GEOMONUMENTAL ROUTES: THE GRANITIC BRIDGES OVER THE GUADARRAMA RIVER (MADRID, SPAIN) AND THE CALCARENITIC COASTAL TOWERS FROM THE SALENTO (ITALY)

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Abstract

This paper focuses on the new concept of GeoMonumental Routes, which mainly consist of the dissemination of architectural heritage with the added value of geology. Geology, so far, has not been considered in all its aspects in architectural heritage: i.e. geography, geomorphology, quarries provenance, building stones, and their relationship with historical and architectural aspects, constructive techniques and technological developments, as well as the connection of heritage structures to the settlement of historical routes. For this purpose, two scientific teams have gathered to develop two of this kind of routes following a common methodology, based on different geographical context, geological settlement, history, structure tipology and building stones.

Keywords: geomonumental routes, granite, calcarenite, bridge, tower, cultural heritage, dissemination

1. Introduction

The main objective of the *GeoMonumental Routes* is the knowledge and dissemination of architectural heritage (Pérez-Monserrat et al, 2006; Alvarez de Buergo et al, 2007). In this specific case, two research groups, from Spain and Italy, gathered to develop two different geomonumental routes and exchange different approaches. The scientific approach is intended to be multi-disciplinary. One route is located in the South of Italy: it is the route of the coastal towers built in the 16th century with calcarenitic stones that outcrop along the Salento coast. The second route is located in Madrid, Spain: it is the granitic bridges´ route over the northern section of the *Guadarrama* River.

The procedure followed for the design and development of both routes was focused on the determination of: the historic and architectural aspects of the structures (both the towers and the bridges); their constructive history and techniques; the analysis of both building stones (calcarenite and granite); an approach to the quarries from which the building stones were extracted, especially in the case of the Italian towers, due to their close relationship; the conservation or restoration interventions that have been carried in the structures; the conservation/decay condition of the structures, mainly in relation to the building materials and to the surrounding environment (rural and urban, mainly); the relationship of both type of structures with historical paths and roads; and their relation to the geographical and geomorphologic surrounding and landscape.

The preliminary results of this collaboration are shown in this paper. The study and development of both routes are still in process.

2. The GeoMonumental Routes

Both geomonumental routes were selected, besides their monumental significance, attending to their different geographical location (two countries), geomorphology setting (on the seashore and over a river), tipology of structure (towers and bridges), as well as construction period and stone materials nature (limestone and granite).

2.1 The granitic bridges over the *Guadarrama* River, Madrid, Spain

Five bridges were selected to be included in this route, located over the northern section of the *Guadarrama* River, in a section of 25 Km long (Fig. 1): the bridges of *Alcanzorla*, probably Roman, *Herrera*, from the 16th century, and *Retamar*, *Herreño* and *Guadarrama* or *Rosario*, from the 18th century (Fig. 2).

This area was on the route connecting North and South of Spain since Roman times. Later on, during the Arab occupation, the Guadarrama Valley served also as a main route from Toledo to the Christian Northern border (*Duero* River). In Christian-Medieval times, the route was used as a seasonal sheep track. During the 16th century, two facts resulted on the increase of traffic along this route: the set up of Madrid as the capital of the Kingdom, and the construction of the Royal Monastery of *El Escorial.* The King *Felipe II* created and reinforced infrastructures along this route, and so did the following *Borbon* dinasty, beginning with the creation of an active carriages "road" along this path. The reign of *Carlos III* is known as "the period of the three hundred bridges", as a constructive revolution in the bridges´ sector took place, with the application of engineering concepts for bridges construction (mechanics, hydraulics, mathematics). The bridges erected over the *Guadarrama River* during the 18th century are related to the first Spanish paved road built with state budgets, following a technical management project (Hernández, 1973; Sáenz et al., 1986; Andrés, 1989; Fernández, 1990; and Martínez & Sánchez, 1994).

