.22	0.00	0.00	0.00	0.06	0.02	0.31	0.25	0.55	98.51
	SB/04	Dark-Blue	20-02-2013	II	68.31	15.34	2.02	1.97	1.12	6.92	1.66	0.39	0.00	0.05	0.08	0.23	0.00	0.00	0.04	0.00	0.02	0.18	0.29	0.62	99.22
	SB/04	Dark-Blue	20-02-2013	III	69.01	15.34	2.03	2.03	0.92	6.59	1.82	0.37	0.00	0.04	0.05	0.19	0.00	0.00	0.05	0.00	0.05	0.17	0.26	0.61	99.51
	SB/04	Dark-Blue	20-02-2013	IV	68.93	14.84	2.02	2.01	1.04	6.63	1.62	0.40	0.00	0.02	0.00	0.16	0.00	0.00	0.03	0.04	0.05	0.21	0.24	0.48	98.72
	SB/04	Dark-Blue	20-02-2013	V	67.75	15.38	2.07	2.02	0.88	6.39	1.62	0.40	0.00	0.04	0.10	0.22	0.03	0.00	0.07	0.05	0.06	0.12	0.25	0.44	97.88
	SB/04	**Dark-Blue**	**20-02-2013**	**Average**	**68.44**	**15.32**	**2.14**	**2.00**	**1.11**	**6.39**	**1.61**	**0.37**	**0.01**	**0.04**	**0.05**	**0.20**	**0.01**	**0.00**	**0.04**	**0.03**	**0.04**	**0.20**	**0.26**	**0.54**	**98.77**
	SB/04	**Dark-Blue**	**20-02-2013**	**Std. Dev.**	**0.53**	**0.30**	**0.24**	**0.04**	**0.28**	**0.58**	**0.18**	**0.05**	**0.03**	**0.01**	**0.04**	**0.03**	**0.01**	**0.00**	**0.03**	**0.03**	**0.02**	**0.07**	**0.02**	**0.08**	
28	SB/05	Dark-Blue	26-02-2013	I	66.42	15.33	2.03	2.07	0.56	7.55	1.76	0.40	0.00	0.05	0.05	0.25	0.00	0.00	0.01	0.01	0.00	0.12	0.38	0.43	97.42
	SB/05	Dark-Blue	26-02-2013	II	67.44	15.16	1.97	2.12	0.65	6.83	1.72	0.71	0.01	0.06	0.05	0.18	0.00	0.00	0.00	0.01	0.03	0.11	0.34	0.48	97.87
	SB/05	Dark-Blue	26-02-2013	III	67.91	15.29	1.98	2.12	0.96	6.38	1.55	0.46	0.00	0.06	0.03	0.17	0.00	0.00	0.04	0.00	0.02	0.11	0.31	0.46	97.85
	SB/05	Dark-Blue	26-02-2013	IV	67.20	15.99	2.25	2.07	1.19	6.15	1.61	0.37	0.00	0.06	0.08	0.21	0.00	0.00	0.04	0.00	0.02	0.24	0.32	0.58	98.39
	SB/05	Dark-Blue	26-02-2013	V	67.65	15.63	1.94	2.23	0.82	6.84	1.76	0.38	0.01	0.03	0.04	0.19	0.00	0.00	0.05	0.00	0.09	0.19	0.29	0.36	98.49
	SB/05	**Dark-Blue**	**26-02-2013**	**Average**	**67.32**	**15.48**	**2.03**	**2.12**	**0.84**	**6.75**	**1.68**	**0.47**	**0.01**	**0.05**	**0.05**	**0.20**	**0.00**	**0.00**	**0.03**	**0.00**	**0.03**	**0.15**	**0.33**	**0.46**	**98.01**
	SB/05	**Dark-Blue**	**26-02-2013**	**Std. Dev.**	**0.57**	**0.33**	**0.13**	**0.07**	**0.25**	**0.54**	**0.10**	**0.14**	**0.01**	**0.01**	**0.02**	**0.03**	**0.00**	**0.00**	**0.02**	**0.01**	**0.03**	**0.06**	**0.03**	**0.08**	
29	SB/06	Yellow	19-02-2013	I	54.70	14.95	2.29	1.87	1.71	3.83	0.79	0.19	0.00	0.04	0.11	0.01	2.63	16.43	0.02	0.13	0.00	0.24	0.01	0.00	99.94
	SB/06	Yellow	19-02-2013	II	50.33	15.18	2.23	1.75	1.25	4.25	1.07	0.23	0.00	0.00	0.07	0.01	4.61	17.49	0.02	0.53	0.00	0.17	0.00	0.00	99.19
	SB/06	Yellow	19-02-2013	III	57.15	14.62	2.39	1.96	1.60	4.30	0.73	0.21	0.00	0.03	0.02	0.01	1.42	14.34	0.06	0.11	0.00	0.31	0.03	0.00	99.27
	SB/06	Yellow	19-02-2013	IV	53.79	14.87	1.92	1.88	1.36	4.61	1.04	0.28	0.00	0.04	0.12	0.02	1.55	17.84	0.00	0.19	0.02	0.30	0.00	0.00	99.82
	SB/06	Yellow	19-02-2013	V	55.51	14.59	1.75	1.60	1.74	2.59	0.60	0.13	0.00	0.03	0.05	0.00	3.55	17.94	0.03	0.32	0.00	0.18	0.00	0.00	100.60
	SB/06	**Yellow**	**19-02-2013**	**Average**	**54.29**	**14.84**	**2.12**	**1.81**	**1.53**	**3.92**	**0.85**	**0.21**	**0.00**	**0.03**	**0.08**	**0.01**	**2.75**	**16.81**	**0.03**	**0.26**	**0.00**	**0.24**	**0.01**	**0.00**	**99.77**
	SB/06	**Yellow**	**19-02-2013**	**Std. Dev.**	**2.54**	**0.25**	**0.27**	**0.14**	**0.22**	**0.79**	**0.20**	**0.06**	**0.00**	**0.01**	**0.04**	**0.01**	**1.35**	**1.51**	**0.02**	**0.17**	**0.01**	**0.07**	**0.01**	**0.00**	
30	SB/07	Yellow	19-02-2013	I	55.38	15.62	1.50	1.86	0.49	7.05	1.55	0.35	0.00	0.04	0.11	0.01	0.75	12.87	0.04	0.21	0.03	0.06	0.00	0.00	97.92
	SB/07	Yellow	19-02-2013	II	52.06	15.14	1.42	1.73	0.74	6.49	1.34	0.33	0.00	0.02	0.05	0.02	3.28	16.13	0.00	0.23	0.06	0.08	0.00	0.00	99.13
	SB/07	Yellow	19-02-2013	III	50.63	15.30	1.18	1.60	0.90	6.01	1.28	0.28	0.00	0.03	0.00	0.00	3.26	15.60	0.02	0.43	0.00	0.13	0.00	0.00	96.66
	SB/07	Yellow	19-02-2013	IV	65.09	14.04	1.50	2.65	1.24	7.85	1.63	0.44	0.00	0.02	0.00	0.00	0.54	4.41	0.01	0.08	0.00	0.31	0.08	0.00	99.89
	SB/07	Yellow	19-02-2013	V	54.28	15.31	1.42	1.86	0.55	6.43	1.38	0.31	0.00	0.04	0.11	0.02	2.14	14.47	0.07	0.25	0.03	0.18	0.00	0.00	98.83
	SB/07	**Yellow**	**19-02-2013**	**Average**	**55.49**	**15.08**	**1.40**	**1.94**	**0.78**	**6.77**	**1.44**	**0.34**	**0.00**	**0.03**	**0.05**	**0.01**	**2.00**	**12.70**	**0.03**	**0.24**	**0.03**	**0.15**	**0.02**	**0.00**	**98.49**
	SB/07	**Yellow**	**19-02-2013**	**Std. Dev.**	**5.68**	**0.61**	**0.13**	**0.41**	**0.30**	**0.71**	**0.15**	**0.06**	**0.00**	**0.01**	**0.06**	**0.01**	**1.32**	**4.80**	**0.03**	**0.13**	**0.03**	**0.10**	**0.03**	**0.00**	
31	SB/08	Turquoise	27-02-2013	I	65.17	17.46	1.89	1.94	0.94	6.07	1.26	0.35	0.00	0.05	3.90	0.02	0.00	0.00	0.04	0.00	0.04	0.20	0.20	0.00	99.54
	SB/08	Turquoise	27-02-2013	II	64.91	18.18	2.18	1.81	1.19	5.40	1.22	0.30	0.04	0.07	3.34	0.00	0.00	0.00	0.00	0.00	0.05	0.17	0.24	0.01	99.12
	SB/08	Turquoise	27-02-2013	III	65.90	17.16	1.79	1.97	0.94	6.05	1.36	0.34	0.00	0.04	3.37	0.00	0.00	0.00	0.00	0.03	0.03	0.23	0.28	0.00	99.48
	SB/08	Turquoise	27-02-2013	IV	67.20	16.64	1.85	1.93	0.86	6.26	1.28	0.32	0.00	0.04	3.19	0.00	0.00	0.00	0.04	0.00	0.01	0.12	0.24	0.00	99.98
	SB/08	Turquoise	27-02-2013	V	63.53	18.02	2.41	1.76	1.35	6.49	1.37	0.31	0.00	0.04	3.98	0.01	0.01	0.00	0.04	0.00	0.05	0.13	0.14	0.00	99.64
	SB/08	**Turquoise**	**27-02-2013**	**Average**	**65.34**	**17.49**	**2.02**	**1.88**	**1.06**	**6.05**	**1.30**	**0.32**	**0.01**	**0.05**	**3.56**	**0.01**	**0.00**	**0.00**	**0.02**	**0.01**	**0.04**	**0.17**	**0.22**	**0.00**	**99.55**
	SB/08	**Turquoise**	**27-02-2013**	**Std. Dev.**	**1.35**	**0.63**	**0.26**	**0.09**	**0.21**	**0.41**	**0.06**	**0.02**	**0.02**	**0.01**	**0.36**	**0.01**	**0.00**	**0.00**	**0.02**	**0.01**	**0.02**	**0.05**	**0.05**	**0.00**	
32	SB/09	Turquoise	27-02-2013	I	66.02	17.67	2.02	1.68	1.28	5.92	1.30	0.34	0.04	0.05	3.01	0.00	0.00	0.05	0.00	0.05	0.02	0.22	0.26	0.00	99.93
	SB/09	Turquoise	27-02-2013	II	67.51	16.93	1.62	1.99	0.62	6.61	1.25	0.37	0.00	0.06	1.84	0.00	0.00	0.07	0.00	0.00	0.02	0.14	0.32	0.00	99.37
	SB/09	Turquoise	27-02-2013	III	68.97	16.40	1.53	2.05	0.41	6.45	1.38	0.34	0.00	0.05	1.85	0.02	0.00	0.00	0.00	0.08	0.02	0.09	0.25	0.00	99.87
	SB/09	Turquoise	27-02-2013	IV	65.03	17.11	1.76	1.93	0.91	6.18	1.30	0.36	0.00	0.04	3.72	0.00	0.00	0.00	0.00	0.06	0.00	0.20	0.29	0.00	98.88
	SB/09	Turquoise	27-02-2013	V	66.85	17.32	2.30	1.87	1.37	5.96	1.17	0.34	0.00	0.06	2.57	0.00	0.00	0.00	0.02	0.00	0.02	0.24	0.29	0.00	100.37
	SB/09	**Turquoise**	**27-02-2013**	**Average**	**66.88**	**17.08**	**1.85**	**1.90**	**0.92**	**6.22**	**1.28**	**0.35**	**0.01**	**0.05**	**2.60**	**0.00**	**0.00**	**0.02**	**0.00**	**0.04**	**0.02**	**0.18**	**0.28**	**0.00**	**99.68**
	SB/09	**Turquoise**	**27-02-2013**	**Std. Dev.**	**1.49**	**0.47**	**0.31**	**0.14**	**0.41**	**0.30**	**0.08**	**0.02**	**0.02**	**0.01**	**0.80**	**0.01**	**0.00**	**0.03**	**0.01**	**0.04**	**0.01**	**0.06**	**0.03**	**0.00**	

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
33	SB/10	Dark-Blue	26-02-2013	I	67.11	16.57	1.65	2.61	0.77	6.14	1.62	0.40	0.01	0.07	0.08	0.11	0.00	0.03	0.08	0.00	0.05	0.15	0.39	0.34	98.17
	SB/10	Dark-Blue	26-02-2013	II	66.45	16.84	2.08	2.55	1.23	5.76	1.70	0.38	0.00	0.05	0.05	0.24	0.00	0.09	0.02	0.02	0.03	0.20	0.32	0.67	98.68
	SB/10	Dark-Blue	26-02-2013	III	65.63	17.19	2.36	2.42	0.88	5.88	1.49	0.30	0.00	0.05	0.08	0.20	0.00	0.09	0.04	0.00	0.01	0.24	0.31	0.40	97.53
	SB/10	Dark-Blue	26-02-2013	IV	65.80	16.98	2.33	2.55	1.48	5.56	1.80	0.33	0.00	0.03	0.07	0.23	0.00	0.03	0.04	0.00	0.06	0.23	0.37	0.67	98.55
	SB/10	Dark-Blue	26-02-2013	V	68.93	15.24	1.78	2.82	0.79	6.80	1.57	0.43	0.00	0.05	0.13	0.06	0.00	0.00	0.00	0.04	0.05	0.17	0.25	0.04	99.16
	SB/10	**Dark-Blue**	**26-02-2013**	**Average**	**66.78**	**16.57**	**2.04**	**2.59**	**1.03**	**6.03**	**1.64**	**0.37**	**0.00**	**0.05**	**0.08**	**0.17**	**0.00**	**0.05**	**0.03**	**0.01**	**0.04**	**0.20**	**0.33**	**0.43**	**98.42**
	SB/10	**Dark-Blue**	**26-02-2013**	**Std. Dev.**	**1.34**	**0.77**	**0.32**	**0.15**	**0.31**	**0.48**	**0.12**	**0.06**	**0.01**	**0.01**	**0.03**	**0.08**	**0.00**	**0.04**	**0.03**	**0.02**	**0.02**	**0.04**	**0.05**	**0.26**	
34	NG/01	White	13-03-2012	I	64.84	18.36	4.46	2.52	3.07	1.81	0.51	0.09	0.00	0.05	0.00	0.01	0.00	0.06	0.00	0.04	0.00	0.32	0.28	0.00	96.39
	NG/01	White	13-03-2012	II	65.18	18.16	4.36	2.38	3.21	1.91	0.56	0.08	0.02	0.06	0.03	0.02	0.00	0.02	0.07	0.06	0.00	0.40	0.25	0.00	96.75
	NG/01	White	13-03-2012	III	64.51	18.26	4.56	2.23	3.21	1.91	0.51	0.09	0.00	0.04	0.06	0.00	0.00	0.02	0.00	0.02	0.00	0.36	0.25	0.00	96.04
	NG/01	White	13-03-2012	IV	63.87	17.76	4.83	2.34	3.37	1.85	0.56	0.12	0.00	0.03	0.00	0.03	0.00	0.00	0.03	0.05	0.01	0.52	0.25	0.00	95.61
	NG/01	**White**	**13-03-2012**	**Average**	**64.60**	**18.13**	**4.55**	**2.37**	**3.21**	**1.87**	**0.53**	**0.09**	**0.00**	**0.04**	**0.02**	**0.02**	**0.00**	**0.02**	**0.02**	**0.04**	**0.00**	**0.40**	**0.26**	**0.00**	**96.20**
	NG/01	**White**	**13-03-2012**	**Std. Dev.**	**0.56**	**0.26**	**0.20**	**0.12**	**0.12**	**0.05**	**0.03**	**0.02**	**0.01**	**0.01**	**0.03**	**0.01**	**0.00**	**0.02**	**0.03**	**0.02**	**0.00**	**0.09**	**0.02**	**0.00**	
35	NG/02	Yellow	01-03-2012	I	54.37	12.66	1.62	1.60	0.82	5.73	1.26	0.27	0.06	0.04	0.03	0.01	1.07	15.79	0.00	0.35	0.02	0.22	0.00	0.00	95.92
	NG/02	Yellow	01-03-2012	II	53.73	12.72	1.42	1.59	0.90	5.79	1.37	0.31	0.00	0.05	0.00	0.00	0.60	13.20	0.00	0.23	0.01	0.06	0.00	0.00	91.98
	NG/02	Yellow	01-03-2012	III	50.78	12.73	1.43	1.42	0.70	5.50	1.24	0.30	0.00	0.02	0.02	0.05	2.85	16.49	0.00	0.51	0.00	0.12	0.00	0.01	94.16
	NG/02	Yellow	01-03-2012	IV	52.03	12.95	1.36	1.42	0.86	5.56	1.32	0.31	0.00	0.01	0.06	0.00	3.04	15.67	0.04	0.39	0.01	0.00	0.00	0.00	95.02
	NG/02	**Yellow**	**01-03-2012**	**Average**	**52.73**	**12.76**	**1.46**	**1.51**	**0.82**	**5.64**	**1.30**	**0.30**	**0.02**	**0.03**	**0.03**	**0.01**	**1.89**	**15.29**	**0.01**	**0.37**	**0.01**	**0.10**	**0.00**	**0.00**	**94.27**
	NG/02	**Yellow**	**01-03-2012**	**Std. Dev.**	**1.63**	**0.13**	**0.11**	**0.10**	**0.09**	**0.14**	**0.06**	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**	**1.24**	**1.44**	**0.02**	**0.12**	**0.01**	**0.09**	**0.00**	**0.01**	
36	NG/03	Dark-Blue	01-03-2012	I	62.85	16.76	2.80	2.50	2.04	3.81	1.33	0.22	0.00	0.05	0.05	0.22	0.00	0.00	0.05	0.02	0.02	0.31	0.28	0.68	93.98
	NG/03	Dark-Blue	01-03-2012	II	61.37	16.86	2.85	2.50	1.90	4.53	1.13	0.24	0.00	0.05	0.00	0.26	0.00	0.00	0.05	0.01	0.04	0.25	0.28	0.81	93.11
	NG/03	Dark-Blue	01-03-2012	III	61.07	17.28	2.83	2.29	1.69	5.32	1.43	0.27	0.03	0.04	0.00	0.25	0.00	0.03	0.05	0.00	0.09	0.15	0.30	0.56	93.67
	NG/03	Dark-Blue	01-03-2012	IV	61.53	17.13	2.75	2.60	1.75	5.69	1.27	0.31	0.00	0.08	0.08	0.21	0.00	0.00	0.05	0.07	0.00	0.21	0.22	0.33	94.26
	NG/03	**Dark-Blue**	**01-03-2012**	**Average**	**61.70**	**17.01**	**2.81**	**2.47**	**1.84**	**4.84**	**1.29**	**0.26**	**0.01**	**0.05**	**0.03**	**0.24**	**0.00**	**0.01**	**0.05**	**0.03**	**0.04**	**0.23**	**0.27**	**0.60**	**93.76**
	NG/03	**Dark-Blue**	**01-03-2012**	**Std. Dev.**	**0.79**	**0.24**	**0.04**	**0.13**	**0.16**	**0.84**	**0.13**	**0.04**	**0.02**	**0.02**	**0.04**	**0.02**	**0.00**	**0.02**	**0.00**	**0.03**	**0.04**	**0.07**	**0.03**	**0.20**	
37	NG/04	Turquoise	13-03-2012	I	61.21	21.08	1.31	1.50	0.55	5.78	1.50	0.30	0.00	0.02	3.30	0.03	0.00	0.00	0.05	0.02	0.07	0.12	0.22	0.00	97.05
	NG/04	Turquoise	13-03-2012	II	63.43	19.93	1.32	1.52	0.56	6.12	1.60	0.35	0.00	0.00	3.46	0.00	0.01	0.00	0.00	0.01	0.07	0.33	0.28	0.00	98.98
	NG/04	Turquoise	13-03-2012	III	61.45	21.63	1.51	1.51	0.60	5.86	1.43	0.31	0.00	0.01	2.91	0.00	0.00	0.00	0.00	0.00	0.03	0.09	0.24	0.00	97.58
	NG/04	**Turquoise**	**13-03-2012**	**Average**	**62.03**	**20.88**	**1.38**	**1.51**	**0.57**	**5.92**	**1.51**	**0.32**	**0.00**	**0.01**	**3.22**	**0.01**	**0.00**	**0.00**	**0.02**	**0.01**	**0.06**	**0.18**	**0.25**	**0.00**	**97.87**
	NG/04	**Turquoise**	**13-03-2012**	**Std. Dev.**	**1.22**	**0.87**	**0.11**	**0.01**	**0.03**	**0.18**	**0.08**	**0.02**	**0.00**	**0.01**	**0.28**	**0.02**	**0.01**	**0.00**	**0.03**	**0.01**	**0.03**	**0.13**	**0.03**	**0.00**	
38	NG/05	Green	13-03-2012	I	55.35	14.49	1.43	1.45	0.74	6.37	1.55	0.34	0.00	0.03	1.47	0.02	2.12	12.85	0.02	0.21	0.00	0.12	0.00	0.00	98.54
	NG/05	Green	13-03-2012	II	57.25	14.37	1.50	1.63	0.84	6.37	1.55	0.32	0.05	0.02	1.23	0.00	2.65	11.12	0.00	0.41	0.07	0.16	0.00	0.00	99.53
	NG/05	Green	13-03-2012	III	57.35	14.85	1.63	1.63	0.76	7.02	1.73	0.35	0.00	0.07	1.13	0.03	0.83	9.56	0.00	0.41	0.08	0.07	0.00	0.00	97.50
	NG/05	**Green**	**13-03-2012**	**Average**	**56.65**	**14.57**	**1.52**	**1.57**	**0.78**	**6.59**	**1.61**	**0.34**	**0.02**	**0.04**	**1.27**	**0.02**	**1.87**	**11.18**	**0.01**	**0.34**	**0.05**	**0.12**	**0.00**	**0.00**	**98.52**
	NG/05	**Green**	**13-03-2012**	**Std. Dev.**	**1.13**	**0.25**	**0.10**	**0.10**	**0.05**	**0.37**	**0.10**	**0.01**	**0.03**	**0.03**	**0.17**	**0.01**	**0.94**	**1.65**	**0.01**	**0.12**	**0.04**	**0.04**	**0.00**	**0.00**	
39	NG/06	Yellow	21-05-2012	I	54.72	13.93	1.84	2.24	1.26	3.88	0.99	0.19	0.04	0.05	0.09	0.00	3.82	15.01	0.03	0.31	0.04	0.32	0.00	0.00	98.76
	NG/06	Yellow	21-05-2012	II	56.40	13.29	1.77	2.90	0.91	5.93	1.30	0.28	0.00	0.02	0.08	0.00	2.34	13.90	0.04	0.34	0.00	0.20	0.00	0.00	99.68
	NG/06	Yellow	21-05-2012	III	53.07	13.64	1.59	2.40	0.96	4.46	1.21	0.19	0.00	0.04	0.01	0.01	4.43	17.78	0.01	0.39	0.01	0.22	0.00	0.00	100.40
	NG/06	**Yellow**	**21-05-2012**	**Average**	**54.73**	**13.62**	**1.73**	**2.52**	**1.05**	**4.76**	**1.16**	**0.22**	**0.01**	**0.04**	**0.06**	**0.00**	**3.53**	**15.56**	**0.02**	**0.35**	**0.02**	**0.24**	**0.00**	**0.00**	**99.61**
	NG/06	**Yellow**	**21-05-2012**	**Std. Dev.**	**1.67**	**0.32**	**0.13**	**0.34**	**0.19**	**1.05**	**0.16**	**0.05**	**0.02**	**0.02**	**0.05**	**0.01**	**1.07**	**2.00**	**0.02**	**0.04**	**0.02**	**0.06**	**0.00**	**0.00**	
40	NG/07	Yellow	01-05-2012	I	55.73	13.85	1.79	1.64	0.87	5.68	1.35	0.32	0.00	0.03	0.02	0.01	2.57	15.00	0.00	0.30	0.00	0.16	0.13	0.00	99.46
	NG/07	Yellow	01-05-2012	II	53.68	13.70	1.98	1.63	0.86	5.61	1.37	0.31	0.00	0.04	0.00	0.00	3.18	15.79	0.00	0.34	0.01	0.13	0.15	0.00	98.76
	NG/07	Yellow	01-05-2012	III	55.35	14.20	1.79	1.57	0.85	5.72	1.35	0.31	0.00	0.04	0.04	0.00	2.11	15.68	0.01	0.36	0.02	0.13	0.15	0.00	99.64
	NG/07	Yellow	01-05-2012	IV	56.72	13.82	1.93	1.83	0.89	5.49	1.45	0.34	0.00	0.03	0.06	0.00	2.55	13.91	0.00	0.41	0.03	0.13	0.22	0.00	99.80
	NG/07	Yellow	01-05-2012	V	56.60	12.59	1.56	1.79	0.65	5.32	1.27	0.29	0.00	0.06	0.03	0.00	3.20	16.54	0.00	0.30	0.00	0.10	0.07	0.01	100.35
	NG/07	**Yellow**	**01-05-2012**	**Average**	**55.62**	**13.63**	**1.81**	**1.69**	**0.83**	**5.56**	**1.36**	**0.31**	**0.00**	**0.04**	**0.03**	**0.00**	**2.72**	**15.38**	**0.00**	**0.34**	**0.01**	**0.13**	**0.14**	**0.00**	**99.60**

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	NG/07	Yellow	01-05-2012	Std. Dev.	1.23	0.61	0.16	0.11	0.10	0.16	0.07	0.02	0.00	0.01	0.02	0.00	0.47	0.99	0.01	0.04	0.01	0.02	0.05	0.00	
41	NG/08	Dark-Blue	16-05-2012	I	63.92	18.59	2.79	2.38	1.77	5.64	1.41	0.28	0.00	0.03	0.00	0.27	0.00	0.00	0.02	0.04	0.04	0.27	0.35	0.74	98.55
	NG/08	Dark-Blue	16-05-2012	II	64.52	18.09	3.08	2.38	1.82	5.33	1.43	0.27	0.00	0.02	0.00	0.30	0.01	0.00	0.06	0.00	0.05	0.29	0.27	0.72	98.62
	NG/08	Dark-Blue	16-05-2012	III	64.32	18.55	2.85	2.32	1.73	5.60	1.59	0.34	0.00	0.03	0.00	0.26	0.01	0.00	0.00	0.10	0.07	0.17	0.21	0.54	98.68
	NG/08	Dark-Blue	16-05-2012	IV	64.92	17.63	2.84	2.36	1.73	5.38	1.64	0.30	0.02	0.03	0.04	0.31	0.00	0.04	0.00	0.00	0.03	0.25	0.35	0.54	98.39
	NG/08	Dark-Blue	16-05-2012	Average	64.42	18.21	2.89	2.36	1.76	5.49	1.52	0.30	0.00	0.03	0.01	0.29	0.01	0.01	0.02	0.03	0.05	0.25	0.30	0.63	98.56
	NG/08	Dark-Blue	16-05-2012	Std. Dev.	0.42	0.45	0.13	0.03	0.04	0.16	0.11	0.03	0.01	0.00	0.02	0.02	0.01	0.02	0.03	0.05	0.02	0.05	0.07	0.11	
42	NG/09	Dark-Blue	16-05-2012	I	64.40	18.60	2.61	2.48	1.54	5.95	1.57	0.30	0.00	0.06	0.03	0.30	0.00	0.04	0.01	0.00	0.05	0.29	0.28	0.81	99.32
	NG/09	Dark-Blue	16-05-2012	II	64.29	17.35	2.42	2.51	1.35	6.88	1.84	0.34	0.04	0.05	0.00	0.29	0.00	0.00	0.02	0.00	0.07	0.32	0.28	0.25	98.29
	NG/09	Dark-Blue	16-05-2012	III	65.22	17.77	2.77	2.47	1.63	5.41	1.56	0.27	0.04	0.06	0.02	0.31	0.00	0.01	0.05	0.02	0.00	0.26	0.28	0.61	98.75
	NG/09	Dark-Blue	16-05-2012	IV	65.13	17.94	2.62	2.40	1.69	5.41	1.67	0.23	0.00	0.06	0.01	0.27	0.00	0.00	0.01	0.00	0.00	0.17	0.29	0.85	98.75
	NG/09	Dark-Blue	16-05-2012	Average	64.76	17.92	2.61	2.46	1.55	5.91	1.66	0.29	0.02	0.06	0.01	0.29	0.00	0.01	0.02	0.01	0.03	0.26	0.28	0.63	98.78
	NG/09	Dark-Blue	16-05-2012	Std. Dev.	0.48	0.52	0.14	0.05	0.15	0.69	0.13	0.05	0.02	0.01	0.01	0.02	0.00	0.02	0.02	0.01	0.03	0.06	0.00	0.28	
43	NG/10	Turquoise	01-05-2012	I	62.52	21.04	1.27	1.84	0.49	5.79	1.36	0.34	0.01	0.02	3.37	0.00	0.00	0.00	0.00	0.05	0.07	0.25	0.22	0.01	98.63
	NG/10	Turquoise	01-05-2012	II	62.47	21.55	1.35	1.70	0.55	5.74	1.43	0.33	0.00	0.03	3.31	0.00	0.00	0.00	0.00	0.00	0.04	0.22	0.24	0.00	98.96
	NG/10	Turquoise	01-05-2012	III	62.74	21.66	1.33	1.57	0.49	5.68	1.29	0.33	0.00	0.04	2.54	0.00	0.00	0.00	0.00	0.00	0.08	0.24	0.22	0.00	98.21
	NG/10	Turquoise	01-05-2012	IV	61.82	21.23	1.38	1.53	0.53	5.76	1.39	0.35	0.00	0.03	3.89	0.01	0.00	0.01	0.00	0.00	0.02	0.24	0.22	0.00	98.41
	NG/10	Turquoise	01-05-2012	V	62.08	21.85	1.47	1.44	0.48	5.78	1.38	0.35	0.00	0.04	2.97	0.00	0.00	0.00	0.01	0.00	0.05	0.23	0.27	0.00	98.40
	NG/10	Turquoise	01-05-2012	Average	62.32	21.47	1.36	1.62	0.51	5.75	1.37	0.34	0.00	0.03	3.22	0.00	0.00	0.00	0.00	0.01	0.05	0.24	0.23	0.00	98.52
	NG/10	Turquoise	01-05-2012	Std. Dev.	0.37	0.33	0.07	0.16	0.03	0.04	0.05	0.01	0.00	0.01	0.50	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.02	0.01	
44	NG/11	Turquoise(D)	16-05-2012	I	62.32	18.62	2.11	2.48	1.16	6.18	1.45	0.33	0.00	0.01	3.28	0.00	0.01	0.00	0.00	0.12	0.06	0.10	0.29	0.01	98.51
	NG/11	Turquoise(D)	16-05-2012	II	65.69	17.52	1.74	2.63	0.88	4.73	1.30	0.30	0.02	0.02	2.93	0.00	0.00	0.03	0.01	0.02	0.01	0.16	0.25	0.00	98.25
	NG/11	Turquoise(D)	16-05-2012	III	63.26	18.19	2.00	2.56	1.01	5.83	1.47	0.30	0.00	0.03	2.93	0.01	0.04	0.02	0.04	0.03	0.04	0.18	0.27	0.00	98.18
	NG/11	Turquoise(D)	16-05-2012	IV	64.07	17.78	2.07	2.39	1.06	5.61	1.40	0.28	0.00	0.02	3.24	0.02	0.02	0.04	0.04	0.01	0.00	0.16	0.29	0.00	98.49
	NG/11	Turquoise(D)	16-05-2012	Average	63.83	18.03	1.98	2.51	1.03	5.59	1.40	0.31	0.00	0.02	3.09	0.01	0.02	0.02	0.02	0.04	0.03	0.15	0.28	0.00	98.36
	NG/11	Turquoise(D)	16-05-2012	Std. Dev.	1.43	0.48	0.16	0.10	0.12	0.62	0.07	0.02	0.01	0.01	0.19	0.01	0.02	0.02	0.02	0.05	0.02	0.04	0.02	0.00	
45	NG/12	Dark-Blue	16-05-2012	I	63.71	18.55	2.95	2.34	1.81	5.69	1.50	0.25	0.00	0.01	0.04	0.34	0.00	0.00	0.01	0.03	0.01	0.31	0.36	0.69	98.59
	NG/12	Dark-Blue	16-05-2012	II	64.60	17.55	2.68	2.47	1.55	5.58	1.50	0.30	0.00	0.03	0.01	0.25	0.00	0.07	0.00	0.07	0.00	0.19	0.29	0.56	97.67
	NG/12	Dark-Blue	16-05-2012	III	65.19	17.64	2.53	2.60	1.32	6.08	1.62	0.32	0.00	0.03	0.05	0.27	0.00	0.00	0.06	0.04	0.05	0.12	0.33	0.60	98.84
	NG/12	Dark-Blue	16-05-2012	IV	64.36	18.02	2.28	2.45	1.26	6.32	1.96	0.39	0.00	0.04	0.04	0.35	0.00	0.00	0.07	0.00	0.07	0.31	0.36	0.66	98.95
	NG/12	Dark-Blue	16-05-2012	Average	64.46	17.94	2.61	2.46	1.49	5.92	1.64	0.31	0.00	0.03	0.03	0.30	0.00	0.02	0.04	0.03	0.03	0.23	0.34	0.63	98.51
	NG/12	Dark-Blue	16-05-2012	Std. Dev.	0.61	0.45	0.28	0.11	0.25	0.35	0.22	0.06	0.00	0.01	0.02	0.05	0.00	0.04	0.04	0.03	0.03	0.10	0.04	0.06	
46	NG/13	Turquoise(D)	21-05-2012	I	62.92	19.65	2.12	1.72	1.11	5.85	1.54	0.30	0.00	0.06	3.14	0.01	0.02	0.00	0.02	0.04	0.00	0.20	0.22	0.00	98.91
	NG/13	Turquoise(D)	21-05-2012	II	61.87	20.76	2.96	1.66	1.64	4.84	1.35	0.24	0.00	0.04	2.99	0.03	0.01	0.09	0.01	0.00	0.06	0.33	0.20	0.00	99.09
	NG/13	Turquoise(D)	21-05-2012	III	60.62	20.33	2.25	1.73	1.16	6.88	1.64	0.34	0.08	0.05	3.21	0.02	0.02	0.03	0.03	0.00	0.06	0.12	0.27	0.01	98.84
	NG/13	Turquoise(D)	21-05-2012	Average	61.81	20.25	2.44	1.70	1.30	5.86	1.51	0.30	0.03	0.05	3.11	0.02	0.02	0.04	0.02	0.01	0.04	0.22	0.23	0.00	98.95
	NG/13	Turquoise(D)	21-05-2012	Std. Dev.	1.15	0.56	0.45	0.04	0.29	1.02	0.15	0.05	0.04	0.01	0.12	0.01	0.01	0.05	0.01	0.02	0.04	0.10	0.03	0.00	
47	NG/14	Turquoise	08-06-2012	I	62.61	18.68	2.21	1.75	1.03	6.30	1.57	0.35	0.00	0.05	2.94	0.01	0.00	0.16	0.01	0.01	0.05	0.06	0.14	0.00	97.92
	NG/14	Turquoise	08-06-2012	II	61.22	19.04	2.34	1.71	1.07	7.21	1.69	0.42	0.00	0.07	3.36	0.01	0.00	0.09	0.00	0.00	0.03	0.23	0.18	0.00	98.65
	NG/14	Turquoise	08-06-2012	III	63.83	18.06	2.26	1.80	1.25	6.37	1.46	0.31	0.05	0.04	2.56	0.00	0.01	0.00	0.00	0.00	0.06	0.21	0.17	0.00	98.44
	NG/14	Turquoise	08-06-2012	IV	63.21	17.49	1.85	1.95	0.89	7.88	1.73	0.42	0.00	0.04	2.77	0.00	0.00	0.14	0.01	0.00	0.02	0.23	0.11	0.00	98.75
	NG/14	Turquoise	08-06-2012	Average	62.72	18.32	2.16	1.80	1.06	6.94	1.61	0.37	0.01	0.05	2.91	0.00	0.00	0.10	0.01	0.00	0.04	0.18	0.15	0.00	98.44
	NG/14	Turquoise	08-06-2012	Std. Dev.	1.12	0.68	0.22	0.11	0.15	0.75	0.12	0.05	0.02	0.02	0.34	0.01	0.00	0.07	0.01	0.00	0.02	0.08	0.03	0.00	
48	NG/15	Dark-Blue	08-06-2012	I	64.99	16.16	2.56	1.82	1.06	7.00	1.94	0.39	0.00	0.03	0.08	0.41	0.00	0.00	0.06	0.00	0.01	0.12	0.16	1.00	97.78
	NG/15	Dark-Blue	08-06-2012	II	65.29	16.14	2.69	1.90	1.42	6.95	1.74	0.40	0.00	0.06	0.03	0.27	0.00	0.07	0.03	0.01	0.08	0.24	0.23	0.35	97.88
	NG/15	Dark-Blue	08-06-2012	III	64.68	16.72	2.32	1.89	1.04	7.70	1.99	0.43	0.00	0.00	0.04	0.37	0.00	0.00	0.00	0.00	0.02	0.07	0.18	0.85	98.29

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	NG/15	Dark-Blue	08-06-2012	IV	64.49	16.49	2.57	1.87	1.26	7.40	1.96	0.44	0.00	0.06	0.01	0.29	0.00	0.00	0.00	0.00	0.04	0.11	0.21	0.58	97.78
	NG/15	**Dark-Blue**	**08-06-2012**	**Average**	**64.86**	**16.38**	**2.53**	**1.87**	**1.20**	**7.26**	**1.91**	**0.41**	**0.00**	**0.04**	**0.04**	**0.34**	**0.00**	**0.02**	**0.02**	**0.00**	**0.04**	**0.13**	**0.19**	**0.70**	**97.93**
	NG/15	**Dark-Blue**	**08-06-2012**	**Std. Dev.**	**0.35**	**0.28**	**0.15**	**0.03**	**0.18**	**0.35**	**0.12**	**0.03**	**0.00**	**0.03**	**0.03**	**0.07**	**0.00**	**0.04**	**0.03**	**0.00**	**0.03**	**0.07**	**0.03**	**0.29**	
49	NG/16	White	03-10-2012	I	62.19	18.64	4.24	2.71	3.17	2.19	0.61	0.10	0.00	0.07	0.00	0.03	0.00	0.05	0.01	0.05	0.00	0.32	0.25	0.00	94.62
	NG/16	White	03-10-2012	II	61.73	18.79	4.11	2.70	3.30	2.26	0.73	0.09	0.00	0.04	0.05	0.00	0.00	0.00	0.00	0.03	0.07	0.38	0.27	0.00	94.54
	NG/16	White	03-10-2012	III	61.80	18.94	4.19	2.73	3.35	2.23	0.58	0.10	0.00	0.05	0.04	0.00	0.00	0.06	0.02	0.06	0.00	0.45	0.22	0.00	94.80
	NG/16	**White**	**03-10-2012**	**Average**	**61.90**	**18.79**	**4.18**	**2.71**	**3.27**	**2.22**	**0.64**	**0.10**	**0.00**	**0.05**	**0.03**	**0.01**	**0.00**	**0.04**	**0.01**	**0.05**	**0.02**	**0.39**	**0.24**	**0.00**	**94.65**
	NG/16	**White**	**03-10-2012**	**Std. Dev.**	**0.25**	**0.15**	**0.06**	**0.02**	**0.10**	**0.03**	**0.08**	**0.01**	**0.00**	**0.01**	**0.03**	**0.02**	**0.00**	**0.03**	**0.01**	**0.01**	**0.04**	**0.07**	**0.03**	**0.00**	
50	NG/17	Green	03-10-2012	I	52.16	14.22	1.39	1.41	0.75	6.23	1.44	0.27	0.00	0.03	1.83	0.00	1.55	11.09	0.04	0.82	0.02	0.10	0.00	0.00	93.32
	NG/17	Green	03-10-2012	II	52.93	14.85	1.20	1.41	0.73	6.84	1.57	0.30	0.05	0.00	1.39	0.00	1.86	12.22	0.00	0.24	0.04	0.23	0.00	0.00	95.86
	NG/17	Green	03-10-2012	III	59.69	14.34	1.92	1.57	1.12	7.13	1.72	0.37	0.00	0.03	0.63	0.00	0.20	6.21	0.09	0.05	0.06	0.01	0.04	0.00	95.18
	NG/17	Green	03-10-2012	IV	53.40	14.31	1.37	1.43	0.77	6.88	1.53	0.30	0.10	0.01	1.60	0.01	1.47	12.36	0.00	0.54	0.02	0.09	0.00	0.00	96.20
	NG/17	**Green**	**03-10-2012**	**Average**	**54.54**	**14.43**	**1.47**	**1.46**	**0.84**	**6.77**	**1.57**	**0.31**	**0.04**	**0.02**	**1.36**	**0.00**	**1.27**	**10.47**	**0.03**	**0.41**	**0.03**	**0.11**	**0.01**	**0.00**	**95.14**
	NG/17	**Green**	**03-10-2012**	**Std. Dev.**	**3.47**	**0.28**	**0.31**	**0.08**	**0.19**	**0.38**	**0.12**	**0.04**	**0.05**	**0.01**	**0.52**	**0.00**	**0.73**	**2.90**	**0.04**	**0.34**	**0.02**	**0.09**	**0.02**	**0.00**	
51	QK/01	Dark-Blue	20-11-2013	I	62.47	18.35	2.60	1.81	0.95	7.81	1.80	0.33	0.00	0.06	0.02	0.52	0.00	0.00	0.00	0.00	0.06	0.16	0.15	1.21	98.31
	QK/01	Dark-Blue	20-11-2013	II	63.52	17.36	2.32	1.89	0.85	7.52	1.74	0.35	0.00	0.01	0.01	0.69	0.00	0.00	0.08	0.03	0.05	0.13	0.12	1.52	98.19
	QK/01	Dark-Blue	20-11-2013	III	62.91	18.17	2.38	1.85	0.85	7.37	1.84	0.31	0.00	0.05	0.00	0.59	0.03	0.00	0.05	0.06	0.02	0.22	0.21	1.52	98.43
	QK/01	Dark-Blue	20-11-2013	IV	61.64	19.05	2.94	1.72	1.10	7.46	1.77	0.34	0.07	0.06	0.05	0.70	0.00	0.00	0.08	0.05	0.01	0.24	0.20	1.20	98.68
	QK/01	Dark-Blue	20-11-2013	V	61.38	18.81	2.83	1.73	1.04	8.27	1.63	0.41	0.00	0.03	0.06	0.60	0.00	0.05	0.08	0.01	0.02	0.20	0.22	0.77	98.14
	QK/01	**Dark-Blue**	**20-11-2013**	**Average**	**62.39**	**18.35**	**2.62**	**1.80**	**0.96**	**7.69**	**1.76**	**0.35**	**0.01**	**0.04**	**0.03**	**0.62**	**0.01**	**0.01**	**0.06**	**0.03**	**0.03**	**0.19**	**0.18**	**1.25**	**98.35**
	QK/01	**Dark-Blue**	**20-11-2013**	**Std. Dev.**	**0.89**	**0.65**	**0.27**	**0.07**	**0.11**	**0.37**	**0.08**	**0.04**	**0.03**	**0.02**	**0.03**	**0.07**	**0.01**	**0.02**	**0.04**	**0.02**	**0.02**	**0.04**	**0.04**	**0.31**	
52	QK/02	Dark-Blue	29-11-2013	I	62.24	18.94	2.06	2.71	1.17	7.67	1.73	0.37	0.00	0.06	0.05	0.37	0.00	0.00	0.02	0.01	0.04	0.09	0.24	1.04	98.79
	QK/02	Dark-Blue	29-11-2013	II	64.73	16.81	1.95	3.06	0.92	7.41	1.58	0.33	0.00	0.01	0.00	0.15	0.00	0.00	0.02	0.00	0.02	0.14	0.10	0.08	97.30
	QK/02	Dark-Blue	29-11-2013	III	58.67	20.02	2.01	2.48	1.54	9.01	2.34	0.40	0.00	0.05	0.04	0.17	0.00	0.02	0.01	0.00	0.05	0.21	0.45	0.44	97.90
	QK/02	Dark-Blue	29-11-2013	IV	58.88	19.78	2.26	2.53	1.46	9.13	2.68	0.38	0.00	0.07	0.03	0.19	0.00	0.02	0.04	0.00	0.02	0.22	0.38	0.28	98.34
	QK/02	Dark-Blue	29-11-2013	V	59.93	19.15	1.81	2.61	1.10	8.55	2.16	0.37	0.00	0.07	0.11	0.27	0.00	0.00	0.04	0.04	0.00	0.13	0.33	0.45	97.09
	QK/02	**Dark-Blue**	**29-11-2013**	**Average**	**60.89**	**18.94**	**2.02**	**2.68**	**1.24**	**8.35**	**2.10**	**0.37**	**0.00**	**0.05**	**0.05**	**0.23**	**0.00**	**0.01**	**0.02**	**0.01**	**0.03**	**0.16**	**0.30**	**0.46**	**97.88**
	QK/02	**Dark-Blue**	**29-11-2013**	**Std. Dev.**	**2.57**	**1.27**	**0.17**	**0.23**	**0.26**	**0.78**	**0.45**	**0.03**	**0.00**	**0.03**	**0.04**	**0.09**	**0.00**	**0.01**	**0.02**	**0.02**	**0.02**	**0.06**	**0.13**	**0.36**	
53	QK/03	Dark-Blue	26-11-2013	I	62.83	17.78	2.08	2.89	1.04	7.26	1.72	0.36	0.00	0.07	0.05	0.48	0.00	0.00	0.08	0.02	0.01	0.13	0.19	1.05	98.03
	QK/03	Dark-Blue	26-11-2013	II	59.62	19.55	2.05	2.71	1.26	9.18	2.52	0.44	0.02	0.06	0.06	0.28	0.00	0.00	0.03	0.02	0.06	0.21	0.31	0.17	98.53
	QK/03	Dark-Blue	26-11-2013	III	62.81	18.55	1.88	2.79	0.51	7.65	1.69	0.32	0.05	0.07	0.06	0.27	0.00	0.00	0.04	0.00	0.02	0.16	0.13	0.64	97.62
	QK/03	Dark-Blue	26-11-2013	IV	64.88	16.95	1.85	3.03	0.91	7.73	1.72	0.36	0.00	0.06	0.00	0.17	0.00	0.00	0.03	0.05	0.01	0.13	0.08	0.33	98.28
	QK/03	Dark-Blue	26-11-2013	V	63.41	17.27	1.99	2.99	1.02	8.12	1.84	0.38	0.00	0.08	0.01	0.35	0.00	0.00	0.05	0.02	0.01	0.15	0.23	0.47	98.36
	QK/03	**Dark-Blue**	**26-11-2013**	**Average**	**62.71**	**18.02**	**1.97**	**2.88**	**0.95**	**7.99**	**1.90**	**0.37**	**0.01**	**0.07**	**0.03**	**0.31**	**0.00**	**0.00**	**0.04**	**0.02**	**0.02**	**0.16**	**0.19**	**0.53**	**98.17**
	QK/03	**Dark-Blue**	**26-11-2013**	**Std. Dev.**	**1.92**	**1.05**	**0.10**	**0.13**	**0.28**	**0.73**	**0.35**	**0.04**	**0.02**	**0.01**	**0.03**	**0.11**	**0.00**	**0.00**	**0.02**	**0.02**	**0.02**	**0.03**	**0.09**	**0.34**	
54	QK/04	Dark-Blue	20-11-2013	I	62.12	18.45	1.97	2.79	0.97	7.74	1.80	0.35	0.00	0.06	0.04	0.34	0.00	0.00	0.06	0.00	0.00	0.21	0.22	1.00	98.13
	QK/04	Dark-Blue	20-11-2013	II	62.47	18.42	2.64	2.77	1.49	5.81	1.67	0.26	0.00	0.09	0.00	0.53	0.00	0.00	0.03	0.01	0.02	0.17	0.23	1.72	98.30
	QK/04	Dark-Blue	20-11-2013	III	62.70	19.41	2.15	2.74	0.74	7.65	1.76	0.38	0.00	0.05	0.03	0.21	0.00	0.02	0.05	0.05	0.05	0.12	0.22	0.56	98.88
	QK/04	Dark-Blue	20-11-2013	IV	62.05	19.35	2.09	2.79	0.83	8.32	1.93	0.36	0.00	0.07	0.00	0.20	0.00	0.00	0.01	0.02	0.00	0.19	0.19	0.19	98.58
	QK/04	Dark-Blue	20-11-2013	V	63.57	18.41	1.82	2.94	0.88	7.49	1.69	0.38	0.00	0.03	0.04	0.26	0.00	0.01	0.07	0.01	0.03	0.12	0.18	0.63	98.54
	QK/04	**Dark-Blue**	**20-11-2013**	**Average**	**62.58**	**18.81**	**2.13**	**2.81**	**0.98**	**7.40**	**1.77**	**0.34**	**0.00**	**0.06**	**0.02**	**0.31**	**0.00**	**0.01**	**0.04**	**0.02**	**0.02**	**0.16**	**0.21**	**0.82**	**98.49**
	QK/04	**Dark-Blue**	**20-11-2013**	**Std. Dev.**	**0.61**	**0.52**	**0.31**	**0.08**	**0.30**	**0.94**	**0.10**	**0.05**	**0.00**	**0.02**	**0.02**	**0.14**	**0.00**	**0.01**	**0.02**	**0.02**	**0.02**	**0.04**	**0.02**	**0.58**	

Appendix 7.18 Chemical compositions of the tile glazes from Mughal buildings at Agra determined through EPMA-WDS analyses. All results are in wt%.

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
1	KMA/01	Turquoise	19-01-2014	I	63.59	17.44	3.20	1.84	1.72	5.62	1.44	0.30	0.08	0.02	5.11	0.02	0.00	0.00	0.03	0.02	0.04	0.32	0.17	0.00	100.97
	KMA/01	Turquoise	19-01-2014	II	64.69	16.83	3.27	1.89	1.92	5.21	1.33	0.29	0.00	0.03	4.53	0.00	0.01	0.07	0.02	0.00	0.08	0.29	0.15	0.00	100.60
	KMA/01	Turquoise	19-01-2014	III	62.23	17.98	3.76	1.88	2.41	5.24	1.40	0.26	0.01	0.04	4.35	0.00	0.05	0.00	0.04	0.06	0.05	0.35	0.24	0.00	100.33
	KMA/01	Turquoise	19-01-2014	IV	64.72	17.09	3.02	1.93	2.06	4.53	1.39	0.25	0.00	0.03	4.32	0.00	0.00	0.00	0.07	0.00	0.05	0.32	0.23	0.00	100.01
	KMA/01	Turquoise	19-01-2014	V	61.30	18.46	3.66	1.86	2.31	4.81	1.34	0.28	0.01	0.06	5.35	0.02	0.00	0.06	0.00	0.00	0.09	0.41	0.24	0.00	100.25
	KMA/01	**Turquoise**	**19-01-2014**	**Average**	**63.31**	**17.56**	**3.38**	**1.88**	**2.08**	**5.08**	**1.38**	**0.27**	**0.02**	**0.04**	**4.73**	**0.01**	**0.01**	**0.03**	**0.03**	**0.02**	**0.06**	**0.34**	**0.21**	**0.00**	**100.43**
	KMA/01	**Turquoise**	**19-01-2014**	**Std. Dev.**	**1.52**	**0.66**	**0.31**	**0.03**	**0.28**	**0.42**	**0.05**	**0.02**	**0.03**	**0.02**	**0.47**	**0.01**	**0.02**	**0.04**	**0.03**	**0.03**	**0.02**	**0.05**	**0.04**	**0.00**	
2	KMA/02	Turquoise	19-01-2014	I	62.02	18.07	3.64	1.95	2.23	5.28	1.31	0.23	0.02	0.05	5.04	0.01	0.00	0.00	0.04	0.05	0.01	0.23	0.13	0.00	100.29
	KMA/02	Turquoise	19-01-2014	II	59.92	18.29	3.95	1.81	2.26	5.97	1.48	0.26	0.00	0.06	5.31	0.03	0.01	0.00	0.05	0.00	0.05	0.35	0.20	0.00	99.98
	KMA/02	Turquoise	19-01-2014	III	63.24	17.80	3.12	2.03	1.93	5.71	1.59	0.27	0.00	0.01	4.57	0.01	0.00	0.03	0.01	0.00	0.02	0.32	0.20	0.00	100.85
	KMA/02	Turquoise	19-01-2014	IV	64.27	17.43	3.49	2.01	2.29	4.06	1.63	0.24	0.00	0.06	4.44	0.01	0.01	0.00	0.03	0.05	0.03	0.28	0.25	0.00	100.58
	KMA/02	Turquoise	19-01-2014	V	62.05	18.17	3.39	1.89	1.91	5.52	1.42	0.33	0.00	0.05	5.35	0.00	0.03	0.04	0.02	0.01	0.02	0.29	0.23	0.00	100.70
	KMA/02	Turquoise	19-01-2014	VI	62.84	17.60	3.44	1.96	2.33	5.41	1.43	0.27	0.05	0.03	4.31	0.00	0.00	0.00	0.03	0.06	0.06	0.30	0.31	0.00	100.42
	KMA/02	**Turquoise**	**19-01-2014**	**Average**	**62.39**	**17.89**	**3.50**	**1.94**	**2.16**	**5.32**	**1.48**	**0.27**	**0.01**	**0.04**	**4.84**	**0.01**	**0.01**	**0.01**	**0.03**	**0.03**	**0.03**	**0.30**	**0.22**	**0.00**	**100.47**
	KMA/02	**Turquoise**	**19-01-2014**	**Std. Dev.**	**1.47**	**0.34**	**0.27**	**0.08**	**0.19**	**0.66**	**0.12**	**0.03**	**0.02**	**0.02**	**0.46**	**0.01**	**0.01**	**0.02**	**0.01**	**0.03**	**0.02**	**0.04**	**0.06**	**0.00**	
3	KMA/03	Yellow	19-01-2014	I	56.67	15.24	1.82	1.54	1.24	6.52	1.65	0.31	0.00	0.03	0.00	0.00	1.82	12.62	0.04	0.14	0.00	0.11	0.00	0.00	99.76
	KMA/03	Yellow	19-01-2014	II	49.94	15.27	1.62	1.33	0.84	6.31	1.43	0.34	0.00	0.04	0.00	0.02	4.25	17.07	0.03	0.19	0.00	0.18	0.00	0.00	98.85
	KMA/03	Yellow	19-01-2014	III	49.42	15.54	1.38	1.29	0.81	6.24	1.65	0.33	0.00	0.03	0.15	0.00	3.33	19.75	0.01	0.20	0.00	0.10	0.00	0.00	100.22
	KMA/03	Yellow	19-01-2014	IV	49.21	15.27	2.11	1.30	1.14	5.86	1.49	0.32	0.00	0.04	0.01	0.00	1.70	17.04	0.04	0.25	0.00	0.11	0.00	0.00	95.89
	KMA/03	Yellow	19-01-2014	V	52.86	15.64	2.08	1.36	0.80	6.43	1.76	0.39	0.00	0.04	0.17	0.03	2.40	16.31	0.00	0.16	0.00	0.01	0.00	0.00	100.43
	KMA/03	Yellow	19-01-2014	VI	57.74	15.69	1.72	1.61	0.55	7.76	1.59	0.37	0.00	0.06	0.03	0.00	0.70	11.46	0.00	0.11	0.00	0.11	0.00	0.00	99.49
	KMA/03	**Yellow**	**19-01-2014**	**Average**	**52.64**	**15.44**	**1.79**	**1.40**	**0.90**	**6.52**	**1.59**	**0.34**	**0.00**	**0.04**	**0.06**	**0.01**	**2.37**	**15.71**	**0.02**	**0.17**	**0.00**	**0.10**	**0.00**	**0.00**	**99.11**
	KMA/03	**Yellow**	**19-01-2014**	**Std. Dev.**	**3.79**	**0.20**	**0.28**	**0.14**	**0.25**	**0.65**	**0.12**	**0.03**	**0.00**	**0.01**	**0.08**	**0.01**	**1.27**	**3.10**	**0.02**	**0.05**	**0.00**	**0.05**	**0.00**	**0.00**	
4	NK/01	Yellow	19-01-2014	I	62.73	16.17	1.83	1.96	1.53	9.48	2.72	0.37	0.00	0.03	0.00	0.04	0.00	3.71	0.06	0.07	0.03	0.24	0.12	0.00	101.06
	NK/01	Yellow	19-01-2014	II	65.92	18.03	1.21	1.87	0.58	8.38	2.61	0.40	0.00	0.04	0.08	0.00	0.00	0.89	0.06	0.05	0.02	0.12	0.17	0.00	100.42
	NK/01	Yellow	19-01-2014	III	58.93	16.18	1.27	1.78	0.80	7.51	2.29	0.41	0.00	0.04	0.01	0.01	0.46	5.18	0.02	0.24	0.03	0.12	0.20	0.00	95.47
	NK/01	Yellow	19-01-2014	IV	61.46	15.71	1.48	1.72	1.00	7.92	2.30	0.42	0.00	0.03	0.03	0.01	0.65	7.17	0.00	0.20	0.01	0.20	0.07	0.00	100.36
	NK/01	Yellow	19-01-2014	V	62.72	15.24	1.30	1.97	0.96	8.24	2.12	0.43	0.00	0.04	0.04	0.00	0.14	5.59	0.03	0.05	0.10	0.07	0.11	0.00	99.15
	NK/01	Yellow	19-01-2014	VI	60.05	13.74	1.60	1.94	1.26	8.91	2.47	0.42	0.00	0.06	0.00	0.01	0.47	7.39	0.01	0.20	0.00	0.18	0.00	0.00	98.70
	NK/01	**Yellow**	**19-01-2014**	**Average**	**61.97**	**15.84**	**1.45**	**1.87**	**1.02**	**8.41**	**2.42**	**0.41**	**0.00**	**0.04**	**0.03**	**0.01**	**0.29**	**4.99**	**0.03**	**0.13**	**0.03**	**0.16**	**0.11**	**0.00**	**99.20**
	NK/01	**Yellow**	**19-01-2014**	**Std. Dev.**	**2.45**	**1.40**	**0.24**	**0.10**	**0.34**	**0.70**	**0.22**	**0.02**	**0.00**	**0.01**	**0.03**	**0.01**	**0.28**	**2.42**	**0.02**	**0.09**	**0.04**	**0.06**	**0.07**	**0.00**	
5	NK/02	Yellow	19-01-2014	I	50.54	13.56	1.55	1.08	0.81	6.68	1.63	0.25	0.00	0.05	0.01	0.00	2.40	17.97	0.04	0.36	0.00	0.19	0.00	0.00	97.11
	NK/02	Yellow	19-01-2014	II	51.68	11.99	1.30	1.11	0.86	7.19	1.66	0.30	0.00	0.02	0.03	0.01	3.30	19.32	0.05	0.44	0.00	0.16	0.00	0.00	99.42
	NK/02	Yellow	19-01-2014	III	54.26	13.96	1.50	1.23	0.96	7.15	1.40	0.33	0.00	0.07	0.00	0.01	2.02	15.93	0.00	0.46	0.00	0.09	0.00	0.00	99.36
	NK/02	Yellow	19-01-2014	IV	54.78	13.21	1.46	1.25	0.81	7.63	1.53	0.32	0.02	0.02	0.00	0.02	1.80	16.46	0.05	0.26	0.00	0.18	0.00	0.00	99.80
	NK/02	Yellow	19-01-2014	V	50.95	13.63	1.35	1.12	0.94	7.13	1.39	0.34	0.00	0.04	0.01	0.02	2.97	18.27	0.01	0.58	0.00	0.14	0.00	0.00	98.89
	NK/02	Yellow	19-01-2014	VI	49.35	14.17	1.40	1.24	0.85	6.94	1.87	0.31	0.00	0.03	0.00	0.01	2.45	17.61	0.02	0.57	0.02	0.23	0.00	0.00	97.06
	NK/02	**Yellow**	**19-01-2014**	**Average**	**51.93**	**13.42**	**1.43**	**1.17**	**0.87**	**7.12**	**1.58**	**0.31**	**0.00**	**0.04**	**0.01**	**0.01**	**2.49**	**17.59**	**0.03**	**0.44**	**0.00**	**0.17**	**0.00**	**0.00**	**98.61**
	NK/02	**Yellow**	**19-01-2014**	**Std. Dev.**	**2.15**	**0.78**	**0.09**	**0.08**	**0.07**	**0.31**	**0.18**	**0.03**	**0.01**	**0.02**	**0.01**	**0.01**	**0.57**	**1.24**	**0.02**	**0.13**	**0.01**	**0.05**	**0.00**	**0.00**	
6	CR/01	Purple	04-03-2013	I	67.40	15.66	3.45	2.97	2.86	1.69	0.93	0.08	0.00	2.51	0.00	0.08	0.01	0.00	0.10	0.11	0.04	0.59	0.35	0.07	98.90
	CR/01	Purple	04-03-2013	II	71.06	15.83	3.10	3.01	2.41	1.43	0.72	0.03	0.03	1.71	0.07	0.06	0.00	0.14	0.06	0.17	0.04	0.43	0.26	0.07	100.62
	CR/01	Purple	04-03-2013	III	69.40	15.58	3.32	3.03	2.04	1.71	0.81	0.11	0.00	1.93	0.08	0.00	0.00	0.00	0.03	0.13	0.00	0.26	0.35	0.00	98.79
	CR/01	Purple	04-03-2013	IV	69.08	16.37	3.41	2.94	2.69	1.79	0.78	0.06	0.00	1.83	0.00	0.01	0.01	0.06	0.00	0.00	0.05	0.33	0.36	0.04	99.80