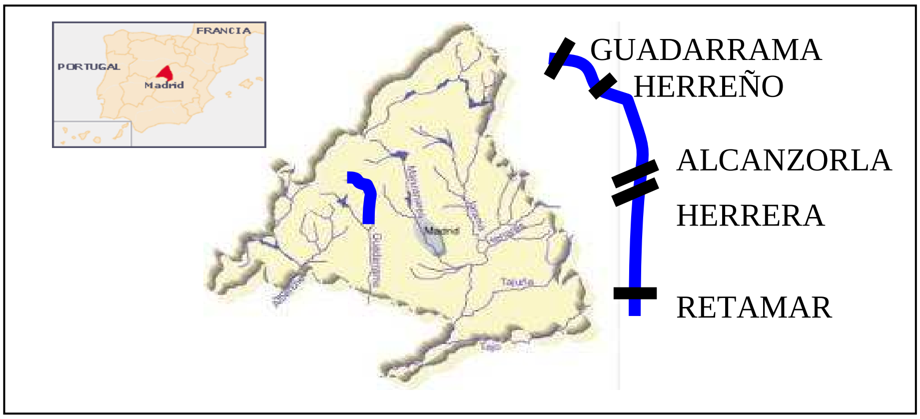

Figure 1: Location map of the five bridges along the northern section of the *Guadarrama* River, Madrid, Spain.

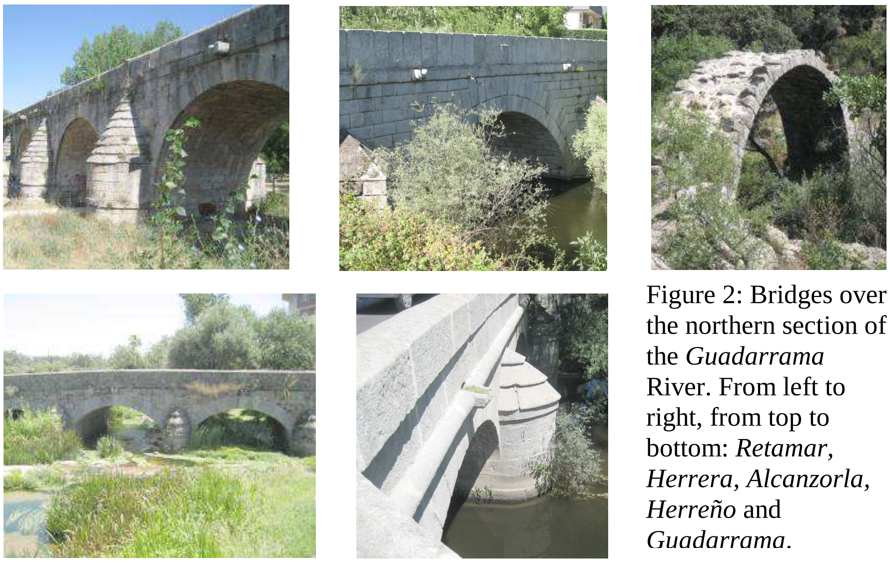

Figure 2: Bridges over the northern section of the *Guadarrama* River. From left to right, from top to bottom: *Retamar, Herrera, Alcanzorla, Herreño* and *Guadarrama*.

All the studied bridges were built with granitic stones. Granite is a building stone traditionally used in the central area of Spain, so-called as *Berroqueña* stone. Its provenance is located towards the southwest of the *Guadarrama* Mountain Range, which forms the northeastern section of the 500-Km-long Spanish Central System. This is mainly composed of Hercynian granitoids and high- to medium-grade metamorphic rocks. Granitoids form the *Guadarrama* Batholith, consisting primarily of peraluminous monzogranites to leucogranites, with minor rocks of more basic composition (González Casado et al., 1996). Monzogranites are the most abundant rocks, with differences in their texture. The granite samples taken from the bridges can be classified as biotitic monzogranite, inequigranular and hypidiomorphic granites, mainly constituted of quartz, plagioclase, potassium feldspar and biotite. Secondary minerals are sericite, muscovite, chlorite and occasionally prehnite; apatite, zircon and opaque minerals are the accessory minerals. Two types of monzogranites can be distinguished in the bridges (Fig. 3): a medium to coarse grained granite, with a slight porphyric tendency caused by the presence of feldspar phenocrysts. It is light coloured. This granite correspond to samples from *Herrera* and *Retamar* bridges; and a fine grained granite, slightly less porous and darker than the previous one, due to the greater amount of biotite and less amount of K-feldspar crystals. This granite was analysed from samples taken from *Herrera, Alcanzorla, Herreño* and *Guadarrama* bridges. Plagioclase and biotite are highly altered in both monzogranites due to alteration processes; the first one is commonly altered to sericite, and the second one to muscovite and chlorite, as well as the quartz minerals are intensely fractured.