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	CR/01	Purple	04-03-2013	V	67.88	15.06	3.61	2.94	2.93	1.89	0.74	0.08	0.00	1.84	0.02	0.06	0.10	0.02	0.05	0.01	0.00	0.36	0.34	0.00	97.92
	CR/01	**Purple**	**04-03-2013**	**Average**	**68.97**	**15.70**	**3.38**	**2.98**	**2.59**	**1.70**	**0.80**	**0.07**	**0.01**	**1.96**	**0.03**	**0.04**	**0.03**	**0.04**	**0.05**	**0.08**	**0.03**	**0.40**	**0.33**	**0.03**	**99.21**
	CR/01	**Purple**	**04-03-2013**	**Std. Dev.**	**1.43**	**0.47**	**0.19**	**0.04**	**0.37**	**0.17**	**0.08**	**0.03**	**0.01**	**0.32**	**0.04**	**0.03**	**0.04**	**0.06**	**0.04**	**0.08**	**0.02**	**0.12**	**0.04**	**0.03**	
7	CR/02	Purple	04-03-2013	I	69.13	15.45	3.44	3.87	2.88	1.78	0.69	0.09	0.00	1.95	0.01	0.02	0.00	0.27	0.00	0.03	0.44	0.17	0.42	0.10	100.74
	CR/02	Purple	04-03-2013	II	67.57	15.46	3.57	3.89	2.83	1.88	0.64	0.12	0.00	1.98	0.09	0.04	0.02	0.00	0.04	0.10	0.37	0.37	0.39	0.06	99.39
	CR/02	Purple	04-03-2013	III	68.32	15.72	3.62	3.83	2.96	1.96	0.80	0.08	0.00	1.89	0.11	0.00	0.00	0.07	0.05	0.10	0.33	0.43	0.44	0.00	100.70
	CR/02	Purple	04-03-2013	IV	69.42	14.98	3.15	4.07	2.74	1.58	0.53	0.08	0.00	1.79	0.05	0.00	0.00	0.08	0.01	0.11	0.37	0.19	0.33	0.00	99.50
	CR/02	Purple	04-03-2013	V	67.73	15.52	3.58	3.85	2.69	1.80	0.70	0.09	0.09	2.03	0.01	0.00	0.00	0.00	0.00	0.00	0.41	0.33	0.41	0.00	99.27
	CR/02	**Purple**	**04-03-2013**	**Average**	**68.44**	**15.43**	**3.47**	**3.90**	**2.82**	**1.80**	**0.67**	**0.09**	**0.02**	**1.93**	**0.06**	**0.01**	**0.00**	**0.08**	**0.02**	**0.07**	**0.39**	**0.30**	**0.40**	**0.03**	**99.92**
	CR/02	**Purple**	**04-03-2013**	**Std. Dev.**	**0.82**	**0.27**	**0.19**	**0.10**	**0.11**	**0.14**	**0.10**	**0.02**	**0.04**	**0.09**	**0.05**	**0.02**	**0.01**	**0.11**	**0.02**	**0.05**	**0.04**	**0.11**	**0.04**	**0.05**	
8	CR/03	Yellow	05-03-2013	I	59.75	13.99	2.40	2.74	2.46	1.12	0.29	0.05	0.00	0.01	0.00	0.01	2.48	11.05	0.00	0.02	0.07	0.60	0.00	0.00	97.03
	CR/03	Yellow	05-03-2013	II	57.69	14.73	2.77	2.61	2.29	1.16	0.41	0.02	0.04	0.05	0.00	0.00	3.12	14.64	0.00	0.22	0.00	0.33	0.00	0.00	100.08
	CR/03	Yellow	05-03-2013	III	57.20	14.11	2.38	2.65	2.61	1.17	0.34	0.02	0.00	0.05	0.09	0.01	2.44	13.59	0.00	0.14	0.14	0.26	0.00	0.00	97.20
	CR/03	Yellow	05-03-2013	IV	56.56	15.11	2.71	2.54	2.61	1.34	0.44	0.05	0.00	0.01	0.01	0.01	1.60	12.17	0.06	0.05	0.01	0.22	0.00	0.00	95.49
	CR/03	Yellow	05-03-2013	V	61.32	13.41	2.89	2.79	2.69	1.26	0.35	0.05	0.00	0.02	0.06	0.04	0.30	10.15	0.02	0.12	0.00	0.61	0.01	0.04	96.10
	CR/03	**Yellow**	**05-03-2013**	**Average**	**58.50**	**14.27**	**2.63**	**2.67**	**2.53**	**1.21**	**0.37**	**0.04**	**0.01**	**0.03**	**0.03**	**0.01**	**1.99**	**12.32**	**0.01**	**0.11**	**0.04**	**0.40**	**0.00**	**0.01**	**97.18**
	CR/03	**Yellow**	**05-03-2013**	**Std. Dev.**	**1.98**	**0.67**	**0.23**	**0.10**	**0.16**	**0.09**	**0.06**	**0.02**	**0.02**	**0.02**	**0.04**	**0.01**	**1.09**	**1.83**	**0.02**	**0.08**	**0.06**	**0.19**	**0.00**	**0.02**	
9	CR/04	Yellow	05-03-2013	I	51.67	12.19	1.08	2.00	1.75	1.45	0.45	0.08	0.04	0.00	0.00	0.03	9.17	16.27	0.09	0.39	0.00	0.08	0.00	0.00	96.73
	CR/04	Yellow	05-03-2013	II	57.02	13.19	2.19	2.12	2.26	1.41	0.52	0.06	0.00	0.02	0.01	0.00	1.57	13.90	0.08	0.49	0.06	0.20	0.00	0.00	95.10
	CR/04	Yellow	05-03-2013	III	55.75	12.85	2.18	2.17	2.04	1.32	0.50	0.04	0.29	0.00	0.00	0.00	2.55	15.63	0.11	0.32	0.00	0.12	0.00	0.00	95.86
	CR/04	Yellow	05-03-2013	IV	56.17	11.74	2.38	2.52	2.28	3.20	0.76	0.11	0.00	0.06	0.18	0.09	0.94	12.76	0.10	0.21	0.05	0.49	0.00	0.13	94.15
	CR/04	Yellow	05-03-2013	V	56.16	10.62	2.42	2.14	2.27	1.25	0.33	0.04	0.00	0.09	0.18	0.05	0.58	12.74	0.01	0.25	0.07	0.33	0.00	0.00	89.51
	CR/04	**Yellow**	**05-03-2013**	**Average**	**55.35**	**12.12**	**2.05**	**2.19**	**2.12**	**1.73**	**0.51**	**0.06**	**0.07**	**0.03**	**0.08**	**0.03**	**2.96**	**14.26**	**0.08**	**0.33**	**0.04**	**0.24**	**0.00**	**0.03**	**94.27**
	CR/04	**Yellow**	**05-03-2013**	**Std. Dev.**	**2.11**	**1.01**	**0.56**	**0.20**	**0.23**	**0.83**	**0.16**	**0.03**	**0.12**	**0.04**	**0.10**	**0.04**	**3.55**	**1.63**	**0.04**	**0.11**	**0.03**	**0.17**	**0.00**	**0.06**	
10	CR/05	Green	16-12-2013	I	58.13	12.09	2.20	4.09	2.35	1.24	0.45	0.11	0.00	0.02	1.85	0.01	2.53	11.93	0.00	0.43	0.04	0.20	0.06	0.00	97.73
	CR/05	Green	16-12-2013	II	55.93	12.08	2.25	4.11	2.24	1.30	0.31	0.05	0.00	0.05	1.87	0.00	3.14	11.64	0.06	0.25	0.16	0.36	0.06	0.00	95.86
	CR/05	Green	16-12-2013	III	58.29	11.63	1.97	4.21	1.65	1.04	0.38	0.05	0.00	0.02	1.80	0.02	2.97	12.49	0.04	0.45	0.00	0.00	0.00	0.00	97.01
	CR/05	Green	16-12-2013	IV	58.29	10.85	2.40	4.17	2.08	1.28	0.47	0.03	0.00	0.01	1.85	0.01	2.21	12.21	0.02	0.24	0.00	0.15	0.00	0.00	96.27
	CR/05	**Green**	**16-12-2013**	**Average**	**57.66**	**11.66**	**2.21**	**4.14**	**2.08**	**1.22**	**0.40**	**0.06**	**0.00**	**0.02**	**1.84**	**0.01**	**2.71**	**12.07**	**0.03**	**0.34**	**0.05**	**0.18**	**0.03**	**0.00**	**96.72**
	CR/05	**Green**	**16-12-2013**	**Std. Dev.**	**1.16**	**0.58**	**0.18**	**0.06**	**0.31**	**0.12**	**0.07**	**0.03**	**0.00**	**0.02**	**0.03**	**0.01**	**0.42**	**0.37**	**0.03**	**0.11**	**0.07**	**0.15**	**0.03**	**0.00**	
11	CR/06	Green	16-12-2013	I	51.35	12.76	2.84	2.82	2.26	1.81	0.37	0.09	0.03	0.03	1.44	0.05	4.67	18.91	0.00	0.32	0.00	0.25	0.00	0.00	100.01
	CR/06	Green	16-12-2013	II	58.26	13.24	2.64	3.19	2.50	1.25	0.37	0.03	0.02	0.00	1.63	0.01	1.94	14.73	0.11	0.12	0.03	0.00	0.00	0.00	100.08
	CR/06	Green	16-12-2013	III	58.16	13.51	2.66	3.30	2.88	1.55	0.47	0.01	0.00	0.04	1.77	0.01	1.54	13.74	0.00	0.30	0.05	0.51	0.00	0.00	100.49
	CR/06	Green	16-12-2013	IV	56.19	13.03	2.19	3.17	2.08	1.39	0.44	0.07	0.00	0.04	1.66	0.00	3.76	15.70	0.00	0.24	0.00	0.27	0.00	0.00	100.22
	CR/06	**Green**	**16-12-2013**	**Average**	**55.99**	**13.14**	**2.58**	**3.12**	**2.43**	**1.50**	**0.41**	**0.05**	**0.01**	**0.03**	**1.62**	**0.02**	**2.98**	**15.77**	**0.03**	**0.25**	**0.02**	**0.26**	**0.00**	**0.00**	**100.20**
	CR/06	**Green**	**16-12-2013**	**Std. Dev.**	**3.23**	**0.32**	**0.28**	**0.21**	**0.35**	**0.24**	**0.05**	**0.04**	**0.01**	**0.02**	**0.14**	**0.02**	**1.49**	**2.24**	**0.05**	**0.09**	**0.02**	**0.21**	**0.00**	**0.00**	
12	CR/07	Green	16-12-2013	I	55.77	15.59	1.14	2.45	0.64	6.95	1.44	0.36	0.00	0.10	1.60	0.00	1.90	12.01	0.07	0.00	0.00	0.17	0.02	0.05	100.26
	CR/07	Green	16-12-2013	II	54.48	15.53	1.26	2.20	0.70	6.32	1.34	0.27	0.12	0.00	1.69	0.09	2.72	14.42	0.10	0.03	0.06	0.54	0.00	0.00	101.87
	CR/07	Green	16-12-2013	III	54.60	15.00	0.83	2.51	0.65	7.21	1.24	0.36	0.00	0.01	1.32	0.00	3.11	13.10	0.06	0.00	0.02	0.12	0.00	0.00	100.12
	CR/07	Green	16-12-2013	IV	56.98	15.48	1.30	2.52	0.63	7.06	1.47	0.31	0.00	0.02	1.53	0.00	1.67	11.49	0.00	0.10	0.07	0.26	0.12	0.00	101.00
	CR/07	**Green**	**16-12-2013**	**Average**	**55.46**	**15.40**	**1.13**	**2.42**	**0.65**	**6.89**	**1.37**	**0.32**	**0.03**	**0.03**	**1.54**	**0.02**	**2.35**	**12.76**	**0.06**	**0.03**	**0.04**	**0.27**	**0.04**	**0.01**	**100.81**
	CR/07	**Green**	**16-12-2013**	**Std. Dev.**	**1.17**	**0.27**	**0.21**	**0.15**	**0.03**	**0.39**	**0.10**	**0.04**	**0.06**	**0.04**	**0.16**	**0.05**	**0.68**	**1.30**	**0.04**	**0.05**	**0.03**	**0.19**	**0.06**	**0.02**	
13	CR/08	Dark-Blue	04-03-2013	I	70.86	12.46	3.16	2.76	2.72	1.50	0.97	0.06	0.07	0.00	0.02	0.63	0.00	0.10	0.09	0.00	0.00	0.84	0.25	0.60	97.06
	CR/08	Dark-Blue	04-03-2013	II	67.42	14.40	3.02	3.16	2.99	1.98	2.09	0.05	0.00	0.91	0.49	0.64	0.00	0.11	0.00	0.03	0.00	0.56	0.29	0.51	98.65
	CR/08	Dark-Blue	04-03-2013	III	70.09	14.65	3.23	3.10	2.67	1.65	1.40	0.07	0.06	0.08	0.15	0.43	0.00	0.20	0.07	0.02	0.00	0.29	0.29	0.40	98.85
	CR/08	Dark-Blue	04-03-2013	IV	67.78	13.10	4.07	3.55	3.10	3.59	1.96	0.08	0.00	0.03	0.12	0.34	0.00	0.12	0.01	0.00	0.02	0.36	0.55	0.50	99.26

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	CR/08	Dark-Blue	04-03-2013	V	69.52	13.03	2.69	3.16	2.62	1.88	1.18	0.11	0.00	0.03	0.11	0.41	0.00	0.00	0.08	0.04	0.06	0.54	0.36	0.36	96.16
	CR/08	**Dark-Blue**	**04-03-2013**	**Average**	**69.13**	**13.53**	**3.23**	**3.15**	**2.82**	**2.12**	**1.52**	**0.07**	**0.02**	**0.21**	**0.18**	**0.49**	**0.00**	**0.11**	**0.05**	**0.02**	**0.02**	**0.52**	**0.35**	**0.47**	**98.00**
	CR/08	**Dark-Blue**	**04-03-2013**	**Std. Dev.**	**1.48**	**0.95**	**0.51**	**0.28**	**0.21**	**0.84**	**0.49**	**0.02**	**0.03**	**0.39**	**0.18**	**0.14**	**0.00**	**0.07**	**0.04**	**0.02**	**0.02**	**0.21**	**0.12**	**0.10**	
14	CR/09	Dark-Blue	04-03-2013	I	70.50	13.90	3.40	3.32	2.89	1.87	1.19	0.07	0.00	0.08	0.11	0.39	0.00	0.17	0.13	0.02	0.02	0.65	0.32	0.27	99.29
	CR/09	Dark-Blue	04-03-2013	II	71.36	11.85	2.59	2.96	2.22	1.64	1.23	0.03	0.00	0.06	0.24	0.40	0.07	0.00	0.07	0.05	0.00	0.24	0.36	0.36	95.72
	CR/09	Dark-Blue	04-03-2013	III	73.11	12.79	3.05	3.30	2.74	1.43	1.39	0.07	0.00	0.00	0.24	0.53	0.00	0.09	0.06	0.00	0.03	0.66	0.22	0.22	99.90
	CR/09	Dark-Blue	04-03-2013	IV	70.01	15.36	3.26	2.99	2.70	1.34	1.30	0.04	0.12	0.05	0.12	0.54	0.00	0.08	0.00	0.00	0.05	0.19	0.33	0.50	98.96
	CR/09	Dark-Blue	04-03-2013	V	69.65	15.15	3.17	3.06	2.76	1.48	1.24	0.02	0.09	0.09	0.36	0.58	0.00	0.05	0.12	0.03	0.01	0.55	0.30	0.21	98.91
	CR/09	**Dark-Blue**	**04-03-2013**	**Average**	**70.92**	**13.81**	**3.09**	**3.12**	**2.66**	**1.55**	**1.27**	**0.04**	**0.04**	**0.06**	**0.21**	**0.49**	**0.01**	**0.08**	**0.07**	**0.02**	**0.02**	**0.46**	**0.30**	**0.31**	**98.56**
	CR/09	**Dark-Blue**	**04-03-2013**	**Std. Dev.**	**1.38**	**1.51**	**0.31**	**0.17**	**0.26**	**0.21**	**0.08**	**0.02**	**0.06**	**0.03**	**0.10**	**0.09**	**0.03**	**0.06**	**0.05**	**0.02**	**0.02**	**0.23**	**0.05**	**0.12**	
15	CR/10	Dark-Blue	04-03-2013	I	69.91	15.12	3.43	3.51	2.90	1.64	1.28	0.11	0.00	0.02	0.00	0.35	0.00	0.12	0.00	0.00	0.00	0.51	0.29	0.13	99.33
	CR/10	Dark-Blue	04-03-2013	II	70.18	14.17	3.37	3.55	2.74	1.53	1.36	0.01	0.00	0.07	0.00	0.41	0.00	0.00	0.13	0.01	0.00	0.48	0.32	0.17	98.48
	CR/10	Dark-Blue	04-03-2013	III	68.94	14.51	3.23	3.69	2.44	1.92	1.41	0.14	0.07	0.03	0.04	0.45	0.00	0.00	0.12	0.04	0.00	0.15	0.39	0.47	98.01
	CR/10	Dark-Blue	04-03-2013	IV	70.23	14.52	3.13	3.81	2.77	1.58	1.51	0.08	0.00	0.06	0.16	0.55	0.00	0.00	0.05	0.00	0.00	0.49	0.20	0.36	99.51
	CR/10	Dark-Blue	04-03-2013	V	71.13	14.65	3.06	3.64	2.73	1.44	1.07	0.06	0.00	0.00	0.12	0.41	0.00	0.01	0.00	0.10	0.00	0.37	0.31	0.31	99.39
	CR/10	**Dark-Blue**	**04-03-2013**	**Average**	**70.08**	**14.59**	**3.24**	**3.64**	**2.72**	**1.62**	**1.33**	**0.08**	**0.01**	**0.03**	**0.06**	**0.43**	**0.00**	**0.03**	**0.06**	**0.03**	**0.00**	**0.40**	**0.30**	**0.29**	**98.94**
	CR/10	**Dark-Blue**	**04-03-2013**	**Std. Dev.**	**0.78**	**0.35**	**0.16**	**0.12**	**0.17**	**0.18**	**0.16**	**0.05**	**0.03**	**0.03**	**0.07**	**0.07**	**0.00**	**0.05**	**0.06**	**0.04**	**0.00**	**0.15**	**0.07**	**0.14**	
16	CR/11	Dark-Blue	04-03-2013	I	69.88	14.39	2.85	3.04	2.40	1.65	3.05	0.18	0.00	0.00	0.06	0.42	0.00	0.18	0.00	0.00	0.00	0.46	0.20	0.38	99.13
	CR/11	Dark-Blue	04-03-2013	II	69.72	14.41	3.12	3.02	2.43	1.79	1.33	0.07	0.00	0.03	0.12	0.26	0.00	0.06	0.00	0.04	0.09	0.61	0.27	0.42	97.76
	CR/11	Dark-Blue	04-03-2013	III	70.35	13.77	3.20	3.20	2.45	2.02	1.20	0.06	0.00	0.00	0.19	0.39	0.06	0.05	0.04	0.00	0.00	0.31	0.24	0.42	97.94
	CR/11	Dark-Blue	04-03-2013	IV	69.22	14.00	3.29	2.80	2.67	2.02	1.25	0.06	0.01	0.03	0.21	0.27	0.01	0.14	0.03	0.00	0.00	0.23	0.24	0.25	96.73
	CR/11	**Dark-Blue**	**04-03-2013**	**Average**	**69.79**	**14.14**	**3.11**	**3.01**	**2.49**	**1.87**	**1.71**	**0.09**	**0.00**	**0.01**	**0.14**	**0.34**	**0.02**	**0.11**	**0.02**	**0.01**	**0.02**	**0.40**	**0.24**	**0.39**	**97.91**
	CR/11	**Dark-Blue**	**04-03-2013**	**Std. Dev.**	**0.47**	**0.31**	**0.19**	**0.16**	**0.12**	**0.18**	**0.90**	**0.06**	**0.01**	**0.02**	**0.07**	**0.08**	**0.03**	**0.06**	**0.02**	**0.02**	**0.04**	**0.17**	**0.03**	**0.08**	
17	CR/12	Dark-Blue	05-03-2013	I	71.38	13.89	3.15	3.48	2.90	1.45	1.30	0.10	0.00	0.03	0.21	0.20	0.00	0.00	0.04	0.00	0.03	0.34	0.41	0.08	99.00
	CR/12	Dark-Blue	05-03-2013	II	70.41	13.82	3.36	3.64	2.76	1.51	1.10	0.06	0.00	0.05	0.09	0.32	0.00	0.02	0.03	0.03	0.00	0.57	0.46	0.09	98.32
	CR/12	Dark-Blue	05-03-2013	III	70.72	14.70	3.38	3.00	2.78	1.72	1.04	0.12	0.05	0.04	0.14	0.27	0.00	0.13	0.04	0.00	0.02	0.31	0.37	0.19	99.00
	CR/12	Dark-Blue	05-03-2013	IV	72.68	13.84	2.98	3.61	2.71	1.85	1.34	0.06	0.00	0.08	0.06	0.50	0.00	0.00	0.06	0.00	0.00	0.40	0.22	0.24	100.62
	CR/12	Dark-Blue	05-03-2013	V	72.18	13.96	3.07	3.64	2.51	1.39	1.09	0.02	0.00	0.01	0.00	0.80	0.00	0.24	0.01	0.03	0.01	0.00	0.23	0.38	99.56
	CR/12	**Dark-Blue**	**05-03-2013**	**Average**	**71.47**	**14.04**	**3.19**	**3.47**	**2.73**	**1.58**	**1.17**	**0.07**	**0.01**	**0.04**	**0.10**	**0.42**	**0.00**	**0.08**	**0.04**	**0.01**	**0.01**	**0.33**	**0.34**	**0.20**	**99.30**
	CR/12	**Dark-Blue**	**05-03-2013**	**Std. Dev.**	**0.96**	**0.37**	**0.18**	**0.27**	**0.14**	**0.19**	**0.14**	**0.04**	**0.02**	**0.02**	**0.08**	**0.24**	**0.00**	**0.11**	**0.02**	**0.02**	**0.01**	**0.21**	**0.11**	**0.12**	
18	CR/13	Turquoise	29-01-2014	I	71.92	13.69	2.88	3.39	2.03	1.53	0.56	0.04	0.00	0.02	3.76	0.00	0.00	0.00	0.00	0.00	0.11	0.37	0.02	0.40	100.71
	CR/13	Turquoise	29-01-2014	II	72.59	13.92	2.79	3.04	2.03	1.65	0.73	0.05	0.06	0.01	4.00	0.00	0.02	0.00	0.08	0.00	0.02	0.00	0.00	0.24	101.21
	CR/13	Turquoise	29-01-2014	III	71.41	14.72	2.85	3.37	2.07	1.82	0.74	0.03	0.00	0.00	3.73	0.04	0.00	0.05	0.01	0.11	0.00	0.14	0.00	0.41	101.48
	CR/13	Turquoise	29-01-2014	IV	70.96	15.06	3.03	3.33	2.04	1.72	0.67	0.09	0.00	0.07	3.68	0.00	0.00	0.00	0.00	0.00	0.01	0.41	0.00	0.32	101.38
	CR/13	Turquoise	29-01-2014	V	72.35	14.09	2.92	3.19	2.09	1.39	0.59	0.07	0.00	0.06	4.01	0.05	0.00	0.08	0.00	0.02	0.02	0.24	0.00	0.35	101.50
	CR/13	Turquoise	29-01-2014	VI	71.39	14.56	2.89	3.31	2.11	1.56	0.55	0.03	0.03	0.00	3.18	0.00	0.02	0.03	0.05	0.13	0.00	0.34	0.00	0.28	100.44
	CR/13	**Turquoise**	**29-01-2014**	**Average**	**71.77**	**14.34**	**2.89**	**3.27**	**2.06**	**1.61**	**0.64**	**0.05**	**0.01**	**0.03**	**3.73**	**0.02**	**0.01**	**0.03**	**0.02**	**0.04**	**0.02**	**0.25**	**0.00**	**0.33**	**101.12**
	CR/13	**Turquoise**	**29-01-2014**	**Std. Dev.**	**0.63**	**0.52**	**0.08**	**0.13**	**0.04**	**0.15**	**0.08**	**0.02**	**0.02**	**0.03**	**0.30**	**0.02**	**0.01**	**0.03**	**0.03**	**0.06**	**0.04**	**0.16**	**0.01**	**0.07**	
19	CR/14	Turquoise	29-01-2014	I	62.39	17.67	1.71	2.70	0.88	8.46	1.82	0.37	0.02	0.02	4.06	0.00	0.00	0.04	0.01	0.00	0.07	0.18	0.23	0.00	100.63
	CR/14	Turquoise	29-01-2014	II	63.46	17.18	1.55	2.71	0.90	8.48	1.73	0.38	0.03	0.03	3.57	0.00	0.01	0.00	0.00	0.11	0.06	0.26	0.22	0.00	100.67
	CR/14	Turquoise	29-01-2014	III	61.87	18.17	1.74	2.59	0.87	8.64	2.22	0.42	0.00	0.04	3.82	0.02	0.00	0.01	0.04	0.00	0.03	0.20	0.31	0.00	100.97
	CR/14	Turquoise	29-01-2014	IV	62.51	18.00	1.77	2.58	0.49	8.13	1.77	0.38	0.02	0.02	4.12	0.00	0.00	0.11	0.00	0.00	0.02	0.18	0.21	0.00	100.30
	CR/14	Turquoise	29-01-2014	V	63.45	17.51	1.72	2.61	0.82	8.36	1.91	0.41	0.00	0.03	3.58	0.02	0.00	0.03	0.01	0.00	0.08	0.10	0.24	0.00	100.88
	CR/14	Turquoise	29-01-2014	VI	64.06	17.06	1.65	2.59	0.81	8.21	1.73	0.38	0.02	0.04	3.73	0.00	0.00	0.08	0.03	0.09	0.07	0.14	0.26	0.00	100.94
	CR/14	**Turquoise**	**29-01-2014**	**Average**	**62.96**	**17.60**	**1.69**	**2.63**	**0.79**	**8.38**	**1.86**	**0.39**	**0.02**	**0.03**	**3.81**	**0.01**	**0.00**	**0.05**	**0.01**	**0.03**	**0.05**	**0.18**	**0.24**	**0.00**	**100.73**
	CR/14	**Turquoise**	**29-01-2014**	**Std. Dev.**	**0.83**	**0.44**	**0.08**	**0.06**	**0.15**	**0.19**	**0.19**	**0.02**	**0.01**	**0.01**	**0.23**	**0.01**	**0.01**	**0.04**	**0.02**	**0.05**	**0.03**	**0.06**	**0.03**	**0.00**	

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
20	CR/15	Turquoise	29-01-2014	I	66.38	16.60	3.39	3.31	3.22	1.49	0.56	0.05	0.00	0.07	3.98	0.00	0.01	0.15	0.02	0.01	0.07	0.28	0.25	0.00	99.84
	CR/15	Turquoise	29-01-2014	II	66.60	16.29	3.28	3.33	3.09	1.30	0.41	0.08	0.00	0.04	3.44	0.00	0.00	0.24	0.01	0.00	0.02	0.41	0.24	0.00	98.76
	CR/15	Turquoise	29-01-2014	III	67.23	16.42	3.08	3.13	2.90	1.38	0.55	0.04	0.00	0.03	3.77	0.00	0.06	0.13	0.04	0.00	0.07	0.44	0.24	0.00	99.52
	CR/15	Turquoise	29-01-2014	IV	68.54	15.94	2.95	3.43	2.94	1.44	0.51	0.07	0.00	0.00	3.36	0.01	0.00	0.16	0.05	0.00	0.03	0.42	0.37	0.00	100.21
	CR/15	Turquoise	29-01-2014	V	67.16	16.27	3.19	3.38	3.12	1.54	0.64	0.05	0.00	0.04	3.65	0.00	0.00	0.12	0.00	0.00	0.03	0.42	0.26	0.00	99.89
	CR/15	Turquoise	29-01-2014	VI	68.23	15.86	2.99	3.43	3.00	1.45	0.49	0.04	0.03	0.05	3.35	0.01	0.02	0.10	0.00	0.00	0.04	0.40	0.30	0.00	99.78
	CR/15	**Turquoise**	**29-01-2014**	**Average**	**67.36**	**16.23**	**3.15**	**3.33**	**3.05**	**1.43**	**0.53**	**0.05**	**0.00**	**0.04**	**3.59**	**0.00**	**0.02**	**0.15**	**0.02**	**0.00**	**0.04**	**0.39**	**0.28**	**0.00**	**99.67**
	CR/15	**Turquoise**	**29-01-2014**	**Std. Dev.**	**0.86**	**0.28**	**0.17**	**0.11**	**0.12**	**0.09**	**0.08**	**0.01**	**0.01**	**0.02**	**0.26**	**0.00**	**0.02**	**0.05**	**0.02**	**0.00**	**0.02**	**0.06**	**0.05**	**0.00**	
21	CR/16	White	05-03-2013	I	68.48	15.85	3.41	3.01	2.66	3.05	0.45	0.11	0.00	0.04	0.06	0.00	0.00	0.11	0.00	0.05	0.00	0.65	0.27	0.00	98.19
	CR/16	White	05-03-2013	II	68.89	17.55	3.91	2.84	3.09	1.22	0.49	0.08	0.00	0.05	0.03	0.00	0.01	0.22	0.02	0.00	0.03	0.44	0.39	0.00	99.24
	CR/16	White	05-03-2013	III	67.01	17.94	3.88	2.82	3.39	1.34	0.45	0.04	0.07	0.07	0.00	0.00	0.06	0.00	0.02	0.00	0.00	0.39	0.18	0.00	97.66
	CR/16	White	05-03-2013	IV	69.03	17.23	3.67	2.87	3.36	1.69	0.52	0.06	0.09	0.05	0.08	0.00	0.04	0.00	0.08	0.00	0.01	0.20	0.25	0.00	99.22
	CR/16	White	05-03-2013	V	68.40	17.59	4.09	2.76	3.34	1.36	0.56	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.07	0.25	0.25	0.00	98.75
	CR/16	**White**	**05-03-2013**	**Average**	**68.36**	**17.23**	**3.79**	**2.86**	**3.17**	**1.73**	**0.49**	**0.07**	**0.03**	**0.04**	**0.03**	**0.00**	**0.02**	**0.07**	**0.03**	**0.01**	**0.02**	**0.38**	**0.27**	**0.00**	**98.61**
	CR/16	**White**	**05-03-2013**	**Std. Dev.**	**0.80**	**0.81**	**0.26**	**0.09**	**0.31**	**0.76**	**0.05**	**0.02**	**0.05**	**0.03**	**0.04**	**0.00**	**0.03**	**0.10**	**0.03**	**0.02**	**0.03**	**0.18**	**0.08**	**0.00**	
22	CR/17	White	17-12-2013	I	70.90	15.32	3.20	3.88	2.80	1.80	0.74	0.04	0.01	0.05	0.01	0.00	0.03	0.18	0.05	0.00	0.01	0.25	0.52	0.00	99.78
	CR/17	White	17-12-2013	II	72.14	15.41	3.49	3.32	2.62	1.69	0.44	0.03	0.15	0.03	0.00	0.00	0.00	0.00	0.04	0.02	0.00	0.13	0.49	0.00	100.00
	CR/17	White	17-12-2013	III	69.49	14.15	3.07	3.56	2.37	1.68	0.40	0.04	0.00	0.08	0.01	0.00	0.00	0.00	0.02	0.05	0.03	0.36	0.44	0.00	95.76
	CR/17	White	17-12-2013	IV	71.41	15.56	3.34	3.78	2.80	1.87	0.57	0.05	0.09	0.00	0.00	0.04	0.02	0.00	0.09	0.00	0.03	0.78	0.43	0.08	100.93
	CR/17	**White**	**17-12-2013**	**Average**	**70.99**	**15.11**	**3.27**	**3.64**	**2.65**	**1.76**	**0.54**	**0.04**	**0.06**	**0.04**	**0.00**	**0.01**	**0.01**	**0.05**	**0.05**	**0.02**	**0.02**	**0.38**	**0.47**	**0.02**	**99.12**
	CR/17	**White**	**17-12-2013**	**Std. Dev.**	**1.12**	**0.65**	**0.18**	**0.25**	**0.20**	**0.09**	**0.15**	**0.01**	**0.07**	**0.03**	**0.01**	**0.02**	**0.02**	**0.09**	**0.03**	**0.02**	**0.02**	**0.28**	**0.04**	**0.04**	
23	CR/18	Dark-Blue	17-12-2013	I	68.64	16.05	3.61	3.47	2.54	1.84	1.46	0.01	0.00	0.02	0.00	0.44	0.00	0.08	0.11	0.02	0.08	0.43	0.31	0.54	99.63
	CR/18	Dark-Blue	17-12-2013	II	70.16	15.19	3.22	3.61	2.03	1.56	1.58	0.06	0.00	0.06	0.08	0.43	0.00	0.00	0.03	0.04	0.00	0.35	0.51	0.42	99.32
	CR/18	Dark-Blue	17-12-2013	III	72.00	13.96	3.28	3.96	2.35	1.56	1.53	0.04	0.00	0.04	0.06	0.41	0.00	0.00	0.01	0.00	0.06	0.46	0.39	0.38	100.49
	CR/18	Dark-Blue	17-12-2013	IV	71.57	15.00	3.53	3.59	2.13	1.49	1.67	0.02	0.02	0.04	0.08	0.53	0.00	0.01	0.14	0.03	0.00	0.50	0.58	0.36	101.28
	CR/18	**Dark-Blue**	**17-12-2013**	**Average**	**70.59**	**15.05**	**3.41**	**3.66**	**2.26**	**1.61**	**1.56**	**0.03**	**0.00**	**0.04**	**0.06**	**0.45**	**0.00**	**0.02**	**0.07**	**0.02**	**0.03**	**0.43**	**0.45**	**0.42**	**100.18**
	CR/18	**Dark-Blue**	**17-12-2013**	**Std. Dev.**	**1.52**	**0.85**	**0.19**	**0.21**	**0.23**	**0.16**	**0.09**	**0.02**	**0.01**	**0.01**	**0.04**	**0.05**	**0.00**	**0.04**	**0.06**	**0.02**	**0.04**	**0.06**	**0.12**	**0.08**	
24	CR/19	Turquoise	17-12-2013	I	68.16	16.66	3.39	3.95	2.50	1.84	0.59	0.04	0.00	0.00	3.12	0.02	0.00	0.00	0.00	0.00	0.00	0.37	0.45	0.01	101.08
	CR/19	Turquoise	17-12-2013	II	69.09	16.14	3.73	3.90	2.30	1.74	0.61	0.01	0.00	0.03	2.26	0.04	0.00	0.05	0.05	0.01	0.00	0.00	0.41	0.00	100.36
	CR/19	Turquoise	17-12-2013	III	68.42	16.43	3.48	3.87	2.34	1.54	0.54	0.06	0.00	0.03	2.88	0.00	0.00	0.02	0.00	0.00	0.06	0.30	0.44	0.05	100.45
	CR/19	Turquoise	17-12-2013	IV	68.08	16.62	3.72	3.75	2.24	1.75	0.51	0.09	0.08	0.07	3.21	0.01	0.00	0.00	0.06	0.03	0.03	0.25	0.40	0.00	100.90
	CR/19	**Turquoise**	**17-12-2013**	**Average**	**68.44**	**16.46**	**3.58**	**3.86**	**2.35**	**1.72**	**0.56**	**0.05**	**0.02**	**0.03**	**2.87**	**0.02**	**0.00**	**0.02**	**0.03**	**0.01**	**0.02**	**0.23**	**0.43**	**0.01**	**100.70**
	CR/19	**Turquoise**	**17-12-2013**	**Std. Dev.**	**0.46**	**0.24**	**0.17**	**0.08**	**0.11**	**0.12**	**0.04**	**0.03**	**0.04**	**0.03**	**0.43**	**0.02**	**0.00**	**0.02**	**0.03**	**0.01**	**0.03**	**0.16**	**0.02**	**0.02**	
25	CR/20	Turquoise	17-12-2013	I	67.07	14.10	2.56	3.84	1.67	1.27	0.54	0.10	0.05	0.04	2.05	0.02	0.06	0.00	0.00	0.07	0.02	0.23	0.35	0.08	94.10
	CR/20	Turquoise	17-12-2013	II	68.87	16.18	2.71	4.44	2.08	1.78	0.78	0.07	0.01	0.04	2.37	0.00	0.04	0.00	0.04	0.00	0.00	0.28	0.25	0.09	100.03
	CR/20	Turquoise	17-12-2013	III	70.15	16.07	2.98	4.30	2.20	1.87	0.63	0.06	0.00	0.00	2.82	0.02	0.05	0.14	0.03	0.09	0.01	0.25	0.37	0.00	102.02
	CR/20	Turquoise	17-12-2013	IV	69.43	16.22	2.64	4.22	1.82	1.98	0.56	0.06	0.09	0.08	2.40	0.01	0.00	0.06	0.06	0.00	0.00	0.34	0.28	0.00	100.24
	CR/20	**Turquoise**	**17-12-2013**	**Average**	**68.88**	**15.64**	**2.72**	**4.20**	**1.94**	**1.73**	**0.63**	**0.07**	**0.04**	**0.04**	**2.41**	**0.01**	**0.04**	**0.05**	**0.03**	**0.04**	**0.01**	**0.27**	**0.31**	**0.04**	**99.10**
	CR/20	**Turquoise**	**17-12-2013**	**Std. Dev.**	**1.31**	**1.03**	**0.19**	**0.26**	**0.24**	**0.31**	**0.11**	**0.02**	**0.04**	**0.03**	**0.32**	**0.01**	**0.03**	**0.06**	**0.02**	**0.05**	**0.01**	**0.05**	**0.06**	**0.05**	

Appendix 7.19 Chemical compositions of the tile glazes from Mughal buildings at Punjab determined through EPMA-WDS analyses. All results are in wt%.

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
1	DS/01	Yellow	13-12-2013	I	57.26	14.25	3.07	3.02	2.78	2.57	0.70	0.01	0.10	0.09	0.00	0.00	2.05	12.50	0.00	0.00	0.02	0.45	0.00	0.00	98.86
	DS/01	Yellow	13-12-2013	II	63.01	12.90	3.27	2.80	2.45	1.86	0.57	0.07	0.00	0.03	0.19	0.02	1.89	10.80	0.02	0.10	0.00	0.04	0.13	0.02	100.18
	DS/01	Yellow	13-12-2013	III	59.10	14.18	3.29	2.84	2.48	1.85	0.53	0.05	0.01	0.01	0.00	0.01	2.57	11.56	0.00	0.12	0.00	0.53	0.03	0.00	99.17
	DS/01	Yellow	13-12-2013	IV	58.12	14.04	2.50	3.10	2.15	4.89	0.73	0.10	0.10	0.00	0.00	0.04	2.39	11.83	0.07	0.00	0.00	0.61	0.00	0.00	100.68
	DS/01	**Yellow**	**13-12-2013**	**Average**	**59.37**	**13.84**	**3.03**	**2.94**	**2.47**	**2.79**	**0.63**	**0.06**	**0.05**	**0.03**	**0.05**	**0.02**	**2.23**	**11.67**	**0.02**	**0.06**	**0.00**	**0.41**	**0.04**	**0.01**	**99.72**
	DS/01	**Yellow**	**13-12-2013**	**Std. Dev.**	**2.54**	**0.63**	**0.37**	**0.14**	**0.26**	**1.44**	**0.10**	**0.04**	**0.06**	**0.04**	**0.09**	**0.02**	**0.31**	**0.70**	**0.03**	**0.07**	**0.01**	**0.25**	**0.06**	**0.01**	
2	DS/02	Turquoise	13-12-2013	I	65.31	16.50	4.29	3.23	3.31	2.40	0.89	0.09	0.00	0.07	1.93	0.00	0.00	0.07	0.00	0.00	0.06	0.50	0.34	0.00	98.98
	DS/02	Turquoise	13-12-2013	II	64.03	17.05	4.55	3.11	2.88	2.58	0.81	0.08	0.00	0.02	3.44	0.07	0.03	0.18	0.08	0.00	0.04	0.38	0.17	0.00	99.48
	DS/02	Turquoise	13-12-2013	III	62.27	16.92	5.02	2.95	3.04	2.59	0.81	0.12	0.06	0.03	3.37	0.03	0.03	0.18	0.02	0.00	0.00	0.26	0.28	0.00	97.96
	DS/02	Turquoise	13-12-2013	IV	63.72	16.86	4.35	3.03	3.41	2.37	0.75	0.17	0.00	0.08	2.79	0.00	0.00	0.15	0.00	0.24	0.06	0.48	0.37	0.00	98.83
	DS/02	**Turquoise**	**13-12-2013**	**Average**	**63.83**	**16.83**	**4.55**	**3.08**	**3.16**	**2.48**	**0.81**	**0.11**	**0.02**	**0.05**	**2.88**	**0.03**	**0.01**	**0.14**	**0.02**	**0.06**	**0.04**	**0.40**	**0.29**	**0.00**	**98.81**
	DS/02	**Turquoise**	**13-12-2013**	**Std. Dev.**	**1.25**	**0.23**	**0.33**	**0.12**	**0.25**	**0.12**	**0.05**	**0.04**	**0.03**	**0.03**	**0.70**	**0.03**	**0.02**	**0.05**	**0.04**	**0.12**	**0.03**	**0.11**	**0.09**	**0.00**	
3	DS/03	Yellow	13-12-2013	I	56.87	16.23	3.78	2.57	2.46	2.77	0.69	0.10	0.00	0.03	0.01	0.01	1.22	10.77	0.03	0.00	0.04	0.00	0.20	0.05	97.82
	DS/03	Yellow	13-12-2013	II	54.05	16.41	4.02	2.52	2.61	2.43	0.56	0.10	0.00	0.01	0.02	0.00	2.45	12.56	0.00	0.00	0.09	0.40	0.01	0.00	98.24
	DS/03	Yellow	13-12-2013	III	56.20	15.69	2.96	2.72	2.54	2.81	0.71	0.11	0.00	0.06	0.03	0.02	2.99	12.14	0.03	0.12	0.00	0.33	0.01	0.00	99.46
	DS/03	Yellow	13-12-2013	IV	59.52	16.85	2.80	2.91	2.97	3.07	0.92	0.07	0.06	0.03	0.00	0.02	0.77	9.23	0.00	0.00	0.02	0.14	0.00	0.00	99.39
	DS/03	**Yellow**	**13-12-2013**	**Average**	**56.66**	**16.29**	**3.39**	**2.68**	**2.64**	**2.77**	**0.72**	**0.09**	**0.01**	**0.03**	**0.02**	**0.01**	**1.86**	**11.17**	**0.01**	**0.03**	**0.04**	**0.22**	**0.05**	**0.01**	**98.73**
	DS/03	**Yellow**	**13-12-2013**	**Std. Dev.**	**2.26**	**0.48**	**0.60**	**0.17**	**0.23**	**0.26**	**0.15**	**0.02**	**0.03**	**0.02**	**0.01**	**0.01**	**1.04**	**1.51**	**0.02**	**0.06**	**0.04**	**0.18**	**0.10**	**0.03**	
4	DS/04	Turquoise	13-12-2013	I	62.99	17.15	3.71	3.64	2.92	2.78	0.97	0.13	0.09	0.04	3.05	0.03	0.02	0.27	0.06	0.00	0.04	0.23	0.24	0.00	98.34
	DS/04	Turquoise	13-12-2013	II	61.02	17.47	3.97	3.29	3.40	3.17	0.76	0.14	0.00	0.04	3.45	0.05	0.02	0.10	0.00	0.13	0.04	0.24	0.23	0.00	97.51
	DS/04	Turquoise	13-12-2013	III	62.09	17.15	4.06	3.69	3.36	2.78	0.94	0.15	0.08	0.12	3.49	0.02	0.06	0.24	0.00	0.00	0.00	0.36	0.26	0.01	98.87
	DS/04	Turquoise	13-12-2013	IV	62.71	17.49	4.00	3.67	3.46	2.97	0.76	0.15	0.00	0.04	3.00	0.05	0.00	0.40	0.00	0.04	0.01	0.47	0.31	0.00	99.52
	DS/04	**Turquoise**	**13-12-2013**	**Average**	**62.20**	**17.31**	**3.93**	**3.57**	**3.28**	**2.93**	**0.86**	**0.14**	**0.04**	**0.06**	**3.24**	**0.03**	**0.03**	**0.25**	**0.02**	**0.04**	**0.02**	**0.32**	**0.26**	**0.00**	**98.56**
	DS/04	**Turquoise**	**13-12-2013**	**Std. Dev.**	**0.87**	**0.19**	**0.16**	**0.19**	**0.25**	**0.19**	**0.12**	**0.01**	**0.05**	**0.04**	**0.26**	**0.01**	**0.03**	**0.12**	**0.03**	**0.06**	**0.02**	**0.11**	**0.04**	**0.00**	
5	DS/05	Yellow	16-12-2013	I	56.34	16.46	3.91	2.51	2.41	2.85	0.77	0.12	0.05	0.00	0.00	0.00	1.69	10.13	0.07	0.00	0.05	0.23	0.10	0.00	97.70
	DS/05	Yellow	16-12-2013	II	49.82	14.97	3.05	2.48	2.28	2.59	0.72	0.05	0.00	0.03	0.04	0.07	4.16	14.78	0.13	0.00	0.07	0.30	0.00	0.00	95.51
	DS/05	Yellow	16-12-2013	III	58.47	15.08	2.97	2.31	2.57	2.25	0.65	0.12	0.09	0.05	0.08	0.00	1.48	12.12	0.01	0.00	0.03	0.63	0.00	0.00	98.90
	DS/05	Yellow	16-12-2013	IV	54.11	14.67	3.10	2.39	2.39	2.22	0.83	0.10	0.04	0.02	0.00	0.01	3.31	10.20	0.00	0.00	0.00	0.12	0.00	0.00	93.52
	DS/05	**Yellow**	**16-12-2013**	**Average**	**54.68**	**15.29**	**3.26**	**2.42**	**2.41**	**2.48**	**0.74**	**0.10**	**0.04**	**0.03**	**0.03**	**0.02**	**2.66**	**11.81**	**0.05**	**0.00**	**0.04**	**0.32**	**0.03**	**0.00**	**96.41**
	DS/05	**Yellow**	**16-12-2013**	**Std. Dev.**	**3.70**	**0.80**	**0.44**	**0.09**	**0.12**	**0.30**	**0.08**	**0.03**	**0.04**	**0.02**	**0.04**	**0.03**	**1.29**	**2.19**	**0.06**	**0.00**	**0.03**	**0.22**	**0.05**	**0.00**	
6	DS/06	Dark-Blue	24-02-2014	I	71.13	13.54	4.77	3.71	3.33	2.24	1.39	0.11	0.00	0.04	0.01	0.23	0.00	0.17	0.00	0.11	0.00	0.09	0.00	0.26	101.14
	DS/06	Dark-Blue	24-02-2014	II	68.41	14.24	5.19	3.57	3.82	2.48	1.42	0.10	0.00	0.03	0.17	0.20	0.00	0.05	0.00	0.03	0.00	0.47	0.03	0.40	100.60
	DS/06	Dark-Blue	24-02-2014	III	65.88	13.89	6.61	3.45	4.51	2.45	2.42	0.06	0.00	0.04	0.00	0.27	0.00	0.41	0.02	0.02	0.00	0.07	0.00	0.26	100.36
	DS/06	Dark-Blue	24-02-2014	IV	71.56	12.25	4.10	3.51	2.58	2.94	1.21	0.08	0.00	0.00	0.00	0.15	0.00	0.04	0.03	0.01	0.02	0.55	0.00	0.43	99.45
	DS/06	Dark-Blue	24-02-2014	V	68.60	14.56	5.24	3.63	3.60	2.12	1.29	0.10	0.19	0.01	0.00	0.25	0.00	0.05	0.07	0.00	0.00	0.47	0.20	0.23	100.61
	DS/06	Dark-Blue	24-02-2014	VI	72.04	12.82	3.73	3.46	2.95	3.96	1.34	0.13	0.05	0.02	0.02	0.09	0.05	0.00	0.03	0.01	0.00	0.44	0.00	0.21	101.34
	DS/06	**Dark-Blue**	**24-02-2014**	**Average**	**69.60**	**13.55**	**4.94**	**3.56**	**3.46**	**2.70**	**1.51**	**0.10**	**0.04**	**0.02**	**0.03**	**0.20**	**0.01**	**0.12**	**0.02**	**0.03**	**0.00**	**0.35**	**0.04**	**0.30**	**100.58**
	DS/06	**Dark-Blue**	**24-02-2014**	**Std. Dev.**	**2.38**	**0.87**	**1.01**	**0.10**	**0.68**	**0.68**	**0.45**	**0.02**	**0.08**	**0.02**	**0.07**	**0.07**	**0.02**	**0.15**	**0.02**	**0.04**	**0.01**	**0.21**	**0.08**	**0.09**	
7	DS/07	Dark-Blue	24-02-2014	I	63.08	19.20	4.20	3.19	3.38	2.50	2.62	0.14	0.00	0.05	0.13	0.46	0.00	0.00	0.00	0.07	0.04	0.47	0.00	0.42	99.95
	DS/07	Dark-Blue	24-02-2014	II	61.29	18.62	5.06	3.20	3.43	2.94	1.23	0.14	0.10	0.00	0.14	0.21	0.01	0.00	0.00	0.00	0.09	0.19	0.00	0.44	97.10
	DS/07	Dark-Blue	24-02-2014	III	66.71	18.65	3.41	3.36	3.06	2.42	1.73	0.12	0.05	0.03	0.15	0.39	0.05	0.04	0.07	0.00	0.07	0.72	0.16	0.38	101.57
	DS/07	Dark-Blue	24-02-2014	IV	59.64	16.85	3.19	3.28	2.65	3.38	1.82	0.13	0.00	0.00	0.04	0.26	0.01	0.04	0.03	0.26	0.00	0.92	0.02	0.58	93.09
	DS/07	Dark-Blue	**24-02-2014**	**Average**	**62.68**	**18.33**	**3.96**	**3.26**	**3.13**	**2.81**	**1.85**	**0.13**	**0.04**	**0.02**	**0.11**	**0.33**	**0.02**	**0.02**	**0.02**	**0.08**	**0.05**	**0.57**	**0.05**	**0.46**	**97.93**