Among the five bridges, the Roman one (*Alcanzorla*) is the one in worst conservation condition, almost ruined, to which more attention should be paid. The other four are in general, in a moderate conservation condition. In summary, they are affected by graffittis, efflorescences, some fissures and cracks, biodeterioration; blisters, flaking, spalling and grain disintegration, as well as inappropriate restorations (common use of Portland cement) (Fig. 4). In general, bridges lack of a proper maintenance programme.

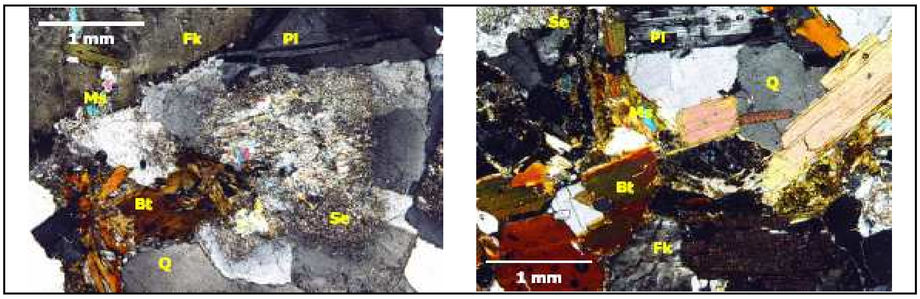

Figure 3: Micrographs of bridges´ granite samples. Left: coarse to medium grain variety, lighter. Right: fine grain granite, darker. Q: quartz, Bt: biotite, Fk: potassium feldspar, Pl: plagioclase, Ms: muscovite; Se: sericite

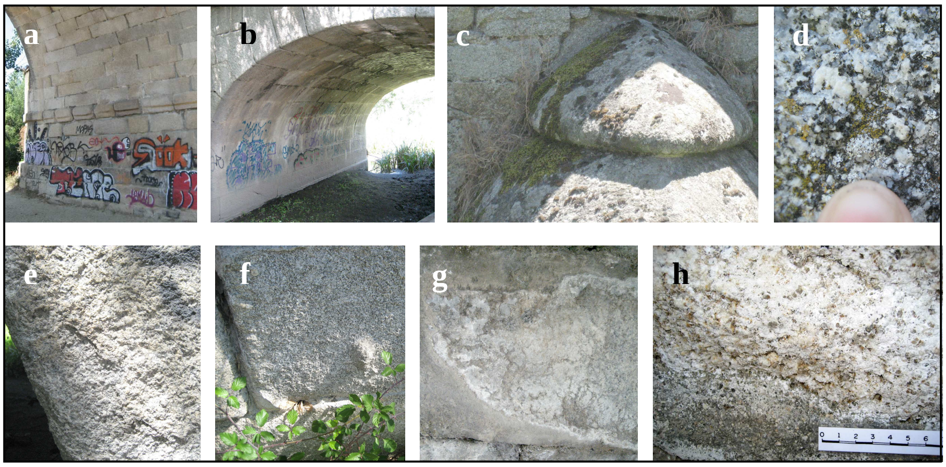

Figure 4: Main decay forms observed in the bridges. a) graffittis in the vault, b) graffitis, dampness and eflorescences in the vault, c) and d) biodeterioration, e) flaking and grain-disintegration, f) spalling, g) spalling due to salt crystallization, h) efflorescences