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	DS/07	**Dark-Blue**	**24-02-2014**	**Std. Dev.**	**3.03**	**1.02**	**0.85**	**0.08**	**0.36**	**0.44**	**0.57**	**0.01**	**0.05**	**0.02**	**0.05**	**0.12**	**0.02**	**0.02**	**0.03**	**0.12**	**0.04**	**0.32**	**0.08**	**0.09**	
8	DS/08	White	24-01-2014	I	64.63	20.09	4.27	2.83	3.57	2.65	0.75	0.14	0.00	0.06	0.00	0.00	0.00	0.00	0.05	0.00	0.04	0.43	0.18	0.00	99.70
	DS/08	White	24-01-2014	II	63.87	19.07	4.30	2.96	3.48	2.90	0.82	0.10	0.00	0.04	0.03	0.00	0.00	0.00	0.00	0.10	0.02	0.45	0.14	0.00	98.28
	DS/08	White	24-01-2014	III	63.11	18.11	2.56	3.55	2.04	7.39	1.85	0.36	0.00	0.03	0.00	0.03	0.00	0.00	0.02	0.05	0.03	0.22	0.29	0.00	99.65
	DS/08	White	24-01-2014	IV	63.96	19.97	4.24	2.81	3.61	2.72	0.66	0.09	0.00	0.06	0.00	0.01	0.00	0.02	0.00	0.05	0.02	0.45	0.15	0.00	98.81
	DS/08	White	24-01-2014	V	64.86	19.88	4.21	2.89	3.63	2.71	0.63	0.14	0.00	0.04	0.03	0.00	0.00	0.00	0.00	0.05	0.04	0.37	0.11	0.00	99.58
	DS/08	White	24-01-2014	VI	64.68	19.81	4.46	2.58	3.70	2.65	0.72	0.10	0.00	0.07	0.04	0.02	0.00	0.10	0.00	0.00	0.00	0.49	0.15	0.00	99.57
	DS/08	**White**	**24-01-2014**	**Average**	**64.19**	**19.49**	**4.00**	**2.94**	**3.34**	**3.50**	**0.91**	**0.15**	**0.00**	**0.05**	**0.02**	**0.01**	**0.00**	**0.02**	**0.01**	**0.04**	**0.02**	**0.40**	**0.17**	**0.00**	**99.26**
	DS/08	**White**	**24-01-2014**	**Std. Dev.**	**0.66**	**0.76**	**0.71**	**0.33**	**0.64**	**1.91**	**0.47**	**0.10**	**0.00**	**0.01**	**0.02**	**0.01**	**0.00**	**0.04**	**0.02**	**0.04**	**0.01**	**0.10**	**0.06**	**0.00**	
9	DS/09	Green	24-01-2014	I	56.48	15.17	1.55	2.13	1.17	7.98	1.93	0.40	0.00	0.03	0.94	0.00	1.25	9.77	0.04	0.12	0.03	0.22	0.03	0.00	99.25
	DS/09	Green	24-01-2014	II	60.56	16.51	1.67	2.35	1.17	8.77	2.37	0.36	0.00	0.03	0.31	0.01	0.01	3.63	0.02	0.00	0.04	0.28	0.13	0.00	98.23
	DS/09	Green	24-01-2014	III	55.69	14.84	2.45	1.77	1.87	6.10	1.49	0.22	0.00	0.01	1.54	0.00	1.36	11.57	0.04	0.01	0.00	0.19	0.03	0.00	99.16
	DS/09	Green	24-01-2014	IV	58.87	15.77	1.83	2.16	1.26	8.62	2.36	0.38	0.02	0.04	0.43	0.02	0.87	7.95	0.00	0.00	0.03	0.24	0.07	0.00	100.93
	DS/09	Green	24-01-2014	V	57.86	13.22	1.74	2.14	1.46	7.88	2.05	0.44	0.00	0.04	0.98	0.00	1.03	10.50	0.02	0.02	0.00	0.19	0.00	0.00	99.57
	DS/09	Green	24-01-2014	VI	58.57	13.20	1.75	2.26	1.46	8.06	2.09	0.41	0.00	0.03	0.65	0.00	1.00	10.81	0.02	0.00	0.01	0.23	0.02	0.00	100.56
	DS/09	**Green**	**24-01-2014**	**Average**	**58.01**	**14.79**	**1.83**	**2.13**	**1.40**	**7.90**	**2.05**	**0.37**	**0.00**	**0.03**	**0.81**	**0.00**	**0.92**	**9.04**	**0.02**	**0.02**	**0.02**	**0.23**	**0.05**	**0.00**	**99.62**
	DS/09	**Green**	**24-01-2014**	**Std. Dev.**	**1.75**	**1.35**	**0.32**	**0.20**	**0.27**	**0.95**	**0.33**	**0.07**	**0.01**	**0.01**	**0.45**	**0.01**	**0.48**	**2.92**	**0.01**	**0.05**	**0.02**	**0.03**	**0.05**	**0.00**	
10	DS/10	Dark-Blue	16-12-2013	I	66.43	15.31	3.86	2.23	2.21	5.24	2.58	0.26	0.26	0.04	0.27	0.84	0.00	0.00	0.00	0.05	0.08	0.26	0.17	0.08	100.16
	DS/10	Dark-Blue	16-12-2013	II	68.41	13.64	2.98	3.19	1.84	5.79	2.91	0.30	0.00	0.09	0.09	0.74	0.00	0.06	0.03	0.00	0.04	0.47	0.23	0.00	100.79
	DS/10	Dark-Blue	16-12-2013	III	64.50	15.12	3.27	2.36	1.66	6.81	2.82	0.34	0.00	0.00	0.36	0.73	0.00	0.00	0.00	0.00	0.06	0.33	0.16	0.12	98.62
	DS/10	Dark-Blue	16-12-2013	IV	66.17	15.15	3.38	2.29	2.02	6.17	2.95	0.34	0.00	0.12	0.29	0.84	0.00	0.00	0.09	0.00	0.00	0.42	0.28	0.23	100.74
	DS/10	**Dark-Blue**	**16-12-2013**	**Average**	**66.38**	**14.80**	**3.37**	**2.52**	**1.93**	**6.00**	**2.82**	**0.31**	**0.07**	**0.06**	**0.25**	**0.79**	**0.00**	**0.02**	**0.03**	**0.01**	**0.04**	**0.37**	**0.21**	**0.11**	**100.08**
	DS/10	**Dark-Blue**	**16-12-2013**	**Std. Dev.**	**1.60**	**0.78**	**0.37**	**0.45**	**0.24**	**0.66**	**0.17**	**0.04**	**0.13**	**0.05**	**0.12**	**0.06**	**0.00**	**0.03**	**0.04**	**0.03**	**0.03**	**0.09**	**0.06**	**0.09**	
11	DS/11	Dark-Blue	16-12-2013	I	67.77	16.22	3.77	2.79	2.79	2.63	1.43	0.10	0.00	0.04	1.32	0.23	0.00	0.00	0.00	0.06	0.00	0.23	0.26	0.00	99.63
	DS/11	Dark-Blue	16-12-2013	II	63.49	17.35	4.17	2.61	2.81	2.89	2.00	0.10	0.00	0.01	1.86	0.33	0.00	0.00	0.01	0.00	0.05	0.55	0.31	0.13	98.66
	DS/11	Dark-Blue	16-12-2013	III	65.35	17.06	3.92	2.72	3.04	2.94	1.74	0.12	0.06	0.12	1.57	0.28	0.00	0.00	0.07	0.00	0.02	0.45	0.34	0.00	99.80
	DS/11	Dark-Blue	16-12-2013	IV	66.49	16.49	3.55	2.82	2.48	2.63	1.69	0.12	0.00	0.05	0.97	0.18	0.00	0.00	0.05	0.01	0.02	0.72	0.46	0.16	98.90
	DS/11	**Dark-Blue**	**16-12-2013**	**Average**	**65.77**	**16.78**	**3.85**	**2.73**	**2.78**	**2.77**	**1.72**	**0.11**	**0.02**	**0.06**	**1.43**	**0.26**	**0.00**	**0.00**	**0.03**	**0.02**	**0.02**	**0.49**	**0.34**	**0.07**	**99.25**
	DS/11	**Dark-Blue**	**16-12-2013**	**Std. Dev.**	**1.82**	**0.51**	**0.26**	**0.09**	**0.23**	**0.17**	**0.23**	**0.01**	**0.03**	**0.05**	**0.38**	**0.06**	**0.00**	**0.00**	**0.03**	**0.03**	**0.02**	**0.20**	**0.09**	**0.09**	
12	DS/12	Turquoise	29-01-2014	I	64.78	15.67	3.64	3.44	2.85	2.67	0.73	0.07	0.04	0.04	3.26	0.00	0.00	0.07	0.00	0.00	0.04	0.40	0.30	0.00	98.00
	DS/12	Turquoise	29-01-2014	II	65.64	16.18	3.69	3.56	2.82	2.74	0.72	0.08	0.00	0.04	2.93	0.00	0.00	0.15	0.04	0.00	0.06	0.36	0.28	0.00	99.27
	DS/12	Turquoise	29-01-2014	III	68.39	15.12	3.71	3.63	2.53	2.17	0.58	0.07	0.01	0.03	2.54	0.01	0.00	0.10	0.00	0.00	0.04	0.30	0.16	0.00	99.38
	DS/12	Turquoise	29-01-2014	IV	65.96	16.49	4.13	3.50	2.94	2.48	0.78	0.10	0.00	0.04	2.77	0.01	0.00	0.11	0.03	0.05	0.03	0.32	0.24	0.00	99.99
	DS/12	Turquoise	29-01-2014	V	66.39	16.04	3.84	3.52	2.91	2.59	0.69	0.06	0.00	0.02	2.53	0.00	0.00	0.06	0.01	0.06	0.01	0.29	0.28	0.00	99.30
	DS/12	Turquoise	29-01-2014	VI	65.94	15.89	3.74	3.46	2.90	2.63	0.65	0.07	0.00	0.03	3.03	0.00	0.00	0.10	0.00	0.00	0.00	0.31	0.31	0.00	99.08
	DS/12	**Turquoise**	**29-01-2014**	**Average**	**66.18**	**15.90**	**3.79**	**3.52**	**2.83**	**2.55**	**0.69**	**0.07**	**0.01**	**0.03**	**2.84**	**0.00**	**0.00**	**0.10**	**0.01**	**0.02**	**0.03**	**0.33**	**0.26**	**0.00**	**99.17**
	DS/12	**Turquoise**	**29-01-2014**	**Std. Dev.**	**1.21**	**0.47**	**0.18**	**0.07**	**0.15**	**0.20**	**0.07**	**0.02**	**0.02**	**0.01**	**0.29**	**0.00**	**0.00**	**0.03**	**0.02**	**0.03**	**0.02**	**0.04**	**0.06**	**0.00**	
13	DS/13	Turquoise	29-01-2014	I	64.40	16.10	3.13	2.76	2.10	6.70	1.58	0.33	0.00	0.07	2.54	0.00	0.00	0.00	0.00	0.00	0.04	0.21	0.10	0.00	100.05
	DS/13	Turquoise	29-01-2014	II	64.26	16.13	2.84	2.82	2.04	7.27	1.77	0.32	0.06	0.05	2.87	0.00	0.00	0.00	0.00	0.05	0.03	0.23	0.11	0.00	100.85
	DS/13	Turquoise	29-01-2014	III	64.19	16.32	2.16	2.68	1.33	6.98	1.31	0.29	0.00	0.02	2.28	0.00	0.02	0.04	0.01	0.03	0.00	0.22	0.15	0.00	98.02
	DS/13	Turquoise	29-01-2014	IV	63.41	17.79	2.86	2.52	2.05	5.65	1.55	0.27	0.00	0.04	2.85	0.01	0.01	0.07	0.00	0.06	0.00	0.36	0.16	0.00	99.66
	DS/13	Turquoise	29-01-2014	V	61.81	16.41	2.28	2.78	1.34	7.64	1.64	0.33	0.07	0.07	2.81	0.01	0.00	0.05	0.02	0.02	0.01	0.15	0.08	0.00	97.52
	DS/13	Turquoise	29-01-2014	VI	63.44	17.38	2.32	2.78	1.45	8.25	1.93	0.38	0.00	0.05	1.82	0.02	0.00	0.04	0.00	0.01	0.00	0.30	0.17	0.00	100.32
	DS/13	**Turquoise**	**29-01-2014**	**Average**	**63.59**	**16.69**	**2.60**	**2.72**	**1.72**	**7.08**	**1.63**	**0.32**	**0.02**	**0.05**	**2.53**	**0.01**	**0.00**	**0.03**	**0.01**	**0.03**	**0.01**	**0.24**	**0.13**	**0.00**	**99.40**
	DS/13	**Turquoise**	**29-01-2014**	**Std. Dev.**	**0.97**	**0.72**	**0.39**	**0.11**	**0.38**	**0.88**	**0.21**	**0.04**	**0.03**	**0.02**	**0.42**	**0.01**	**0.01**	**0.03**	**0.01**	**0.02**	**0.02**	**0.07**	**0.04**	**0.00**	
14	FS/01	Yellow	18-01-2014	I	55.68	14.91	3.42	3.28	3.08	2.68	0.88	0.11	0.00	0.01	0.06	0.01	1.32	12.98	0.03	0.08	0.00	0.41	0.00	0.00	98.93

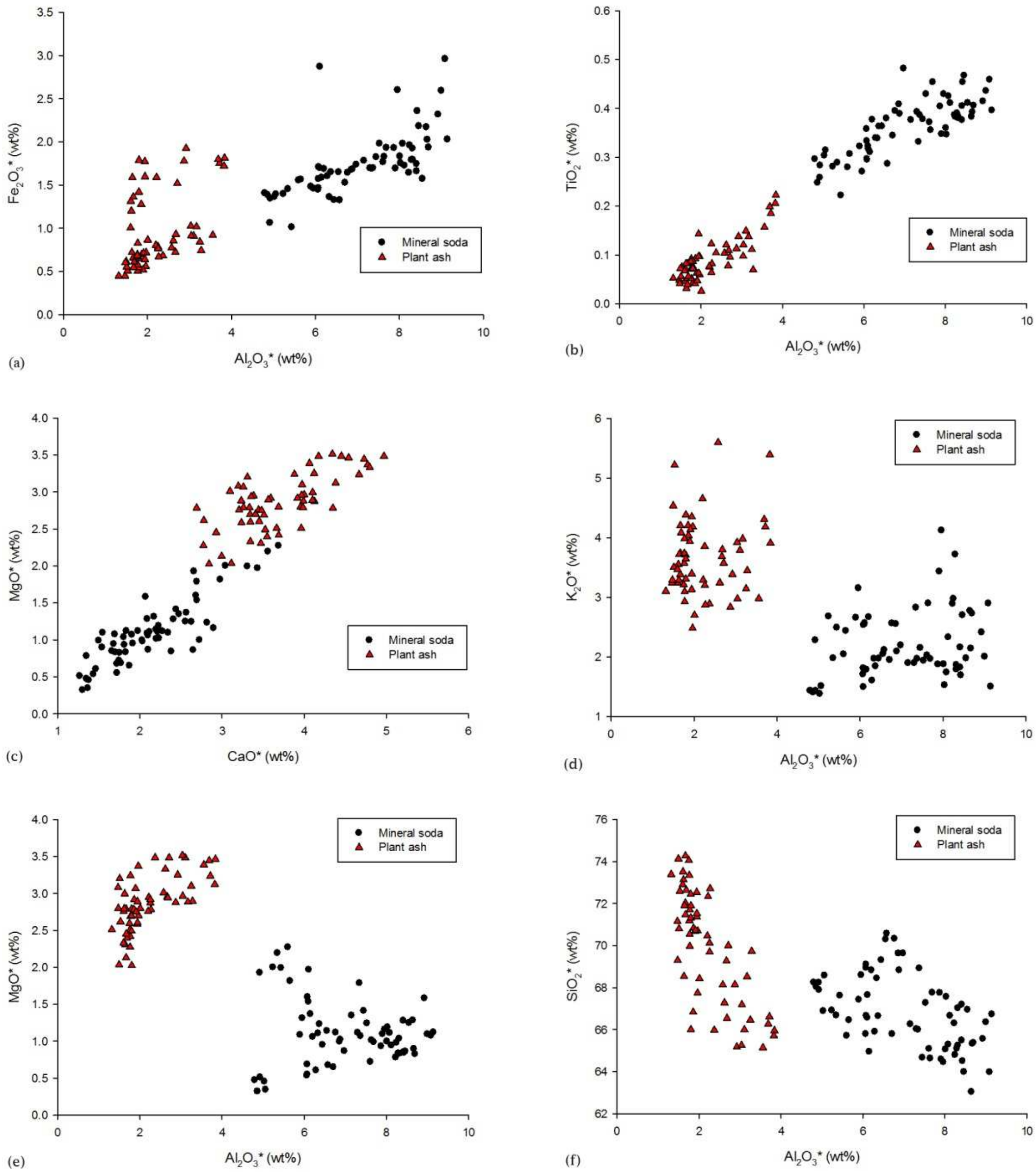
No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	FS/01	Yellow	18-01-2014	II	53.30	15.29	2.93	3.23	2.74	2.62	0.86	0.05	0.00	0.01	0.05	0.00	2.11	12.99	0.00	0.05	0.00	0.40	0.01	0.00	96.66
	FS/01	Yellow	18-01-2014	III	52.71	15.78	3.96	3.15	2.78	2.40	0.89	0.08	0.00	0.04	0.01	0.00	2.04	12.80	0.00	0.08	0.00	0.49	0.03	0.00	97.22
	FS/01	Yellow	18-01-2014	IV	53.72	16.04	3.89	3.22	3.01	2.61	0.82	0.09	0.02	0.03	0.05	0.00	3.13	12.78	0.02	0.10	0.00	0.41	0.05	0.00	99.98
	FS/01	Yellow	18-01-2014	V	55.01	15.03	3.83	3.25	2.87	2.43	0.80	0.06	0.00	0.04	0.00	0.01	1.49	11.58	0.01	0.00	0.04	0.40	0.03	0.00	96.87
	FS/01	Yellow	18-01-2014	VI	48.78	14.90	3.22	3.05	2.72	2.11	0.78	0.09	0.04	0.00	0.00	0.02	3.50	15.89	0.00	0.01	0.00	0.36	0.04	0.00	95.49
	FS/01	**Yellow**	**18-01-2014**	**Average**	**53.20**	**15.33**	**3.54**	**3.20**	**2.87**	**2.47**	**0.84**	**0.08**	**0.01**	**0.02**	**0.03**	**0.01**	**2.26**	**13.17**	**0.01**	**0.05**	**0.01**	**0.41**	**0.03**	**0.00**	**97.52**
	FS/01	**Yellow**	**18-01-2014**	**Std. Dev.**	**2.43**	**0.48**	**0.42**	**0.08**	**0.15**	**0.21**	**0.05**	**0.02**	**0.02**	**0.02**	**0.03**	**0.01**	**0.88**	**1.43**	**0.01**	**0.04**	**0.02**	**0.04**	**0.02**	**0.00**	
15	FS/02	Dark-Blue	18-01-2014	I	64.89	15.40	3.85	3.99	3.28	4.03	2.60	0.18	0.00	0.03	0.13	0.29	0.00	0.00	0.05	0.00	0.00	0.37	0.27	0.62	99.98
	FS/02	Dark-Blue	18-01-2014	II	63.83	16.06	4.53	3.71	3.24	4.21	1.66	0.28	0.00	0.07	0.11	0.24	0.00	0.01	0.02	0.00	0.04	0.41	0.35	0.66	99.42
	FS/02	Dark-Blue	18-01-2014	III	64.78	15.86	4.54	3.70	3.43	3.72	1.63	0.24	0.00	0.05	0.10	0.19	0.00	0.00	0.04	0.00	0.06	0.41	0.29	0.56	99.62
	FS/02	Dark-Blue	18-01-2014	IV	64.91	16.05	4.74	3.73	3.44	2.99	1.27	0.21	0.04	0.04	0.00	0.22	0.00	0.00	0.07	0.01	0.00	0.38	0.22	0.62	98.95
	FS/02	Dark-Blue	18-01-2014	V	62.75	15.79	4.36	3.74	3.39	4.22	1.85	0.19	0.00	0.03	0.06	0.36	0.00	0.09	0.03	0.02	0.03	0.41	0.33	0.92	98.56
	FS/02	Dark-Blue	18-01-2014	VI	62.39	15.30	4.39	3.87	3.37	3.15	1.54	0.19	0.00	0.09	0.19	0.23	0.00	0.00	0.00	0.07	0.00	0.43	0.59	0.31	96.11
	FS/02	**Dark-Blue**	**18-01-2014**	**Average**	**63.93**	**15.74**	**4.40**	**3.79**	**3.36**	**3.72**	**1.76**	**0.22**	**0.01**	**0.05**	**0.10**	**0.25**	**0.00**	**0.02**	**0.04**	**0.02**	**0.02**	**0.40**	**0.34**	**0.62**	**98.77**
	FS/02	**Dark-Blue**	**18-01-2014**	**Std. Dev.**	**1.13**	**0.32**	**0.30**	**0.11**	**0.08**	**0.54**	**0.45**	**0.04**	**0.02**	**0.02**	**0.06**	**0.06**	**0.00**	**0.04**	**0.02**	**0.03**	**0.03**	**0.02**	**0.13**	**0.20**	
16	TU/01	Dark-Blue	28-02-2013	I	61.93	15.28	4.42	3.98	2.91	2.89	1.61	0.20	0.00	0.02	0.17	0.30	0.00	0.07	0.00	0.00	0.03	0.23	0.45	0.42	94.91
	TU/01	Dark-Blue	28-02-2013	II	65.52	14.62	3.90	4.22	3.01	4.70	2.07	0.19	0.00	0.03	0.09	0.26	0.00	0.27	0.00	0.00	0.01	0.41	0.41	0.59	100.30
	TU/01	Dark-Blue	28-02-2013	III	64.83	15.21	4.46	4.22	3.25	3.31	1.64	0.20	0.06	0.03	0.15	0.66	0.08	0.07	0.02	0.05	0.05	0.50	0.37	0.75	99.90
	TU/01	Dark-Blue	28-02-2013	IV	64.35	15.38	4.71	3.95	3.26	3.61	2.04	0.14	0.10	0.08	0.17	0.31	0.00	0.10	0.07	0.04	0.05	0.69	0.49	0.52	100.05
	TU/01	Dark-Blue	28-02-2013	V	65.41	15.08	5.08	3.86	3.22	3.45	1.12	0.16	0.14	0.01	0.15	0.19	0.00	0.05	0.00	0.02	0.00	0.42	0.28	0.29	98.93
	TU/01	**Dark-Blue**	**28-02-2013**	**Average**	**64.41**	**15.12**	**4.51**	**4.04**	**3.13**	**3.59**	**1.70**	**0.18**	**0.06**	**0.04**	**0.15**	**0.34**	**0.02**	**0.11**	**0.02**	**0.02**	**0.03**	**0.45**	**0.40**	**0.51**	**98.82**
	TU/01	**Dark-Blue**	**28-02-2013**	**Std. Dev.**	**1.46**	**0.30**	**0.43**	**0.16**	**0.16**	**0.67**	**0.39**	**0.03**	**0.06**	**0.03**	**0.03**	**0.18**	**0.04**	**0.09**	**0.03**	**0.02**	**0.02**	**0.17**	**0.08**	**0.17**	
17	TU/02	Dark-Blue	28-02-2013	I	65.34	15.12	3.88	4.53	2.94	4.77	1.48	0.22	0.00	0.00	0.03	0.36	0.00	0.00	0.03	0.04	0.00	0.43	0.51	0.74	100.41
	TU/02	Dark-Blue	28-02-2013	II	65.21	15.47	5.01	4.06	3.49	3.12	1.87	0.16	0.00	0.03	0.13	0.30	0.00	0.00	0.00	0.00	0.00	0.71	0.38	0.71	100.63
	TU/02	Dark-Blue	28-02-2013	III	62.73	16.11	5.78	3.66	4.10	2.68	2.17	0.15	0.01	0.05	0.16	0.36	0.00	0.31	0.06	0.00	0.00	0.56	0.43	0.38	99.70
	TU/02	Dark-Blue	28-02-2013	IV	64.50	15.46	4.57	4.38	3.17	4.09	1.64	0.32	0.15	0.03	0.13	0.38	0.01	0.13	0.13	0.00	0.03	0.27	0.25	0.82	100.44
	TU/02	Dark-Blue	28-02-2013	V	67.07	14.11	3.96	4.49	3.19	3.41	1.66	0.14	0.00	0.05	0.02	0.33	0.00	0.04	0.06	0.07	0.02	0.16	0.32	0.73	99.81
	TU/02	**Dark-Blue**	**28-02-2013**	**Average**	**64.97**	**15.25**	**4.64**	**4.22**	**3.38**	**3.61**	**1.76**	**0.20**	**0.03**	**0.03**	**0.10**	**0.34**	**0.00**	**0.10**	**0.06**	**0.02**	**0.01**	**0.42**	**0.38**	**0.67**	**100.20**
	TU/02	**Dark-Blue**	**28-02-2013**	**Std. Dev.**	**1.57**	**0.73**	**0.79**	**0.37**	**0.45**	**0.82**	**0.27**	**0.08**	**0.07**	**0.02**	**0.06**	**0.03**	**0.00**	**0.13**	**0.05**	**0.03**	**0.01**	**0.22**	**0.10**	**0.17**	
18	TU/03	Dark-Blue	28-02-2013	I	63.80	15.52	4.69	5.19	3.16	4.08	1.79	0.16	0.08	0.00	0.15	0.35	0.00	0.14	0.09	0.00	0.00	0.22	0.18	0.74	100.34
	TU/03	Dark-Blue	28-02-2013	II	64.66	16.33	4.79	4.88	3.32	2.50	1.64	0.12	0.00	0.04	0.14	0.24	0.04	0.00	0.06	0.00	0.01	0.25	0.36	0.63	100.00
	TU/03	Dark-Blue	28-02-2013	III	63.17	15.67	4.56	5.02	2.81	4.40	2.28	0.36	0.00	0.10	0.09	0.24	0.02	0.00	0.06	0.00	0.00	0.07	0.32	0.59	99.75
	TU/03	Dark-Blue	28-02-2013	IV	64.11	15.17	4.15	5.44	3.02	5.07	1.35	0.25	0.07	0.04	0.24	0.38	0.00	0.02	0.07	0.07	0.07	0.58	0.25	0.79	101.12
	TU/03	Dark-Blue	28-02-2013	V	66.27	14.77	4.12	5.60	2.85	3.12	1.56	0.14	0.06	0.00	0.02	0.19	0.00	0.01	0.01	0.00	0.06	0.22	0.30	0.65	99.92
	TU/03	Dark-Blue	28-02-2013	VI	64.99	14.60	3.51	5.65	3.23	3.35	1.54	0.19	0.00	0.04	0.02	0.35	0.00	0.00	0.02	0.00	0.00	0.15	0.27	0.40	98.29
	TU/03	**Dark-Blue**	**28-02-2013**	**Average**	**64.50**	**15.34**	**4.30**	**5.29**	**3.07**	**3.75**	**1.69**	**0.20**	**0.04**	**0.04**	**0.11**	**0.29**	**0.01**	**0.03**	**0.05**	**0.01**	**0.02**	**0.25**	**0.28**	**0.63**	**99.90**
	TU/03	**Dark-Blue**	**28-02-2013**	**Std. Dev.**	**1.08**	**0.64**	**0.48**	**0.31**	**0.21**	**0.94**	**0.32**	**0.09**	**0.04**	**0.04**	**0.09**	**0.07**	**0.02**	**0.05**	**0.03**	**0.03**	**0.03**	**0.17**	**0.06**	**0.14**	
19	TU/04	Yellow	28-02-2013	I	46.18	11.11	1.20	3.64	1.76	2.01	0.83	0.05	0.02	0.00	0.06	0.08	10.53	23.80	0.00	0.07	0.00	0.15	0.00	0.00	101.49
	TU/04	Yellow	28-02-2013	II	61.02	14.69	3.52	5.01	2.93	2.10	0.57	0.07	0.00	0.03	0.01	0.00	0.07	7.92	0.00	0.00	0.03	0.65	0.04	0.00	98.66
	TU/04	Yellow	28-02-2013	III	60.62	15.42	3.06	4.93	2.79	2.37	0.66	0.09	0.09	0.02	0.18	0.01	0.89	9.08	0.07	0.00	0.09	0.64	0.00	0.12	101.10
	TU/04	Yellow	28-02-2013	IV	59.68	14.46	2.54	5.15	2.46	1.73	0.61	0.08	0.00	0.04	0.04	0.07	2.30	10.01	0.00	0.00	0.00	0.24	0.00	0.05	99.46
	TU/04	Yellow	28-02-2013	V	55.90	14.57	2.63	4.72	2.61	2.39	0.58	0.09	0.05	0.05	0.08	0.01	2.41	11.47	0.00	0.03	0.03	0.09	0.00	0.09	97.79
	TU/04	Yellow	28-02-2013	VI	61.93	14.39	2.75	4.93	2.72	2.47	0.68	0.15	0.00	0.07	0.10	0.03	1.38	9.24	0.03	0.04	0.00	0.25	0.06	0.00	101.23
	TU/04	**Yellow**	**28-02-2013**	**Average**	**57.55**	**14.11**	**2.62**	**4.73**	**2.54**	**2.18**	**0.66**	**0.09**	**0.03**	**0.04**	**0.08**	**0.03**	**2.93**	**11.92**	**0.02**	**0.02**	**0.02**	**0.33**	**0.02**	**0.04**	**99.95**
	TU/04	**Yellow**	**28-02-2013**	**Std. Dev.**	**5.95**	**1.52**	**0.78**	**0.55**	**0.42**	**0.28**	**0.10**	**0.03**	**0.04**	**0.03**	**0.06**	**0.03**	**3.82**	**5.94**	**0.03**	**0.03**	**0.03**	**0.25**	**0.03**	**0.05**	
20	SM/01	Purple	22-02-2012	I	57.95	13.08	2.83	3.10	2.04	1.64	0.53	0.09	0.00	1.11	0.01	0.04	0.00	0.06	0.04	0.00	0.00	0.20	0.28	0.00	82.98

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	SM/01	Purple	22-02-2012	II	64.36	14.49	3.56	3.31	2.21	1.60	0.64	0.08	0.00	1.54	0.05	0.00	0.00	0.00	0.01	0.09	0.00	0.34	0.32	0.00	92.61
	SM/01	Purple	22-02-2012	III	64.22	14.90	3.24	3.34	2.19	1.50	0.67	0.08	0.00	1.51	0.05	0.04	0.02	0.09	0.04	0.05	0.00	0.20	0.28	0.00	92.39
	SM/01	Purple	22-02-2012	IV	66.41	15.62	3.40	3.55	2.48	1.52	0.65	0.08	0.00	1.29	0.08	0.00	0.00	0.13	0.00	0.00	0.03	0.39	0.30	0.00	95.93
	SM/01	**Purple**	**22-02-2012**	**Average**	**63.23**	**14.52**	**3.26**	**3.32**	**2.23**	**1.57**	**0.62**	**0.08**	**0.00**	**1.36**	**0.05**	**0.02**	**0.00**	**0.07**	**0.02**	**0.03**	**0.01**	**0.28**	**0.30**	**0.00**	**90.98**
	SM/01	**Purple**	**22-02-2012**	**Std. Dev.**	**3.66**	**1.07**	**0.31**	**0.18**	**0.18**	**0.06**	**0.06**	**0.01**	**0.00**	**0.20**	**0.03**	**0.02**	**0.01**	**0.05**	**0.02**	**0.04**	**0.02**	**0.10**	**0.02**	**0.00**	
21	SM/02	Yellow	07-02-2012	I	54.48	15.33	2.16	1.42	1.19	5.92	1.40	0.32	0.00	0.05	0.04	0.04	1.82	16.20	0.01	0.22	0.00	0.18	0.00	0.05	100.82
	SM/02	Yellow	07-02-2012	II	54.23	14.88	1.70	1.92	1.03	5.65	1.39	0.31	0.00	0.02	0.07	0.00	2.98	14.87	0.03	0.29	0.04	0.13	0.00	0.00	99.55
	SM/02	Yellow	07-02-2012	III	50.61	14.77	2.11	1.22	1.02	5.65	1.50	0.28	0.00	0.04	0.06	0.01	4.79	18.12	0.06	0.30	0.03	0.16	0.00	0.00	100.70
	SM/02	**Yellow**	**07-02-2012**	**Average**	**53.11**	**14.99**	**1.99**	**1.52**	**1.08**	**5.74**	**1.43**	**0.30**	**0.00**	**0.04**	**0.06**	**0.02**	**3.20**	**16.40**	**0.03**	**0.27**	**0.02**	**0.16**	**0.00**	**0.02**	**100.36**
	SM/02	**Yellow**	**07-02-2012**	**Std. Dev.**	**2.16**	**0.30**	**0.25**	**0.36**	**0.10**	**0.16**	**0.06**	**0.02**	**0.00**	**0.01**	**0.01**	**0.02**	**1.50**	**1.63**	**0.03**	**0.04**	**0.02**	**0.03**	**0.00**	**0.03**	
22	SM/03	Dark-Blue	16-02-2012	I	67.11	14.74	3.28	3.18	2.47	1.70	1.31	0.07	0.00	0.02	0.07	0.39	0.00	0.09	0.05	0.00	0.00	0.38	0.45	0.14	95.45
	SM/03	Dark-Blue	16-02-2012	II	68.00	15.22	3.22	3.01	2.15	1.69	1.33	0.05	0.00	0.01	0.09	0.39	0.00	0.06	0.05	0.00	0.00	0.32	0.42	0.24	96.24
	SM/03	Dark-Blue	16-02-2012	III	63.06	14.65	3.30	3.00	2.31	1.60	1.31	0.12	0.00	0.02	0.01	0.43	0.00	0.00	0.10	0.00	0.00	0.21	0.38	0.11	90.60
	SM/03	**Dark-Blue**	**16-02-2012**	**Average**	**66.05**	**14.87**	**3.27**	**3.07**	**2.31**	**1.66**	**1.32**	**0.08**	**0.00**	**0.02**	**0.06**	**0.40**	**0.00**	**0.05**	**0.07**	**0.00**	**0.00**	**0.30**	**0.41**	**0.16**	**94.10**
	SM/03	**Dark-Blue**	**16-02-2012**	**Std. Dev.**	**2.63**	**0.31**	**0.04**	**0.10**	**0.16**	**0.06**	**0.01**	**0.03**	**0.00**	**0.01**	**0.04**	**0.03**	**0.00**	**0.05**	**0.03**	**0.00**	**0.00**	**0.09**	**0.03**	**0.07**	
23	SM/04	Orange	01-03-2012	I	52.63	11.20	2.16	2.38	1.89	1.32	0.52	0.09	0.05	0.00	0.05	0.02	5.46	21.81	0.02	1.86	0.01	0.31	0.00	0.00	101.74
	SM/04	Orange	01-03-2012	II	54.19	10.66	2.82	2.41	2.00	1.30	0.52	0.06	0.00	0.03	0.01	0.00	4.79	21.02	0.06	1.68	0.02	0.22	0.00	0.00	101.76
	SM/04	Orange	01-03-2012	III	56.26	10.11	2.45	2.32	1.94	1.45	0.49	0.07	0.00	0.04	0.03	0.02	3.48	17.22	0.02	2.32	0.00	0.09	0.00	0.00	98.28
	SM/04	Orange	01-03-2012	IV	60.94	11.25	2.70	2.61	2.03	1.22	0.51	0.05	0.00	0.00	0.10	0.01	0.79	17.52	0.02	1.25	0.04	0.30	0.00	0.00	101.32
	SM/04	**Orange**	**01-03-2012**	**Average**	**56.00**	**10.80**	**2.53**	**2.43**	**1.96**	**1.32**	**0.51**	**0.07**	**0.01**	**0.02**	**0.05**	**0.01**	**3.63**	**19.39**	**0.03**	**1.78**	**0.02**	**0.23**	**0.00**	**0.00**	**100.78**
	SM/04	**Orange**	**01-03-2012**	**Std. Dev.**	**3.61**	**0.54**	**0.29**	**0.12**	**0.06**	**0.10**	**0.02**	**0.02**	**0.02**	**0.02**	**0.04**	**0.01**	**2.06**	**2.36**	**0.02**	**0.44**	**0.02**	**0.10**	**0.00**	**0.00**	
24	SM/05	Green	14-02-2012	I	53.20	11.13	1.96	2.62	1.52	1.30	0.66	0.05	0.00	0.01	2.92	0.00	4.92	19.97	0.01	0.33	0.06	0.15	0.00	0.05	100.85
	SM/05	Green	14-02-2012	II	53.03	10.89	1.79	2.47	1.63	1.18	0.43	0.04	0.00	0.00	2.90	0.02	3.93	19.51	0.00	0.47	0.01	0.17	0.00	0.01	98.48
	SM/05	Green	14-02-2012	III	48.74	11.00	2.05	2.49	1.56	1.27	0.45	0.05	0.00	0.03	2.98	0.02	6.37	18.76	0.01	0.36	0.04	0.21	0.00	0.00	96.38
	SM/05	Green	14-02-2012	IV	53.81	11.19	2.09	2.59	1.77	1.27	0.41	0.02	0.00	0.04	3.18	0.01	2.95	19.84	0.00	0.33	0.04	0.23	0.00	0.00	99.77
	SM/05	**Green**	**14-02-2012**	**Average**	**52.20**	**11.05**	**1.97**	**2.54**	**1.62**	**1.25**	**0.49**	**0.04**	**0.00**	**0.02**	**3.00**	**0.01**	**4.54**	**19.52**	**0.01**	**0.37**	**0.04**	**0.19**	**0.00**	**0.01**	**98.87**
	SM/05	**Green**	**14-02-2012**	**Std. Dev.**	**2.33**	**0.13**	**0.13**	**0.07**	**0.11**	**0.05**	**0.12**	**0.02**	**0.00**	**0.02**	**0.13**	**0.01**	**1.46**	**0.54**	**0.01**	**0.07**	**0.02**	**0.04**	**0.00**	**0.02**	
25	SM/06	White	14-02-2012	I	63.23	12.45	2.94	3.45	2.09	1.33	0.54	0.04	0.00	0.02	0.00	0.00	0.02	0.16	0.00	0.11	0.04	0.32	0.36	0.00	87.08
	SM/06	White	14-02-2012	II	65.12	13.57	3.25	3.69	2.07	1.56	0.57	0.06	0.00	0.07	0.10	0.02	0.11	0.00	0.03	0.06	0.00	0.34	0.32	0.00	90.94
	SM/06	White	14-02-2012	III	61.38	13.10	3.08	3.54	2.10	1.52	0.49	0.05	0.00	0.06	0.04	0.01	0.08	0.08	0.01	0.05	0.03	0.31	0.33	0.00	86.24
	SM/06	**White**	**14-02-2012**	**Average**	**63.25**	**13.04**	**3.09**	**3.56**	**2.09**	**1.47**	**0.53**	**0.05**	**0.00**	**0.05**	**0.05**	**0.01**	**0.07**	**0.08**	**0.01**	**0.07**	**0.02**	**0.32**	**0.33**	**0.00**	**88.09**
	SM/06	**White**	**14-02-2012**	**Std. Dev.**	**1.87**	**0.56**	**0.16**	**0.12**	**0.01**	**0.12**	**0.04**	**0.01**	**0.00**	**0.03**	**0.05**	**0.01**	**0.05**	**0.08**	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**	**0.00**	
26	SM/07	Turquoise	06-02-2014	I	67.99	16.06	3.41	3.21	2.57	1.74	0.49	0.08	0.00	0.05	3.08	0.00	0.01	0.07	0.00	0.03	0.00	0.41	0.18	0.00	99.37
	SM/07	Turquoise	06-02-2014	II	68.79	15.87	3.16	3.29	2.33	1.92	0.59	0.05	0.00	0.03	3.11	0.00	0.06	0.11	0.00	0.11	0.01	0.34	0.19	0.00	99.96
	SM/07	Turquoise	06-02-2014	III	66.16	15.83	3.34	3.24	2.51	1.77	0.81	0.10	0.00	0.00	3.12	0.02	0.02	0.16	0.00	0.08	0.03	0.25	0.22	0.00	97.67
	SM/07	Turquoise	06-02-2014	IV	67.52	15.43	3.02	3.19	2.23	1.89	0.60	0.48	0.15	0.03	2.90	0.00	0.00	0.08	0.01	0.00	0.00	0.30	0.19	0.00	98.00
	SM/07	Turquoise	06-02-2014	V	67.78	15.82	3.38	3.32	2.59	1.73	0.52	0.06	0.00	0.04	2.98	0.00	0.06	0.11	0.00	0.00	0.01	0.30	0.16	0.01	98.86
	SM/07	Turquoise	06-02-2014	VI	68.91	14.83	3.38	3.12	2.63	2.03	0.64	0.06	0.07	0.06	3.06	0.00	0.08	0.08	0.01	0.05	0.02	0.30	0.19	0.02	99.54
	SM/07	**Turquoise**	**06-02-2014**	**Average**	**67.86**	**15.64**	**3.28**	**3.23**	**2.48**	**1.85**	**0.61**	**0.14**	**0.04**	**0.03**	**3.04**	**0.00**	**0.04**	**0.10**	**0.00**	**0.04**	**0.01**	**0.32**	**0.19**	**0.01**	**98.90**
	SM/07	**Turquoise**	**06-02-2014**	**Std. Dev.**	**1.00**	**0.45**	**0.16**	**0.07**	**0.16**	**0.12**	**0.11**	**0.17**	**0.06**	**0.02**	**0.09**	**0.01**	**0.03**	**0.03**	**0.01**	**0.04**	**0.01**	**0.05**	**0.02**	**0.01**	
27	SM/08	Purple	17-12-2013	I	73.86	14.15	3.05	4.34	2.05	0.94	0.72	0.08	0.15	1.38	0.00	0.02	0.02	0.12	0.00	0.15	0.00	0.00	0.18	0.00	101.19
	SM/08	Purple	17-12-2013	II	74.75	13.95	2.87	4.59	1.88	1.55	0.57	0.08	0.00	1.03	0.09	0.00	0.00	0.20	0.00	0.12	0.08	0.02	0.28	0.01	102.03
	SM/08	Purple	17-12-2013	III	72.21	14.54	3.45	4.60	2.16	1.74	0.63	0.10	0.00	1.06	0.00	0.02	0.01	0.05	0.00	0.00	0.03	0.42	0.34	0.00	101.36
	SM/08	Purple	17-12-2013	IV	73.23	12.93	2.98	4.47	2.00	1.71	0.52	0.03	0.00	0.99	0.09	0.00	0.00	0.00	0.01	0.00	0.07	0.20	0.41	0.00	99.63
	SM/08	**Purple**	**17-12-2013**	**Average**	**73.51**	**13.89**	**3.09**	**4.50**	**2.02**	**1.48**	**0.61**	**0.07**	**0.04**	**1.12**	**0.05**	**0.01**	**0.01**	**0.09**	**0.00**	**0.07**	**0.04**	**0.16**	**0.30**	**0.00**	**101.05**
	SM/08	**Purple**	**17-12-2013**	**Std. Dev.**	**1.07**	**0.69**	**0.26**	**0.12**	**0.12**	**0.37**	**0.09**	**0.03**	**0.08**	**0.18**	**0.05**	**0.01**	**0.01**	**0.08**	**0.01**	**0.08**	**0.04**	**0.20**	**0.10**	**0.00**	

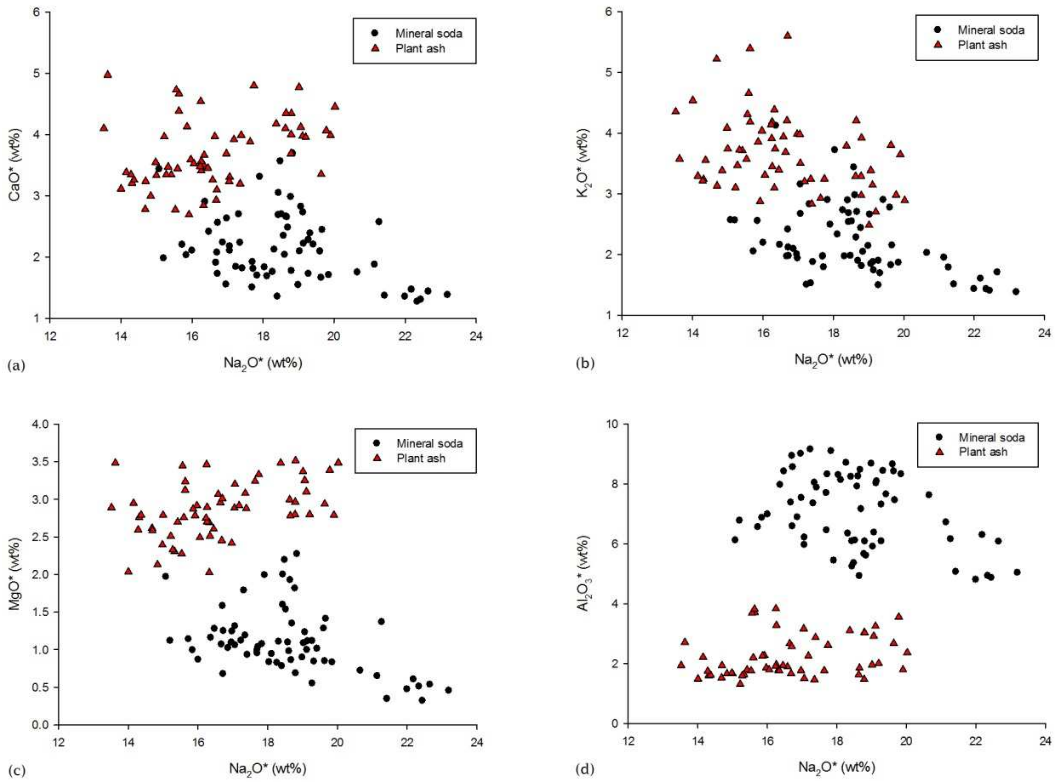
No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
28	SM/09	Yellow	06-02-2014	I	51.19	15.94	2.03	2.93	0.95	6.21	1.30	0.27	0.00	0.05	0.05	0.01	2.83	16.45	0.07	0.20	0.00	0.17	0.00	0.00	100.65
	SM/09	Yellow	06-02-2014	II	52.98	14.05	1.89	2.87	0.71	6.43	1.48	0.30	0.00	0.05	0.12	0.00	2.05	15.68	0.05	0.09	0.00	0.19	0.00	0.00	98.93
	SM/09	Yellow	06-02-2014	III	51.67	14.85	2.01	2.53	0.75	6.33	1.38	0.28	0.00	0.00	0.05	0.00	2.00	18.17	0.00	0.19	0.00	0.15	0.00	0.00	100.35
	SM/09	Yellow	06-02-2014	IV	53.56	15.84	1.82	2.66	1.12	5.86	1.25	0.28	0.00	0.02	0.02	0.00	2.40	15.01	0.03	0.10	0.00	0.19	0.00	0.00	100.15
	SM/09	Yellow	06-02-2014	V	50.59	16.13	1.95	2.62	0.90	6.20	1.40	0.29	0.00	0.06	0.09	0.00	2.55	16.43	0.03	0.17	0.00	0.11	0.00	0.00	99.52
	SM/09	Yellow	06-02-2014	VI	52.83	13.22	1.67	3.02	0.89	7.29	1.38	0.27	0.00	0.07	0.03	0.00	3.33	15.41	0.00	0.20	0.00	0.10	0.00	0.00	99.70
	SM/09	**Yellow**	**06-02-2014**	**Average**	**52.14**	**15.00**	**1.89**	**2.77**	**0.88**	**6.39**	**1.37**	**0.28**	**0.00**	**0.04**	**0.06**	**0.00**	**2.53**	**16.19**	**0.03**	**0.16**	**0.00**	**0.15**	**0.00**	**0.00**	**99.88**
	SM/09	**Yellow**	**06-02-2014**	**Std. Dev.**	**1.16**	**1.18**	**0.14**	**0.19**	**0.15**	**0.48**	**0.08**	**0.01**	**0.00**	**0.03**	**0.04**	**0.00**	**0.50**	**1.12**	**0.03**	**0.05**	**0.00**	**0.04**	**0.00**	**0.00**	
29	SM/10	Dark-Blue	05-02-2014	I	72.34	15.05	3.50	3.65	2.24	1.71	0.81	0.08	0.00	0.06	0.09	0.27	0.00	0.26	0.06	0.07	0.02	0.43	0.21	0.33	101.18
	SM/10	Dark-Blue	05-02-2014	II	71.65	15.84	3.44	3.58	2.49	1.34	1.45	0.07	0.00	0.08	0.15	0.40	0.06	0.31	0.06	0.00	0.00	0.20	0.21	0.28	101.60
	SM/10	Dark-Blue	05-02-2014	III	72.16	15.22	3.17	3.51	2.43	1.53	1.13	0.09	0.00	0.05	0.14	0.28	0.00	0.12	0.07	0.03	0.02	0.22	0.28	0.41	100.86
	SM/10	Dark-Blue	05-02-2014	IV	74.70	14.49	3.27	3.50	2.12	1.96	1.01	0.07	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.43	101.81
	SM/10	Dark-Blue	05-02-2014	V	73.46	15.11	3.45	3.24	2.24	1.38	0.81	0.07	0.00	0.07	0.09	0.30	0.00	0.00	0.00	0.05	0.00	0.41	0.06	0.48	101.23
	SM/10	Dark-Blue	05-02-2014	VI	72.40	15.80	3.20	3.32	2.44	1.65	0.82	0.03	0.00	0.03	0.08	0.23	0.01	0.23	0.00	0.02	0.09	0.47	0.01	0.46	101.29
	SM/10	**Dark-Blue**	**05-02-2014**	**Average**	**72.79**	**15.25**	**3.34**	**3.47**	**2.33**	**1.60**	**1.00**	**0.07**	**0.00**	**0.05**	**0.09**	**0.29**	**0.01**	**0.15**	**0.03**	**0.03**	**0.02**	**0.29**	**0.13**	**0.40**	**101.33**
	SM/10	**Dark-Blue**	**05-02-2014**	**Std. Dev.**	**1.11**	**0.51**	**0.14**	**0.16**	**0.15**	**0.23**	**0.25**	**0.02**	**0.00**	**0.03**	**0.05**	**0.06**	**0.02**	**0.14**	**0.04**	**0.03**	**0.03**	**0.18**	**0.12**	**0.08**	
30	SM/11	Orange	17-12-2013	I	46.76	12.14	1.46	2.87	1.74	1.30	0.46	0.05	0.00	0.10	0.00	0.00	8.86	23.98	0.12	2.08	0.00	0.23	0.00	0.00	102.16
	SM/11	Orange	17-12-2013	II	53.15	12.58	2.24	2.97	1.81	1.29	0.39	0.01	0.00	0.02	0.03	0.00	4.50	20.60	0.00	1.53	0.00	0.00	0.00	0.00	101.13
	SM/11	Orange	17-12-2013	III	54.39	12.21	2.61	3.22	1.83	1.27	0.46	0.02	0.00	0.03	0.19	0.00	3.38	17.34	0.01	1.54	0.05	0.03	0.00	0.00	98.58
	SM/11	Orange	17-12-2013	IV	56.11	12.18	2.31	3.31	1.84	1.06	0.29	0.04	0.08	0.01	0.00	0.00	1.99	19.07	0.00	1.18	0.01	0.13	0.00	0.00	99.62
	SM/11	**Orange**	**17-12-2013**	**Average**	**52.60**	**12.28**	**2.15**	**3.10**	**1.81**	**1.23**	**0.40**	**0.03**	**0.02**	**0.04**	**0.05**	**0.00**	**4.68**	**20.25**	**0.03**	**1.58**	**0.01**	**0.10**	**0.00**	**0.00**	**100.37**
	SM/11	**Orange**	**17-12-2013**	**Std. Dev.**	**4.08**	**0.20**	**0.49**	**0.21**	**0.05**	**0.11**	**0.08**	**0.02**	**0.04**	**0.04**	**0.09**	**0.00**	**2.97**	**2.82**	**0.06**	**0.37**	**0.02**	**0.11**	**0.00**	**0.00**	
31	DKS/01	Turquoise	01-03-2013	I	71.04	14.43	3.71	2.94	2.53	1.29	0.41	0.05	0.00	0.00	2.40	0.00	0.03	0.00	0.07	0.08	0.06	0.45	0.27	0.00	99.74
	DKS/01	Turquoise	01-03-2013	II	68.24	15.07	4.07	2.98	2.31	1.37	0.41	0.05	0.00	0.01	3.10	0.00	0.08	0.02	0.06	0.15	0.03	0.76	0.34	0.18	99.23
	DKS/01	Turquoise	01-03-2013	III	71.85	14.31	3.60	3.25	2.49	1.17	0.46	0.05	0.11	0.04	2.50	0.02	0.00	0.09	0.06	0.00	0.00	0.18	0.33	0.00	100.49
	DKS/01	Turquoise	01-03-2013	IV	70.43	14.65	3.90	2.73	2.41	1.24	0.41	0.05	0.00	0.08	2.85	0.00	0.00	0.12	0.03	0.00	0.07	0.34	0.40	0.00	99.70
	DKS/01	Turquoise	01-03-2013	V	71.35	14.74	3.79	3.02	2.34	1.27	0.46	0.05	0.00	0.02	2.67	0.06	0.00	0.10	0.00	0.00	0.04	0.38	0.19	0.00	100.47
	DKS/01	**Turquoise**	**01-03-2013**	**Average**	**70.58**	**14.64**	**3.81**	**2.98**	**2.41**	**1.27**	**0.43**	**0.05**	**0.02**	**0.03**	**2.70**	**0.02**	**0.02**	**0.06**	**0.04**	**0.04**	**0.04**	**0.42**	**0.31**	**0.04**	**99.93**
	DKS/01	**Turquoise**	**01-03-2013**	**Std. Dev.**	**1.41**	**0.30**	**0.18**	**0.19**	**0.09**	**0.07**	**0.03**	**0.00**	**0.05**	**0.03**	**0.28**	**0.03**	**0.03**	**0.05**	**0.03**	**0.07**	**0.03**	**0.21**	**0.08**	**0.08**	
32	DKS/02	Orange	01-03-2013	I	45.18	11.98	2.24	1.93	1.59	1.04	0.44	0.02	0.00	0.07	0.00	0.00	4.71	27.82	0.00	2.51	0.00	0.41	0.00	0.00	99.94
	DKS/02	Orange	01-03-2013	II	46.61	12.70	2.69	1.62	1.88	1.24	0.52	0.06	0.11	0.00	0.04	0.00	3.26	28.60	0.00	2.18	0.09	0.54	0.00	0.00	102.14
	DKS/02	Orange	01-03-2013	III	42.26	12.76	2.49	1.68	1.70	1.21	0.67	0.00	0.00	0.00	0.00	0.02	4.79	29.63	0.01	2.52	0.07	0.00	0.00	0.00	99.82
	DKS/02	Orange	01-03-2013	IV	44.60	12.53	3.16	1.84	1.98	1.79	0.63	0.01	0.00	0.04	0.08	0.00	2.74	28.08	0.03	2.49	0.08	0.00	0.00	0.01	100.09
	DKS/02	Orange	01-03-2013	V	43.28	12.31	2.25	1.69	1.95	1.24	0.54	0.00	0.07	0.00	0.16	0.01	4.90	31.16	0.00	3.30	0.03	0.37	0.00	0.00	103.25
	DKS/02	**Orange**	**01-03-2013**	**Average**	**44.39**	**12.46**	**2.57**	**1.75**	**1.82**	**1.30**	**0.56**	**0.02**	**0.04**	**0.02**	**0.06**	**0.01**	**4.08**	**29.06**	**0.01**	**2.60**	**0.05**	**0.26**	**0.00**	**0.00**	**101.05**
	DKS/02	**Orange**	**01-03-2013**	**Std. Dev.**	**1.69**	**0.32**	**0.38**	**0.13**	**0.17**	**0.28**	**0.09**	**0.02**	**0.05**	**0.03**	**0.07**	**0.01**	**1.01**	**1.36**	**0.01**	**0.42**	**0.04**	**0.25**	**0.00**	**0.01**	
33	DKS/03	Orange	01-03-2013	I	53.32	15.05	2.82	2.54	2.12	1.25	0.49	0.02	0.00	0.10	0.04	0.00	3.51	16.65	0.00	1.76	0.00	0.22	0.00	0.00	99.88
	DKS/03	Orange	01-03-2013	II	55.96	15.06	2.67	2.61	2.08	1.23	0.42	0.05	0.00	0.04	0.03	0.00	2.24	15.64	0.00	1.85	0.00	0.47	0.00	0.00	100.34
	DKS/03	Orange	01-03-2013	III	56.76	15.26	3.08	2.51	2.45	1.29	0.49	0.08	0.01	0.05	0.00	0.09	0.73	14.57	0.00	1.65	0.07	0.00	0.00	0.00	99.08
	DKS/03	Orange	01-03-2013	IV	58.83	14.99	2.77	2.90	1.96	0.97	0.60	0.00	0.01	0.04	0.00	0.02	2.57	14.90	0.08	1.60	0.00	0.14	0.00	0.00	102.39
	DKS/03	Orange	01-03-2013	V	56.01	15.12	3.18	2.67	2.26	1.21	0.50	0.06	0.00	0.07	0.00	0.00	1.20	15.16	0.00	1.18	0.06	0.28	0.00	0.00	98.94
	DKS/03	Orange	01-03-2013	VI	54.72	15.48	3.35	2.72	2.68	1.20	0.42	0.00	0.00	0.03	0.04	0.07	1.26	15.14	0.07	1.35	0.06	0.43	0.00	0.00	99.00
	DKS/03	**Orange**	**01-03-2013**	**Average**	**55.93**	**15.16**	**2.98**	**2.66**	**2.26**	**1.19**	**0.49**	**0.03**	**0.00**	**0.05**	**0.02**	**0.03**	**1.92**	**15.34**	**0.03**	**1.56**	**0.03**	**0.26**	**0.00**	**0.00**	**99.94**
	DKS/03	**Orange**	**01-03-2013**	**Std. Dev.**	**1.86**	**0.18**	**0.26**	**0.14**	**0.27**	**0.11**	**0.07**	**0.03**	**0.00**	**0.02**	**0.02**	**0.04**	**1.04**	**0.73**	**0.04**	**0.26**	**0.03**	**0.18**	**0.00**	**0.00**	
34	DKS/04	Green	01-03-2013	I	52.73	11.94	3.20	2.89	2.32	1.70	0.56	0.10	0.00	0.04	3.03	0.03	1.89	16.00	0.00	0.39	0.08	0.65	0.00	0.00	97.54
	DKS/04	Green	01-03-2013	II	50.97	10.86	3.11	2.68	2.13	1.71	0.56	0.07	0.00	0.05	3.24	0.01	4.24	18.60	0.07	0.33	0.10	0.26	0.00	0.00	99.02