2.2 The calcarenitic coastal towers from the Salento, Italy

From the Early Middle Ages to the 16th century Salento was often attacked by foreign fleets, because of its geographical position facing both the Adriatic and the Ionian seas: the Arabs and Normans between the 10th and the 12th century, the Swaebians and the Angevins from the 13th to the 14th century, the Aragoneses and the Turks in the 15th century. These facts favoured the building and the improvement of the defence system at different times. The tragic event that took place in Otranto on July 1480, when a Turkish fleet attacked and sieged the town, stimulated the reconstruction of the entire defence system in Salento. Several towers were built near the sea in order to better control and defence the territory by attacks of enemy ships coming from the East (Cazzato, 1989; Paiano & Cazzato, 2000). For most of them the calcarenite mined in its neighbourhood was used. The towers built in the 15th and 16th century, and the quarries exploited, represent a remarkable heritage whose natural and cultural values are expected to be popularised by means of a geomonumental route (Fig. 5). All the available information and the results obtained by integrated investigations on the history, materials and building characteristics will be inserted in a GIS that is structured as a geodatabase. The principal geographical layers are: i) raster cartography (aerial and satellite imagery, DEM); ii) vectorial cartography (administrative boundaries, isoipse, hidrography, routes, tourist facilities); iii) Geomonumental elements (quarries, towers, archaeological sites, historical route). These layers have been related to external tables containing general attributes, bibliography, iconography, architectural and building informations and results obtained by analysis of materials and decay. The proposed geomonumental route is composed by a number of study cases representative of different architectural typologies and state of conservation. This paper shows the early results of the mineralogical and petrographycal analyses performed on both quarries and towers of *Marina Serra* and *Miggiano* sites (Fig. 6). The first one was erected between the 14th and 15th century, the second one around the middle of the 16th century (Paiano & Cazzato, 2000). *Miggiano* Tower has a circular plan and a cone-shaped basement; the tower in *Marina Serra* has a square plan, and is 15 metres high.

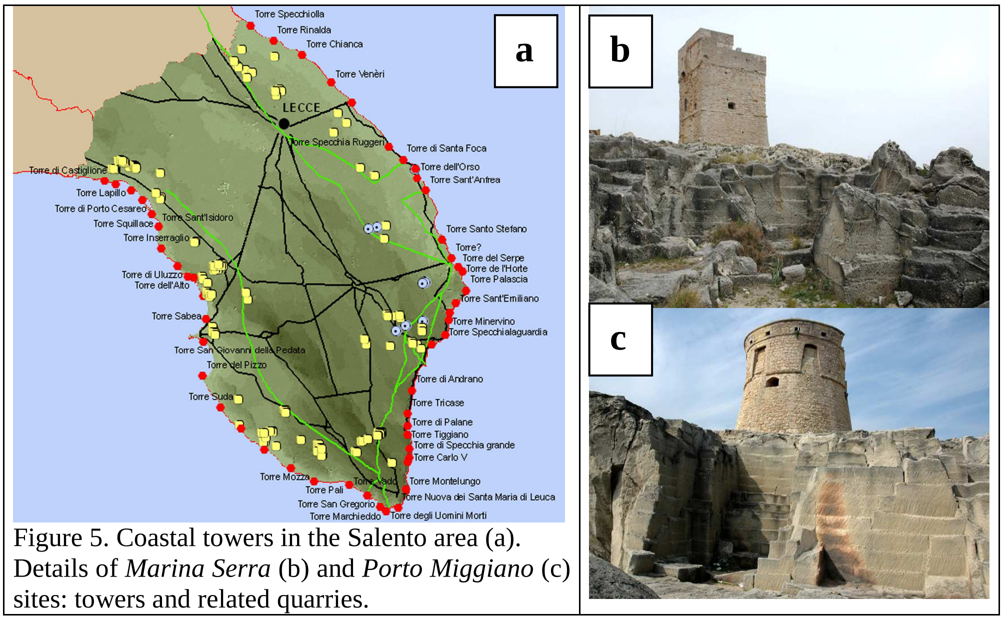

Figure 5. Coastal towers in the Salento area (a). Details of *Marina Serra* (b) and *Porto Miggiano* (c) sites: towers and related quarries.

All the studied towers were built with soft and highly porous calcarenites, which widely outcrop in the Salento peninsula. The sites investigated lie inside the outcrops of calcarenites, known in literature as "*Depositi Marini Terrazzati*" (terrace-shape marine deposits) dating from the Middle-Upper Pleistocene age (Ciaranfi et al., 1992). The calcarenites are widely used as building materials in the whole region since ancient times until nowadays, as well as they were commonly employed in many archaeological sites and artifacts. Ancient quarries have been identified along the coast, which were related to artifacts found in the surroundings (Calia et al., 2000). Calcarenites of *Marina Serra* quarry show a yellowish-greysh colour, homogeneous texture and medium-coarse grain size. They are poorly compacted, fairly cemented and easy to identify macroscopically. The materials of the tower are very similar to the rocks of the quarry. Calcarenites from both quarry and tower of *Porto Miggiano* are also medium-coarse grain size, but yellowish in colour. On the basis of the mineralogical-petrographic observations on thin sections under a polarised microscope, all the collected samples were identified as grainstones (Dunham, 1962). They are made up of calcareous-fossil remains (Algae, Echinodae, Foraminifera, Mollusks and Gastropods) and contain occasional grains of quartz and glauconite. Furthermore, there are variable amounts of iron oxide and hydroxide specks. Samples from both quarry and tower from *Marina Serra* show also the wide presence of lumps.