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	DKS/04	Green	01-03-2013	III	52.99	12.28	3.22	2.85	1.89	1.81	0.72	0.06	0.00	0.00	3.23	0.03	2.23	16.64	0.02	0.31	0.04	0.40	0.00	0.00	98.70
	DKS/04	Green	01-03-2013	IV	50.77	12.30	2.99	2.85	2.31	1.79	0.52	0.08	0.02	0.05	2.92	0.02	1.92	17.00	0.02	0.07	0.06	0.41	0.00	0.00	96.09
	DKS/04	Green	01-03-2013	V	53.99	12.42	3.07	3.11	2.08	1.62	0.57	0.18	0.00	0.01	2.75	0.01	1.62	16.19	0.04	0.22	0.01	0.63	0.00	0.00	98.51
	DKS/04	Green	01-03-2013	VI	54.38	11.64	3.00	2.97	2.21	1.53	0.60	0.07	0.00	0.02	2.91	0.07	2.42	15.81	0.00	0.33	0.00	0.39	0.00	0.00	98.36
	DKS/04	**Green**	**01-03-2013**	**Average**	**52.64**	**11.91**	**3.10**	**2.89**	**2.16**	**1.69**	**0.59**	**0.09**	**0.00**	**0.03**	**3.01**	**0.03**	**2.39**	**16.71**	**0.03**	**0.27**	**0.05**	**0.46**	**0.00**	**0.00**	**98.04**
	DKS/04	**Green**	**01-03-2013**	**Std. Dev.**	**1.50**	**0.58**	**0.10**	**0.14**	**0.16**	**0.10**	**0.07**	**0.04**	**0.01**	**0.02**	**0.19**	**0.02**	**0.95**	**1.02**	**0.03**	**0.11**	**0.04**	**0.15**	**0.00**	**0.00**	
35	TS/01	Purple	02-02-2012	I	64.60	18.41	4.18	3.23	2.92	1.59	0.69	0.08	0.00	0.90	0.05	0.00	0.00	0.09	0.00	0.03	0.00	0.42	0.34	0.00	97.51
	TS/01	Purple	02-02-2012	II	64.49	18.23	4.11	3.13	2.96	1.55	0.76	0.09	0.00	0.91	0.04	0.00	0.00	0.04	0.01	0.03	0.00	0.31	0.44	0.00	97.09
	TS/01	Purple	02-02-2012	III	67.26	17.13	3.72	3.23	2.80	1.60	0.66	0.08	0.00	0.69	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.32	0.33	0.00	97.85
	TS/01	Purple	02-02-2012	IV	65.56	18.25	3.86	3.18	2.92	1.62	0.81	0.09	0.00	0.86	0.07	0.03	0.00	0.02	0.01	0.04	0.00	0.42	0.39	0.00	98.13
	TS/01	Purple	02-02-2012	V	68.58	17.81	3.91	3.12	2.86	1.51	0.56	0.06	0.01	0.89	0.00	0.03	0.00	0.04	0.07	0.09	0.03	0.31	0.38	0.00	100.25
	TS/01	**Purple**	**02-02-2012**	**Average**	**66.10**	**17.97**	**3.96**	**3.17**	**2.89**	**1.57**	**0.70**	**0.08**	**0.00**	**0.85**	**0.04**	**0.01**	**0.00**	**0.04**	**0.02**	**0.04**	**0.01**	**0.36**	**0.38**	**0.00**	**98.16**
	TS/01	**Purple**	**02-02-2012**	**Std. Dev.**	**1.78**	**0.52**	**0.19**	**0.05**	**0.06**	**0.04**	**0.10**	**0.01**	**0.01**	**0.09**	**0.03**	**0.02**	**0.00**	**0.03**	**0.03**	**0.03**	**0.01**	**0.06**	**0.04**	**0.00**	
36	TS/02	Yellow	07-02-2012	I	42.72	10.76	2.16	2.39	1.70	1.93	0.65	0.09	0.00	0.01	0.05	0.06	5.51	29.51	0.00	0.28	0.04	0.25	0.00	0.00	98.10
	TS/02	Yellow	07-02-2012	II	42.64	9.75	1.98	2.56	1.82	2.23	0.63	0.10	0.00	0.00	0.00	0.00	4.91	28.96	0.00	0.44	0.03	0.17	0.00	0.00	96.22
	TS/02	Yellow	07-02-2012	III	43.83	12.49	1.99	2.47	1.90	1.56	0.65	0.05	0.00	0.03	0.06	0.00	4.07	30.14	0.00	0.24	0.00	0.27	0.00	0.00	99.73
	TS/02	Yellow	07-02-2012	IV	42.64	9.75	1.98	2.56	1.82	2.23	0.63	0.10	0.00	0.00	0.00	0.00	4.91	28.96	0.00	0.44	0.03	0.17	0.00	0.00	96.22
	TS/02	**Yellow**	**07-02-2012**	**Average**	**42.96**	**10.69**	**2.03**	**2.50**	**1.81**	**1.99**	**0.64**	**0.09**	**0.00**	**0.01**	**0.03**	**0.01**	**4.85**	**29.39**	**0.00**	**0.35**	**0.02**	**0.21**	**0.00**	**0.00**	**97.57**
	TS/02	**Yellow**	**07-02-2012**	**Std. Dev.**	**0.58**	**1.29**	**0.09**	**0.08**	**0.08**	**0.32**	**0.01**	**0.03**	**0.00**	**0.01**	**0.03**	**0.03**	**0.59**	**0.56**	**0.00**	**0.11**	**0.02**	**0.06**	**0.00**	**0.00**	
37	TS/03	Dark-Blue	16-02-2013	I	62.93	19.34	3.80	3.45	2.77	1.70	2.66	0.05	0.00	0.04	0.18	0.22	0.00	0.00	0.05	0.11	0.01	0.26	0.50	0.00	98.08
	TS/03	Dark-Blue	16-02-2013	II	63.99	19.21	4.02	3.45	2.71	1.73	1.19	0.07	0.00	0.03	0.04	0.22	0.00	0.08	0.00	0.02	0.01	0.36	0.60	0.00	97.75
	TS/03	Dark-Blue	16-02-2013	III	62.67	19.05	3.84	3.50	2.67	1.72	1.74	0.09	0.08	0.04	0.06	0.39	0.00	0.00	0.03	0.05	0.03	0.26	0.50	0.19	96.91
	TS/03	Dark-Blue	16-02-2013	IV	64.44	18.99	3.68	3.64	2.59	1.77	1.30	0.07	0.00	0.03	0.07	0.23	0.00	0.00	0.07	0.02	0.00	0.33	0.53	0.20	97.96
	TS/03	**Dark-Blue**	**16-02-2013**	**Average**	**63.51**	**19.15**	**3.84**	**3.51**	**2.69**	**1.73**	**1.72**	**0.07**	**0.02**	**0.03**	**0.09**	**0.27**	**0.00**	**0.02**	**0.04**	**0.05**	**0.01**	**0.30**	**0.53**	**0.10**	**97.67**
	TS/03	**Dark-Blue**	**16-02-2013**	**Std. Dev.**	**0.84**	**0.16**	**0.14**	**0.09**	**0.07**	**0.03**	**0.67**	**0.01**	**0.04**	**0.01**	**0.06**	**0.08**	**0.00**	**0.04**	**0.03**	**0.04**	**0.01**	**0.05**	**0.05**	**0.11**	
38	TS/04	Orange	22-02-2012	I	51.11	12.08	2.73	2.97	1.91	1.45	0.66	0.07	0.00	0.04	0.05	0.00	3.58	19.54	0.00	1.80	0.02	0.28	0.00	0.00	98.28
	TS/04	Orange	22-02-2012	II	51.12	11.92	1.99	3.02	1.75	1.24	0.42	0.02	0.00	0.08	0.00	0.00	6.07	21.64	0.01	2.09	0.00	0.15	0.00	0.00	101.51
	TS/04	Orange	22-02-2012	III	51.33	11.74	2.78	3.26	2.24	1.56	0.48	0.06	0.00	0.05	0.08	0.01	2.34	15.09	0.01	1.71	0.05	0.21	0.00	0.00	92.99
	TS/04	Orange	22-02-2012	IV	52.41	11.63	2.43	2.95	1.97	1.48	0.54	0.03	0.00	0.04	0.00	0.00	4.38	17.46	0.00	2.11	0.00	0.12	0.00	0.00	97.56
	TS/04	**Orange**	**22-02-2012**	**Average**	**51.49**	**11.84**	**2.48**	**3.05**	**1.97**	**1.43**	**0.53**	**0.04**	**0.00**	**0.05**	**0.03**	**0.00**	**4.09**	**18.43**	**0.01**	**1.93**	**0.02**	**0.19**	**0.00**	**0.00**	**97.58**
	TS/04	**Orange**	**22-02-2012**	**Std. Dev.**	**0.62**	**0.20**	**0.36**	**0.14**	**0.20**	**0.14**	**0.10**	**0.02**	**0.00**	**0.02**	**0.04**	**0.01**	**1.57**	**2.81**	**0.01**	**0.20**	**0.02**	**0.07**	**0.00**	**0.00**	
39	TS/05	Purple	22-02-2012	I	61.80	16.39	1.68	2.72	1.04	8.86	3.38	0.45	0.00	1.06	0.00	0.02	0.00	0.31	0.01	0.03	0.05	0.12	0.40	0.00	98.31
	TS/05	Purple	22-02-2012	II	62.37	17.81	1.52	3.23	1.00	9.63	2.63	0.43	0.00	0.72	0.04	0.01	0.00	0.06	0.01	0.12	0.08	0.25	0.30	0.00	100.18
	TS/05	Purple	22-02-2012	III	62.69	18.72	1.76	2.53	1.09	8.81	2.44	0.48	0.00	0.29	0.00	0.01	0.00	0.54	0.02	0.01	0.03	0.44	0.34	0.02	100.21
	TS/05	Purple	22-02-2012	IV	62.63	16.64	1.66	2.81	1.06	8.15	3.10	0.43	0.00	1.28	0.05	0.01	0.00	0.81	0.00	0.00	0.10	0.39	0.30	0.00	99.42
	TS/05	**Purple**	**22-02-2012**	**Average**	**62.37**	**17.39**	**1.66**	**2.82**	**1.05**	**8.86**	**2.89**	**0.45**	**0.00**	**0.84**	**0.02**	**0.01**	**0.00**	**0.43**	**0.01**	**0.04**	**0.07**	**0.30**	**0.34**	**0.01**	**99.53**
	TS/05	**Purple**	**22-02-2012**	**Std. Dev.**	**0.41**	**1.08**	**0.10**	**0.29**	**0.04**	**0.60**	**0.43**	**0.03**	**0.00**	**0.43**	**0.03**	**0.01**	**0.00**	**0.32**	**0.01**	**0.05**	**0.03**	**0.15**	**0.05**	**0.01**	
40	TS/06	Green	02-02-2012	I	49.69	11.95	2.66	3.20	2.17	1.63	0.64	0.08	0.00	0.00	3.10	0.05	3.84	18.65	0.00	0.37	0.09	0.24	0.00	0.00	98.34
	TS/06	Green	02-02-2012	II	51.24	9.65	2.41	3.64	2.16	1.59	0.58	0.06	0.00	0.01	2.93	0.00	5.70	18.54	0.02	0.34	0.00	0.19	0.00	0.00	99.06
	TS/06	Green	02-02-2012	III	51.55	12.26	2.63	3.45	2.05	1.78	0.56	0.07	0.00	0.06	3.04	0.00	3.61	17.94	0.00	0.31	0.03	0.28	0.00	0.00	99.62
	TS/06	Green	02-02-2012	IV	53.17	11.67	2.35	3.30	1.68	1.42	0.58	0.01	0.00	0.00	3.10	0.01	4.78	18.22	0.00	0.41	0.05	0.07	0.00	0.00	100.81
	TS/06	**Green**	**02-02-2012**	**Average**	**51.41**	**11.38**	**2.51**	**3.40**	**2.01**	**1.61**	**0.59**	**0.06**	**0.00**	**0.02**	**3.04**	**0.02**	**4.49**	**18.33**	**0.01**	**0.36**	**0.04**	**0.19**	**0.00**	**0.00**	**99.46**
	TS/06	**Green**	**02-02-2012**	**Std. Dev.**	**1.43**	**1.18**	**0.16**	**0.19**	**0.23**	**0.15**	**0.03**	**0.03**	**0.00**	**0.03**	**0.08**	**0.02**	**0.96**	**0.32**	**0.01**	**0.05**	**0.04**	**0.09**	**0.00**	**0.00**	
41	TS/07	Green	07-02-2012	I	26.63	2.45	0.00	0.44	0.19	1.30	0.49	0.01	0.00	0.00	1.49	0.00	5.63	60.81	0.00	1.75	0.00	0.19	0.00	0.00	101.37
	TS/07	Green	07-02-2012	II	26.67	2.68	0.00	0.43	0.16	1.24	0.62	0.06	0.00	0.03	1.33	0.00	5.56	61.10	0.05	1.59	0.07	0.00	0.00	0.00	101.57
	TS/07	Green	07-02-2012	III	26.66	2.55	0.00	0.38	0.16	1.13	0.41	0.00	0.00	0.04	1.24	0.03	6.58	60.78	0.12	1.47	0.09	0.01	0.00	0.00	101.64

No.	Sample	Colour	Date	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	Sb_2O_5	MnO	CuO	CoO	SnO_2	PbO	NiO	ZnO	BaO	P_2O_5	SO_3	As_2O_5	Total
	TS/07	Green	07-02-2012	IV	27.75	2.57	0.08	0.42	0.14	1.10	0.40	0.02	0.00	0.02	1.43	0.04	4.78	59.63	0.01	1.53	0.02	0.04	0.00	0.00	99.97
	TS/07	**Green**	**07-02-2012**	**Average**	**26.93**	**2.56**	**0.02**	**0.41**	**0.16**	**1.19**	**0.48**	**0.02**	**0.00**	**0.02**	**1.37**	**0.02**	**5.64**	**60.58**	**0.04**	**1.59**	**0.05**	**0.06**	**0.00**	**0.00**	**101.14**
	TS/07	**Green**	**07-02-2012**	**Std. Dev.**	**0.55**	**0.09**	**0.04**	**0.03**	**0.02**	**0.09**	**0.10**	**0.03**	**0.00**	**0.02**	**0.11**	**0.02**	**0.74**	**0.65**	**0.05**	**0.12**	**0.04**	**0.09**	**0.00**	**0.00**	
42	TS/08	Yellow	21-06-2012	I	49.65	12.52	3.15	2.32	2.03	1.47	0.49	0.03	0.00	0.06	0.00	0.00	1.34	15.15	0.00	0.18	0.03	0.33	0.21	0.00	88.94
	TS/08	Yellow	21-06-2012	II	51.14	11.05	3.01	2.38	2.01	1.57	0.50	0.06	0.00	0.02	0.00	0.02	1.66	15.27	0.07	0.34	0.01	0.31	0.22	0.00	89.63
	TS/08	Yellow	13-12-2013	III	53.19	13.45	2.92	2.47	2.29	1.82	0.70	0.07	0.05	0.07	0.00	0.07	3.36	18.03	0.09	0.55	0.02	0.35	0.00	0.00	99.49
	TS/08	Yellow	13-12-2013	IV	53.25	13.50	2.74	2.51	2.57	1.72	0.64	0.06	0.00	0.04	0.00	0.00	3.08	18.97	0.10	0.45	0.00	0.35	0.00	0.00	99.98
	TS/08	Yellow	13-12-2013	V	51.12	13.16	2.71	2.18	1.93	1.79	0.52	0.01	0.00	0.00	0.00	0.00	5.51	20.33	0.01	0.75	0.00	0.42	0.00	0.00	100.44
	TS/08	**Yellow**	**21-06-2012**	**Average**	**51.67**	**12.74**	**2.91**	**2.37**	**2.16**	**1.67**	**0.57**	**0.05**	**0.01**	**0.04**	**0.00**	**0.02**	**2.99**	**17.55**	**0.05**	**0.45**	**0.01**	**0.35**	**0.09**	**0.00**	**95.70**
	TS/08	**Yellow**	**21-06-2012**	**Std. Dev.**	**1.54**	**1.02**	**0.18**	**0.13**	**0.26**	**0.15**	**0.10**	**0.02**	**0.02**	**0.03**	**0.00**	**0.03**	**1.66**	**2.29**	**0.05**	**0.22**	**0.01**	**0.04**	**0.12**	**0.00**	
43	TS/09	Yellow	21-06-2012	I	44.33	12.56	2.15	2.58	1.82	1.70	0.57	0.12	0.00	0.04	0.05	0.00	2.98	28.79	0.05	0.33	0.00	0.16	0.00	0.00	98.22
	TS/09	Yellow	21-06-2012	II	39.70	12.00	1.93	2.20	1.69	1.68	0.57	0.07	0.00	0.04	0.08	0.00	5.41	32.66	0.06	0.37	0.01	0.18	0.00	0.00	98.65
	TS/09	Yellow	21-06-2012	III	43.85	12.99	2.13	2.50	2.04	1.74	0.65	0.08	0.00	0.02	0.16	0.04	2.57	28.29	0.00	0.31	0.00	0.15	0.00	0.00	97.52
	TS/09	Yellow	21-06-2012	IV	43.22	12.95	2.41	2.50	2.00	1.77	0.61	0.02	0.00	0.04	0.11	0.01	3.65	28.68	0.01	0.40	0.03	0.27	0.00	0.00	98.69
	TS/09	**Yellow**	**21-06-2012**	**Average**	**42.78**	**12.62**	**2.16**	**2.44**	**1.89**	**1.72**	**0.60**	**0.07**	**0.00**	**0.04**	**0.10**	**0.01**	**3.65**	**29.61**	**0.03**	**0.35**	**0.01**	**0.19**	**0.00**	**0.00**	**98.27**
	TS/09	**Yellow**	**21-06-2012**	**Std. Dev.**	**2.10**	**0.46**	**0.20**	**0.17**	**0.17**	**0.04**	**0.04**	**0.04**	**0.00**	**0.01**	**0.04**	**0.02**	**1.26**	**2.05**	**0.03**	**0.04**	**0.02**	**0.05**	**0.00**	**0.00**	
44	TS/10	Dark-Blue	21-06-2012	I	62.26	17.64	4.04	3.85	2.58	1.63	1.17	0.04	0.04	0.09	0.10	0.20	0.00	0.00	0.13	0.07	0.08	0.39	0.58	0.25	95.12
	TS/10	Dark-Blue	21-06-2012	II	62.85	16.48	3.82	3.92	2.37	1.87	1.00	0.03	0.00	0.02	0.13	0.17	0.00	0.00	0.01	0.00	0.00	0.34	0.56	0.08	93.65
	TS/10	Dark-Blue	21-06-2012	III	61.29	17.87	4.43	3.84	2.85	1.63	1.42	0.05	0.00	0.05	0.11	0.23	0.00	0.00	0.03	0.06	0.00	0.41	0.55	0.06	94.88
	TS/10	Dark-Blue	21-06-2012	IV	62.25	17.40	3.90	4.05	2.55	1.76	1.16	0.04	0.00	0.04	0.01	0.24	0.02	0.00	0.02	0.02	0.02	0.31	0.53	0.09	94.40
	TS/10	**Dark-Blue**	**21-06-2012**	**Average**	**62.16**	**17.35**	**4.05**	**3.91**	**2.59**	**1.72**	**1.19**	**0.04**	**0.01**	**0.05**	**0.09**	**0.21**	**0.00**	**0.00**	**0.05**	**0.04**	**0.03**	**0.36**	**0.56**	**0.12**	**94.51**
	TS/10	**Dark-Blue**	**21-06-2012**	**Std. Dev.**	**0.65**	**0.61**	**0.27**	**0.10**	**0.20**	**0.11**	**0.17**	**0.01**	**0.02**	**0.03**	**0.05**	**0.03**	**0.01**	**0.00**	**0.05**	**0.03**	**0.04**	**0.05**	**0.02**	**0.09**	
45	TS/11	Dark-Blue	21-06-2012	I	61.42	11.54	3.69	3.69	2.44	1.54	1.42	0.04	0.00	0.04	0.05	0.33	2.84	1.24	0.01	0.04	0.00	0.24	0.19	0.02	90.77
	TS/11	Dark-Blue	21-06-2012	II	60.23	10.61	3.21	3.44	2.19	1.57	1.09	0.05	0.00	0.04	0.05	0.29	2.13	1.30	0.03	0.09	0.00	0.28	0.18	0.01	86.78
	TS/11	Dark-Blue	21-06-2012	III	56.36	11.50	3.31	3.70	2.57	1.74	1.47	0.06	0.00	0.02	0.05	0.36	3.38	1.48	0.01	0.00	0.00	0.21	0.22	0.00	86.42
	TS/11	**Dark-Blue**	**21-06-2012**	**Average**	**59.34**	**11.22**	**3.40**	**3.61**	**2.40**	**1.61**	**1.33**	**0.05**	**0.00**	**0.03**	**0.05**	**0.33**	**2.78**	**1.34**	**0.02**	**0.04**	**0.00**	**0.24**	**0.20**	**0.01**	**87.99**
	TS/11	**Dark-Blue**	**21-06-2012**	**Std. Dev.**	**2.65**	**0.53**	**0.25**	**0.15**	**0.19**	**0.11**	**0.20**	**0.01**	**0.00**	**0.01**	**0.00**	**0.03**	**0.62**	**0.13**	**0.01**	**0.04**	**0.00**	**0.04**	**0.02**	**0.01**	
46	TS/12	Green	21-06-2012	I	27.43	2.84	0.00	0.50	0.15	1.45	0.61	0.06	0.06	0.01	1.33	0.03	7.21	56.22	0.04	1.42	0.06	0.00	0.00	0.00	99.41
	TS/12	Green	21-06-2012	II	27.62	2.70	0.16	0.47	0.16	1.33	0.48	0.10	0.07	0.01	1.16	0.00	3.53	59.39	0.04	1.24	0.01	0.00	0.00	0.00	98.46
	TS/12	Green	21-06-2012	III	27.90	2.44	0.00	0.46	0.10	0.94	0.30	0.01	0.00	0.00	0.77	0.00	8.09	55.82	0.00	1.08	0.11	0.06	0.00	0.00	98.09
	TS/12	**Green**	**21-06-2012**	**Average**	**27.65**	**2.66**	**0.05**	**0.48**	**0.14**	**1.24**	**0.47**	**0.06**	**0.04**	**0.01**	**1.08**	**0.01**	**6.28**	**57.14**	**0.03**	**1.25**	**0.06**	**0.02**	**0.00**	**0.00**	**98.66**
	TS/12	**Green**	**21-06-2012**	**Std. Dev.**	**0.24**	**0.20**	**0.09**	**0.02**	**0.03**	**0.27**	**0.16**	**0.04**	**0.04**	**0.01**	**0.29**	**0.02**	**2.42**	**1.96**	**0.02**	**0.17**	**0.05**	**0.04**	**0.00**	**0.00**	
47	TS/13	Orange	21-06-2012	I	54.21	12.19	2.51	3.15	1.91	1.06	0.41	0.01	0.00	0.03	0.11	0.00	2.83	18.46	0.00	1.73	0.04	0.16	0.00	0.03	98.83
	TS/13	Orange	21-06-2012	II	44.65	11.13	2.57	2.79	1.94	1.52	0.55	0.03	0.00	0.04	0.01	0.00	3.87	17.11	0.01	1.46	0.02	0.30	0.00	0.00	88.00
	TS/13	Orange	21-06-2012	III	45.61	10.69	2.45	2.43	1.85	1.60	0.61	0.06	0.00	0.02	0.00	0.04	3.67	16.28	0.00	1.41	0.01	0.12	0.00	0.00	86.86
	TS/13	Orange	21-06-2012	IV	53.56	11.44	2.22	3.22	2.01	1.16	0.42	0.04	0.00	0.06	0.03	0.02	3.09	18.60	0.04	1.54	0.04	0.05	0.00	0.06	97.61
	TS/13	**Orange**	**21-06-2012**	**Average**	**49.51**	**11.36**	**2.44**	**2.90**	**1.93**	**1.34**	**0.50**	**0.03**	**0.00**	**0.04**	**0.04**	**0.02**	**3.37**	**17.61**	**0.01**	**1.54**	**0.03**	**0.16**	**0.00**	**0.02**	**92.82**
	TS/13	**Orange**	**21-06-2012**	**Std. Dev.**	**5.08**	**0.63**	**0.15**	**0.36**	**0.07**	**0.26**	**0.10**	**0.02**	**0.00**	**0.02**	**0.05**	**0.02**	**0.49**	**1.11**	**0.02**	**0.14**	**0.01**	**0.11**	**0.00**	**0.03**	



Appendix 7.20 Scatter plots of (a) alumina versus iron oxide, (b) alumina versus titanium oxide, (c) lime versus magnesia, (d) alumina versus potash, (e) alumina versus magnesia, and (f) alumina versus silica contents of the Mughal tile glazes. '*' indicates reduced composition.



Appendix 7.21 Scatter plots of (a) soda versus lime (b) soda versus potash (c) soda versus magnesia and (d) soda versus alumina contents of the Mughal tile glazes. '*' indicates reduced composition.

Appendix 7.22 Compositions of lead stannate particles in select yellow and green glazes from the Delhi group of buildings. All results are in wt% from SEM-EDS analyses, and normalised to 100 %. '-' indicates ‘not detected’ or 'below detection limit’.