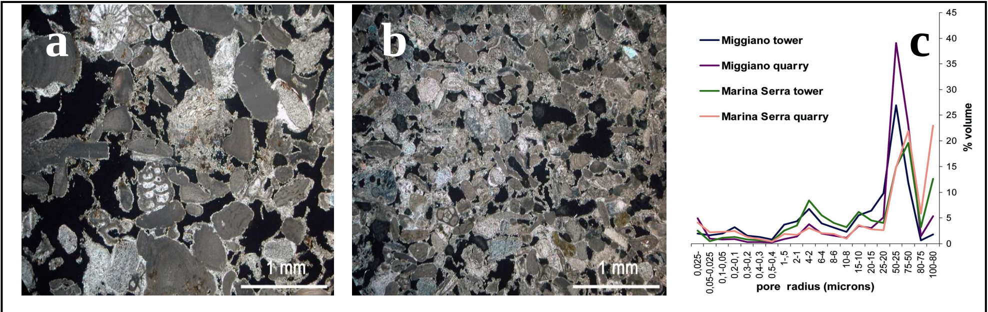

Figure 6. Micrographs of the samples from *Marina Serra* quarry (a) and *Miggiano* tower (b); porosimetric distributions (c).

Samples from the quarry and tower of *Marina Serra* site have similar characteristics. They show a large and non-homogeneous grain size (200 to 1800 µm, prevailing the 600-800 µm grain size); the cement is a fine sparite, concentrated around the edges of the grains (Fig. 6,a). Samples from the quarry tower of *Porto Miggiano* are medium and fine-grained (ranginf from 150 to 800 µm; prevailing in a range between 400 and 600 µm), and very poorly cemented with microsparitic calcite, which is present mainly on the grains border, and only sometimes in between the grains. Similar mineralogical-petrographic characteristics - except for a finer grain size (300-500 µm) – were found in samples from the tower. A representative example of these features is shown in Fig. 6,b. The percentage of carbonates obtained through the determination of the CO_2 volume is generally high. As in the case of *Marina Serra* site, it varies from 91% to 87% in samples from the quarry and from the tower, respectively. The same carbonates content (89%) was detected in samples from both the quarry and tower of *Porto Miggiano* site. XRD analyses on the whole rock resulted on calcite as the main mineralogical compound in all the samples. The mineralogical analyses of the insoluble residue, which was obtained by separation from the whole rock by chemical attack, revealed the dominant presence of quartz; clay minerals and glauconite were found as accessory constituents. The presence of gypsum and potassium chloride was also detected.

The calcarenites here studied have a very high porosity. Values of the integral open porosity measured by mercury porosimetry were 22% and 20% for the samples taken from both the quarry and the tower of *Marina Serra* site, respectively. Higher values were measured in samples from *Porto Miggiano* site (28% for the quarry, and 37% for the tower). The porosimetric distributions are illustrated in Fig. 6, c. The coastal towers show different states of conservation. Some of them encountered restoration works in recent years; some others show critical conditions of conservation, as it is the case of *Marina Serra* tower, whose representative decay map of one of the façades is reported in Fig. 7.

Figure 7. Representative decay map of *Marina Serra* Tower.

3. Conclusions

The carrying out of the geomonumental routes is the result of an integrated approach to the study and the enhancement of cultural heritage, which promote knowledge and “valorisation” (value enhancement) of artifacts, buildings and monuments, as well as of their related aspects, such as material‘s sources, routes of their traffic, exploitation and working technique, etc. This methodology is exportable to any other territory. Dissemination is essential to involve citizenship in heritage conservation. Geomonumental routes make possible to add new values (geo-values) to architectural heritage. If society does not know its heritage, it would hardly contribute to its conservation.

4. Acknowledgements

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