No.	Sample	Colour	Particle	WEIGHT PERCENT					ATOMIC PERCENT					
				SiO_2	ZnO	SnO_2	PbO	Total	O	Si	Zn	Sn	Pb	Total
1	AS/01	Green	I	4.6	-	30.6	64.8	100.0	59.8	5.4	-	14.3	20.5	100.0
	AS/01	Green	II	4.8	-	28.7	66.6	100.0	59.6	5.6	-	13.6	21.2	100.0
	AS/01	Green	III	5.0	-	28.5	66.5	100.0	59.6	5.9	-	13.4	21.1	100.0
	AS/01	Green	IV	4.2	-	30.3	65.5	100.0	59.7	5.0	-	14.4	21.0	100.0
	AS/01	Green	V	4.7	-	29.8	65.5	100.0	59.8	5.6	-	14.0	20.7	100.0
	AS/01	Green	VI	4.4	-	30.3	65.3	100.0	59.7	5.2	-	14.3	20.8	100.0
2	AS/04	Yellow	I	4.3	-	30.2	65.5	100.0	59.7	5.1	-	14.3	20.9	100.0
	AS/04	Yellow	II	5.2	-	27.3	67.5	100.0	59.5	6.2	-	12.8	21.5	100.0
	AS/04	Yellow	III	4.3	-	29.6	66.1	100.0	59.7	5.2	-	14.0	21.1	100.0
	AS/04	Yellow	IV	-	6.0	34.7	59.3	100.0	58.8	-	5.3	16.6	19.3	100.0
	AS/04	Yellow	V	4.5	-	30.6	64.9	100.0	59.9	5.3	-	14.3	20.5	100.0
3	AK/01	Yellow	I	5.4	-	26.6	68.0	100.0	59.6	6.4	-	12.5	21.6	100.0
	AK/01	Yellow	II	-	6.0	34.7	59.3	100.0	58.9	-	5.3	16.6	19.2	100.0
	AK/01	Yellow	III	7.4	-	31.6	61.0	100.0	60.9	8.0	-	13.5	17.6	100.0
	AK/01	Yellow	IV	4.6	-	29.5	66.0	100.0	59.8	5.4	-	13.9	20.9	100.0
4	NG/06	Yellow	I	5.4	-	29.5	65.1	100.0	60.0	6.2	-	13.6	20.2	100.0
	NG/06	Yellow	II	-	6.5	36.2	57.2	100.0	58.6	-	5.8	17.2	18.4	100.0
	NG/06	Yellow	III	5.2	-	27.6	67.2	100.0	59.6	6.2	-	13.0	21.3	100.0
	NG/06	Yellow	IV	5.4	-	31.3	63.4	100.0	60.2	6.1	-	14.3	19.5	100.0
	NG/06	Yellow	V	5.4	-	29.1	65.6	100.0	59.8	6.2	-	13.5	20.5	100.0
5	NG/07	Yellow	I	5.2	-	31.3	63.5	100.0	60.2	5.9	-	14.3	19.6	100.0
	NG/07	Yellow	II	4.8	-	27.6	67.6	100.0	59.3	5.7	-	13.2	21.8	100.0
	NG/07	Yellow	III	-	12.8	33.7	53.5	100.0	57.5	-	10.8	15.3	16.4	100.0
	NG/07	Yellow	IV	5.4	-	31.0	63.6	100.0	60.1	6.2	-	14.1	19.6	100.0
	NG/07	Yellow	V	-	6.5	37.1	56.4	100.0	58.7	-	5.7	17.6	18.0	100.0
	NG/07	Yellow	VI	9.3	-	28.8	61.9	100.0	60.9	9.7	-	12.0	17.4	100.0
6	SB/06	Yellow	I	4.6	-	30.4	65.0	100.0	59.9	5.4	-	14.2	20.5	100.0
	SB/06	Yellow	II	-	6.5	37.1	56.4	100.0	58.8	-	5.7	17.5	18.0	100.0
	SB/06	Yellow	III	5.4	-	27.4	67.2	100.0	59.7	6.3	-	12.8	21.2	100.0
	SB/06	Yellow	IV	-	5.7	36.3	58.0	100.0	58.7	-	5.1	17.4	18.8	100.0
7	SB/07	Yellow	I	-	6.0	36.9	57.1	100.0	58.7	-	5.3	17.6	18.4	100.0
	SB/07	Yellow	II	5.4	-	31.3	63.3	100.0	60.2	6.2	-	14.2	19.4	100.0
	SB/07	Yellow	III	-	6.2	37.2	56.6	100.0	58.8	-	5.4	17.7	18.1	100.0
	SB/07	Yellow	IV	-	6.9	36.9	56.3	100.0	58.7	-	6.0	17.4	17.9	100.0

Appendix 7.23 Compositions of lead stannate particles in select yellow, green, and orange glazes from the Punjab group of buildings. All results are in wt% from SEM-EDS analyses, and normalised to 100 %. '-' indicates 'not detected' or 'below detection limit'.

No.	Sample	Colour	Particle	WEIGHT PERCENT					ATOMIC PERCENT					
				SiO_2	ZnO	SnO_2	PbO	Total	O	Si	Zn	Sn	Pb	Total
1	DS/01	Yellow	I	4.7	-	31.2	64.2	100.0	60.0	5.4	-	14.5	20.1	100.0
	DS/01	Yellow	II	4.8	-	29.5	65.8	100.0	59.7	5.6	-	13.9	20.8	100.0
	DS/01	Yellow	III	4.4	-	30.1	65.5	100.0	59.8	5.2	-	14.2	20.8	100.0
	DS/01	Yellow	IV	4.4	-	30.0	65.6	100.0	59.8	5.2	-	14.2	20.8	100.0
	DS/01	Yellow	V	4.3	-	30.6	65.2	100.0	59.7	5.0	-	14.4	20.8	100.0
2	DS/05	Yellow	I	4.5	-	30.5	65.1	100.0	59.8	5.3	-	14.3	20.6	100.0
	DS/05	Yellow	II	4.2	-	30.8	65.1	100.0	59.7	4.9	-	14.6	20.8	100.0
	DS/05	Yellow	III	4.6	-	29.6	65.8	100.0	59.7	5.4	-	13.9	20.9	100.0
	DS/05	Yellow	IV	4.2	-	31.9	63.9	100.0	59.9	4.9	-	15.0	20.2	100.0
	DS/05	Yellow	V	4.6	-	29.7	65.7	100.0	59.7	5.5	-	14.0	20.9	100.0
3	DS/09	Green	I	5.0	-	28.2	66.8	100.0	59.6	5.9	-	13.3	21.2	100.0
	DS/09	Green	II	6.3	-	26.8	66.9	100.0	59.9	7.3	-	12.2	20.6	100.0
	DS/09	Green	III	4.3	-	31.2	64.5	100.0	59.9	5.1	-	14.6	20.4	100.0
	DS/09	Green	IV	5.8	-	27.9	66.4	100.0	59.8	6.7	-	12.9	20.7	100.0
	DS/09	Green	V	7.1	-	28.2	64.6	100.0	60.2	7.9	-	12.5	19.3	100.0
4	FS/01	Yellow	I	-	6.1	34.7	59.2	100.0	58.5	-	5.4	16.8	19.3	100.0
	FS/01	Yellow	II	4.4	-	29.0	66.7	100.0	59.5	5.2	-	13.8	21.5	100.0
	FS/01	Yellow	III	5.1	-	27.0	67.9	100.0	59.4	6.1	-	12.8	21.7	100.0
	FS/01	Yellow	IV	4.4	-	29.6	66.0	100.0	59.6	5.2	-	14.1	21.2	100.0
	FS/01	Yellow	V	4.7	-	28.7	66.6	100.0	59.6	5.6	-	13.6	21.3	100.0
5	SM/02	Yellow	I	4.8	-	32.0	63.1	100.0	60.1	5.6	-	14.7	19.6	100.0
	SM/02	Yellow	II	-	6.1	37.4	56.5	100.0	58.9	-	5.4	17.7	18.1	100.0
	SM/02	Yellow	III	-	5.8	38.3	55.9	100.0	59.0	-	5.1	18.1	17.8	100.0
	SM/02	Yellow	IV	-	6.1	37.5	56.4	100.0	58.9	-	5.4	17.8	18.0	100.0
	SM/02	Yellow	V	5.2	-	31.4	63.4	100.0	60.2	6.0	-	14.3	19.6	100.0
	SM/02	Yellow	VI	5.1	-	32.8	62.1	100.0	60.3	5.8	-	14.9	19.0	100.0
6	SM/04	Orange	I	-	6.7	38.0	55.3	100.0	58.9	-	5.8	17.8	17.5	100.0
	SM/04	Orange	II	-	6.9	37.2	56.0	100.0	58.7	-	6.0	17.5	17.8	100.0
	SM/04	Orange	III	-	6.2	37.2	56.6	100.0	58.8	-	5.4	17.7	18.1	100.0
	SM/04	Orange	IV	-	6.9	36.9	56.3	100.0	58.7	-	6.0	17.4	17.9	100.0
7	SM/05	Green	I	4.8	-	32.3	62.8	100.0	60.2	5.6	-	14.8	19.4	100.0
	SM/05	Green	II	5.4	-	32.5	62.0	100.0	60.3	6.1	-	14.7	18.9	100.0
	SM/05	Green	III	5.2	-	32.6	62.3	100.0	60.3	5.9	-	14.8	19.0	100.0
	SM/05	Green	IV	7.0	-	33.9	59.1	100.0	61.0	7.5	-	14.5	17.0	100.0
8	SM/11	Orange	I	-	6.4	35.0	58.7	100.0	58.4	-	5.7	16.8	19.1	100.0
	SM/11	Orange	II	-	6.1	35.7	58.2	100.0	58.6	-	5.4	17.1	18.9	100.0
	SM/11	Orange	III	-	6.7	35.2	58.1	100.0	58.4	-	6.0	16.9	18.8	100.0
	SM/11	Orange	IV	-	6.2	34.9	58.9	100.0	58.4	-	5.5	16.9	19.2	100.0
	SM/11	Orange	V	-	6.2	35.0	58.9	100.0	58.4	-	5.5	16.9	19.2	100.0
	SM/11	Orange	VI	-	6.2	35.2	58.6	100.0	58.5	-	5.5	17.0	19.1	100.0

No.	Sample	Colour	Particle	SiO_2	ZnO	SnO_2	PbO	Total	O	Si	Zn	Sn	Pb	Total
9	DKS/03	Orange	I	-	3.8	35.1	61.1	100.0	58.7	-	3.5	17.4	20.4	100.0
	DKS/03	Orange	II	-	4.0	35.4	60.7	100.0	58.7	-	3.6	17.4	20.2	100.0
	DKS/03	Orange	III	-	4.3	35.3	60.4	100.0	58.7	-	3.9	17.4	20.1	100.0
	DKS/03	Orange	IV	-	3.9	35.0	61.1	100.0	58.7	-	3.6	17.3	20.4	100.0
	DKS/03	Orange	V	-	4.3	35.3	60.4	100.0	58.7	-	3.9	17.4	20.1	100.0
10	DKS/04	Green	I	8.8	-	28.5	62.7	100.0	60.7	9.4	-	12.0	17.9	100.0
	DKS/04	Green	II	-	4.2	35.3	60.5	100.0	58.8	-	3.8	17.3	20.1	100.0
	DKS/04	Green	III	5.4	-	27.2	67.5	100.0	59.5	6.3	-	12.8	21.4	100.0
	DKS/04	Green	IV	-	3.9	35.6	60.5	100.0	59.0	-	3.6	17.3	20.1	100.0
	DKS/04	Green	V	4.7	-	30.2	65.2	100.0	59.7	5.5	-	14.1	20.7	100.0
11	CR/03	Yellow	I	-	6.1	35.2	58.7	100.0	59.0	-	5.3	16.8	18.9	100.0
	CR/03	Yellow	II	-	6.2	35.4	58.4	100.0	58.8	-	5.5	16.8	18.9	100.0
	CR/03	Yellow	III	6.0	-	27.4	66.6	100.0	59.9	6.9	-	12.6	20.6	100.0
	CR/03	Yellow	IV	5.6	-	29.2	65.2	100.0	60.0	6.5	-	13.4	20.1	100.0
	CR/03	Yellow	V	5.5	-	30.2	64.2	100.0	60.2	6.3	-	13.8	19.7	100.0
12	CR/04	Yellow	I	-	6.4	34.9	58.7	100.0	58.9	-	5.6	16.6	18.9	100.0
	CR/04	Yellow	II	6.7	-	30.3	63.1	100.0	60.6	7.4	-	13.4	18.7	100.0
	CR/04	Yellow	III	4.6	-	28.2	67.2	100.0	59.5	5.5	-	13.4	21.6	100.0
	CR/04	Yellow	IV	-	6.1	35.3	58.6	100.0	59.0	-	5.3	16.8	18.9	100.0
13	CR/05	Green	I	-	5.5	35.3	59.2	100.0	58.8	-	4.9	17.0	19.3	100.0
	CR/05	Green	II	5.1	-	29.1	65.8	100.0	59.8	6.0	-	13.6	20.7	100.0
	CR/05	Green	III	6.9	-	32.3	60.8	100.0	60.7	7.5	-	14.0	17.8	100.0
	CR/05	Green	IV	5.2	-	29.1	65.7	100.0	59.9	6.1	-	13.5	20.5	100.0
14	CR/06	Green	I	5.0	-	28.3	66.8	100.0	59.7	5.8	-	13.3	21.2	100.0
	CR/06	Green	II	4.9	-	29.0	66.2	100.0	59.8	5.7	-	13.6	20.9	100.0
	CR/06	Green	III	6.6	-	29.2	64.2	100.0	60.2	7.4	-	13.0	19.4	100.0
	CR/06	Green	IV	4.8	-	30.4	64.7	100.0	60.0	5.6	-	14.1	20.2	100.0
	CR/06	Green	V	-	6.0	34.5	59.5	100.0	58.8	-	5.3	16.5	19.4	100.0
	CR/06	Green	VI	6.6	-	28.5	64.9	100.0	60.3	7.4	-	12.7	19.6	100.0
15	CR/07	Green	I	5.9	-	27.5	66.7	100.0	59.8	6.8	-	12.7	20.8	100.0
	CR/07	Green	II	5.0	-	28.3	66.7	100.0	59.6	5.9	-	13.3	21.2	100.0
	CR/07	Green	III	4.9	-	29.4	65.7	100.0	59.8	5.8	-	13.8	20.7	100.0
	CR/07	Green	IV	5.1	-	30.5	64.4	100.0	60.1	5.9	-	14.0	19.9	100.0
16	TS/02	Yellow	I	5.0	-	31.4	63.6	100.0	60.1	5.8	-	14.4	19.7	100.0
	TS/02	Yellow	II	4.8	-	32.0	63.3	100.0	60.1	5.5	-	14.7	19.7	100.0
	TS/02	Yellow	III	5.6	-	30.5	63.9	100.0	60.1	6.4	-	13.9	19.6	100.0
	TS/02	Yellow	IV	5.6	-	30.3	64.1	100.0	60.1	6.4	-	13.8	19.7	100.0
	TS/02	Yellow	V	6.2	-	30.4	63.4	100.0	60.4	6.9	-	13.6	19.1	100.0
17	TS/04	Orange	I	-	6.8	37.3	56.0	100.0	58.7	-	5.9	17.6	17.8	100.0
	TS/04	Orange	II	-	6.6	37.7	55.7	100.0	58.8	-	5.8	17.7	17.7	100.0
	TS/04	Orange	III	-	6.5	37.1	56.4	100.0	58.5	-	5.7	17.6	18.2	100.0
	TS/04	Orange	IV	-	6.7	37.4	55.9	100.0	58.8	-	5.8	17.6	17.8	100.0
	TS/04	Orange	V	-	9.1	38.1	52.8	100.0	58.6	-	7.7	17.4	16.3	100.0

No.	Sample	Colour	Particle	SiO_2	ZnO	SnO_2	PbO	Total	O	Si	Zn	Sn	Pb	Total
18	TS/06	Green	I	5.7	-	32.1	62.3	100.0	60.3	6.4	-	14.4	18.9	100.0
	TS/06	Green	II	5.2	-	32.6	62.2	100.0	60.3	5.9	-	14.8	19.0	100.0
	TS/06	Green	III	5.3	-	31.2	63.6	100.0	60.2	6.0	-	14.2	19.6	100.0
	TS/06	Green	IV	5.7	-	31.5	62.8	100.0	59.8	6.5	-	14.1	19.6	100.0
19	TS/07	Green	I	7.3	-	29.9	62.8	100.0	60.5	8.0	-	13.1	18.5	100.0
	TS/07	Green	II	8.5	-	27.8	63.7	100.0	60.5	9.1	-	11.9	18.4	100.0
	TS/07	Green	III	8.6	-	27.8	63.6	100.0	60.6	9.3	-	11.9	18.3	100.0
	TS/07	Green	IV	4.4	-	29.7	66.0	100.0	59.6	5.2	-	14.1	21.1	100.0
20	TS/13	Orange	I	-	6.5	36.3	57.2	100.0	58.6	-	5.7	17.3	18.4	100.0
	TS/13	Orange	II	-	5.9	35.8	58.3	100.0	58.6	-	5.3	17.2	18.9	100.0
	TS/13	Orange	III	-	6.3	36.1	57.6	100.0	58.6	-	5.6	17.2	18.6	100.0
	TS/13	Orange	IV	-	6.2	35.8	58.0	100.0	58.5	-	5.5	17.2	18.8	100.0
	TS/13	Orange	V	-	6.3	36.4	57.4	100.0	58.7	-	5.5	17.3	18.5	100.0

Appendix 7.24 Major and minor oxide composition of select Mughal glazes determined through LA-ICP-MS and EPMA-WDS analyses. All results are in wt%, and normalised to 100 %. Cl values are not reported for EPMA-WDS analyses on account of software modelling constraints. . '-' for the oxides indicates ‘not detected’. SL/01 and SL/03 are Lodhi period samples added on for comparative purposes.

No.	Sample	Colour	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	CuO	CoO	As_2O_5	SnO_2	PbO	ZnO	P_2O_5	Cl	Total
1	SL/01	Turquoise	LA-ICP-MS	59.56	24.10	1.62	1.05	0.62	4.93	1.14	0.25	4.24	-	0.03	0.01	0.01	-	0.11	2.01	99.67
			EPMA-WDS	59.99	23.21	1.40	1.10	0.65	5.31	1.28	0.22	4.55	-	-	-	0.01	0.03	0.12	-	97.88
2	SL/03	Dark-Blue	LA-ICP-MS	64.99	20.56	1.66	1.60	0.63	5.47	1.27	0.29	0.01	0.65	0.68	-	-	-	0.10	1.73	99.66
			EPMA-WDS	64.32	18.44	1.47	1.70	0.63	5.69	1.56	0.29	0.04	0.51	0.95	0.01	0.02	0.02	0.09	-	95.74
3	IK/01	Dark-Blue	LA-ICP-MS	65.34	19.67	1.67	1.34	0.72	5.86	1.68	0.33	0.06	0.58	0.81	-	0.01	-	0.07	1.47	99.62
			EPMA-WDS	66.99	18.69	1.67	1.45	0.53	5.90	1.42	0.29	0.06	0.45	1.22	-	0.02	0.03	0.04	-	98.77
4	IK/05	Dark-Blue	LA-ICP-MS	67.13	18.99	1.31	1.79	0.54	5.31	1.38	0.30	0.01	0.65	0.87	-	0.03	-	0.10	1.23	99.64
			EPMA-WDS	62.47	20.08	1.78	1.85	0.62	6.38	1.45	0.33	0.06	0.44	1.06	-	0.02	0.01	0.10	-	96.65
5	KM/01	Dark-Blue	LA-ICP-MS	60.42	19.99	2.84	2.40	0.81	7.92	2.10	0.42	0.04	0.40	0.40	-	0.02	0.00	0.07	1.68	99.51
			EPMA-WDS	61.75	18.02	2.56	2.61	0.83	8.17	2.11	0.45	0.03	0.31	0.50	-	0.04	0.03	0.11	-	97.52
6	KM/02	Dark-Blue	LA-ICP-MS	61.04	19.97	2.77	1.59	0.84	8.24	2.27	0.43	0.04	0.46	0.51	-	-	-	0.07	1.27	99.49
			EPMA-WDS	62.35	18.69	2.31	1.64	0.81	8.15	2.28	0.44	0.01	0.31	0.74	-	0.01	0.02	0.06	-	97.81
7	KM/03	Green	LA-ICP-MS	53.27	18.12	1.87	1.91	0.61	6.69	1.40	0.34	2.15	-	0.02	1.77	10.22	0.01	0.12	1.10	99.60
			EPMA-WDS	54.17	17.20	1.46	1.69	0.60	6.34	1.47	0.31	1.89	-	-	1.21	9.04	0.01	0.08	-	95.46
8	KM/04	Dark-Blue	LA-ICP-MS	62.85	16.52	2.84	3.63	0.96	7.57	2.33	0.45	0.05	0.66	0.35	0.02	0.02	0.02	0.07	1.12	99.48
			EPMA-WDS	62.63	15.91	2.82	4.00	1.13	7.74	2.53	0.42	0.08	0.48	0.53	-	0.01	0.02	0.11	-	98.39
9	SB/02	Dark-Blue	LA-ICP-MS	66.86	16.38	2.50	2.33	1.10	6.47	1.93	0.41	0.05	0.36	0.51	-	-	0.01	0.19	0.48	99.58
			EPMA-WDS	68.76	14.87	1.94	2.50	1.09	6.62	1.61	0.39	0.05	0.16	0.46	-	0.01	0.03	0.19	-	98.68
10	SB/03	Dark-Blue	LA-ICP-MS	66.37	16.37	2.38	2.47	1.09	6.81	2.09	0.41	0.06	0.35	0.51	-	-	0.01	0.19	0.47	99.57
			EPMA-WDS	67.87	15.45	1.98	2.49	0.97	6.69	1.63	0.40	0.06	0.21	0.65	-	0.02	0.02	0.14	-	98.58
11	SB/04	Dark-Blue	LA-ICP-MS	66.69	16.68	2.34	1.95	0.94	6.73	2.18	0.41	0.05	0.36	0.46	-	-	0.01	0.17	0.57	99.55
			EPMA-WDS	68.44	15.32	2.14	2.00	1.11	6.39	1.61	0.37	0.05	0.20	0.54	0.01	-	0.03	0.20	-	98.38
12	KMA/01	Turquoise	LA-ICP-MS	61.65	17.40	3.78	1.89	1.87	5.27	1.35	0.31	4.70	-	0.02	0.01	0.01	0.02	0.33	1.01	99.61
			EPMA-WDS	63.31	17.56	3.38	1.88	2.08	5.08	1.38	0.27	4.73	0.01	-	0.01	0.03	0.02	0.34	-	100.09
13	KMA/02	Turquoise	LA-ICP-MS	64.84	16.77	3.39	2.00	1.74	3.87	1.29	0.24	4.00	-	0.02	0.02	0.01	0.02	0.35	1.07	99.64
			EPMA-WDS	62.39	17.89	3.50	1.94	2.16	5.32	1.48	0.27	4.84	0.01	-	0.01	0.01	0.03	0.30	-	100.15
14	KMA/03	Yellow	LA-ICP-MS	55.46	14.56	1.80	1.55	0.77	6.73	1.65	0.41	0.01	-	0.01	2.36	12.81	0.15	0.12	1.18	99.56
			EPMA-WDS	52.64	15.44	1.79	1.40	0.90	6.52	1.59	0.34	0.06	0.01	-	2.37	15.71	0.17	0.10	-	99.04
15	SM/01	Purple	LA-ICP-MS	71.44	14.68	3.15	3.43	2.14	1.70	0.68	0.08	0.01	-	-	0.07	0.07	0.02	0.35	0.52	98.34
			EPMA-WDS	63.23	14.52	3.26	3.32	2.23	1.57	0.62	0.08	0.05	0.02	-	-	0.07	0.03	0.28	-	89.28
16	SM/02	Yellow	LA-ICP-MS	55.04	15.34	1.85	1.75	0.86	5.47	1.26	0.30	0.02	-	-	2.42	13.88	0.24	0.15	1.08	99.67
			EPMA-WDS	53.11	14.99	1.99	1.52	1.08	5.74	1.43	0.30	0.06	0.02	0.02	3.20	16.40	0.27	0.16	-	100.28

No.	Sample	Colour	Analyses	SiO_2	Na_2O	CaO	K_2O	MgO	Al_2O_3	Fe_2O_3	TiO_2	CuO	CoO	As_2O_5	SnO_2	PbO	ZnO	P_2O_5	Cl	Total
17	SM/03	Dark-Blue	LA-ICP-MS	69.19	15.87	3.76	2.96	2.22	1.84	1.38	0.08	0.04	0.56	0.22	0.01	0.07	-	0.28	1.20	99.68
			EPMA-WDS	66.05	14.87	3.27	3.07	2.31	1.66	1.32	0.08	0.06	0.40	0.16	-	0.05	-	0.30	-	93.59
18	SM/07	Turquoise	LA-ICP-MS	68.55	15.61	3.61	3.22	2.15	1.59	0.46	0.07	2.88	-	0.01	0.04	0.08	-	0.31	1.19	99.77
			EPMA-WDS	67.86	15.64	3.28	3.23	2.48	1.85	0.61	0.14	3.04	-	0.01	0.04	0.10	0.04	0.32	-	98.63
19	SM/09	Yellow	LA-ICP-MS	50.78	15.64	2.51	2.73	0.89	5.99	1.39	0.31	0.02	-	-	3.12	14.67	0.30	0.15	1.13	99.63
			EPMA-WDS	52.14	15.00	1.89	2.77	0.88	6.39	1.37	0.28	0.06	-	-	2.53	16.19	0.16	0.15	-	99.81
20	SM/10	Dark-Blue	LA-ICP-MS	72.33	14.41	3.12	3.33	2.01	1.57	0.89	0.07	0.02	0.46	0.20	0.01	0.07	-	0.28	0.99	99.76
			EPMA-WDS	72.79	15.25	3.34	3.47	2.33	1.60	1.00	0.07	0.09	0.29	0.40	0.01	0.15	0.03	0.29	-	101.10
21	CR/05	Green	LA-ICP-MS	55.08	13.14	3.10	4.13	2.34	1.33	0.48	0.06	2.29	-	0.02	2.58	13.43	0.54	0.36	0.93	99.82
			EPMA-WDS	57.66	11.66	2.21	4.14	2.08	1.22	0.40	0.06	1.84	0.01	-	2.71	12.07	0.34	0.18	-	96.58
22	CR/06	Green	LA-ICP-MS	52.29	12.35	2.96	2.89	2.31	1.64	0.42	0.05	1.75	-	0.01	4.00	17.48	0.40	0.31	0.94	99.81
			EPMA-WDS	55.99	13.14	2.58	3.12	2.43	1.50	0.41	0.05	1.62	0.02	-	2.98	15.77	0.25	0.26	-	100.13
23	CR/07	Green	LA-ICP-MS	53.49	14.27	1.50	2.44	0.65	6.89	1.24	0.33	1.66	0.01	0.02	3.32	12.91	0.01	0.15	0.78	99.69
			EPMA-WDS	55.46	15.40	1.13	2.42	0.65	6.89	1.37	0.32	1.54	0.02	0.01	2.35	12.76	0.03	0.27	-	100.62
24	CR/11	Dark-Blue	LA-ICP-MS	68.81	14.87	3.40	3.59	2.74	1.93	2.12	0.07	0.05	0.68	0.28	-	0.01	0.01	0.34	0.67	99.58
			EPMA-WDS	69.79	14.14	3.11	3.01	2.49	1.87	1.71	0.09	0.14	0.34	0.39	0.02	0.11	0.01	0.40	-	97.63
25	CR/12	Dark-Blue	LA-ICP-MS	72.49	13.87	3.16	2.85	2.43	1.56	1.10	0.06	0.10	0.64	0.18	0.01	0.11	0.01	0.28	0.84	99.70
			EPMA-WDS	71.47	14.04	3.19	3.47	2.73	1.58	1.17	0.07	0.10	0.42	0.20	-	0.08	0.01	0.33	-	98.87
26	CR/19	Turquoise	LA-ICP-MS	66.60	16.21	3.73	4.18	2.27	2.01	0.65	0.07	2.91	-	0.01	0.01	0.04	0.01	0.33	0.74	99.77
			EPMA-WDS	68.44	16.46	3.58	3.86	2.35	1.72	0.56	0.05	2.87	0.02	0.01	-	0.02	0.01	0.23	-	100.17
27	CR/20	Turquoise	LA-ICP-MS	68.58	15.67	2.76	4.54	1.85	1.80	0.61	0.07	2.56	-	0.01	-	0.04	0.01	0.28	1.01	99.78
			EPMA-WDS	68.88	15.64	2.72	4.20	1.94	1.73	0.63	0.07	2.41	0.01	0.04	0.04	0.05	0.04	0.27	-	98.67
28	TS/01	Purple	LA-ICP-MS	68.54	16.96	3.63	3.15	2.52	1.96	0.66	0.07	0.01	-	-	-	0.06	0.01	0.31	1.10	99.00
			EPMA-WDS	66.10	17.97	3.96	3.17	2.89	1.57	0.70	0.08	0.04	0.01	-	-	0.04	0.04	0.36	-	96.92
29	TS/03	Dark-Blue	LA-ICP-MS	63.59	20.00	4.57	3.33	2.71	1.99	1.40	0.08	0.03	0.32	0.09	-	0.01	-	0.37	1.16	99.64
			EPMA-WDS	63.51	19.15	3.84	3.51	2.69	1.73	1.72	0.07	0.09	0.27	0.10	-	0.02	0.05	0.30	-	97.03
30	TS/06	Green	LA-ICP-MS	50.67	11.28	3.01	3.00	1.87	1.79	0.53	0.08	2.95	-	0.01	3.59	19.44	0.64	0.26	0.65	99.76
			EPMA-WDS	51.41	11.38	2.51	3.40	2.01	1.61	0.59	0.06	3.04	0.02	-	4.49	18.33	0.36	0.19	-	99.40
31	TS/10	Dark-Blue	LA-ICP-MS	66.69	17.92	3.85	3.98	2.47	1.99	1.00	0.08	0.03	0.28	0.07	-	0.02	0.01	0.35	0.96	99.70
			EPMA-WDS	62.16	17.35	4.05	3.91	2.59	1.72	1.19	0.04	0.09	0.21	0.12	-	-	0.04	0.36	-	93.82
32	TS/12	Green	LA-ICP-MS	28.53	2.37	0.44	0.47	0.19	1.57	0.49	0.08	1.00	-	0.01	5.07	57.14	2.04	0.06	0.14	99.60
			EPMA-WDS	27.65	2.66	0.05	0.48	0.14	1.24	0.47	0.06	1.08	0.01	-	6.28	57.14	1.25	0.02	-	98.52