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The Provenance, Supply and Use of Stone Material at the Roman Town of Ammaia

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Devi Taelman

List of Abbreviations

AGS	average grain size
amsl	above mean sea level
ASPRS	American Society for Photogrammetry and Remote Sensing
BCE	before common era
CCSZ	Coimbra–Cordoba Shear Zone
CE	common era
CIL	Corpus Inscriptionum Latinarum
CIZ	Central–Iberian Zone
CP	check point
DEM	digital elevation model
DSM	digital surface model
DTM	digital terrain model
GBS	grain boundary shape
GCP	ground control point
GIS	geographic information system
GNSS	global navigation satellite system
GPR	ground-penetrating radar
GPS	global positioning system
GPU	graphics processing unit
GSD	ground sampling distance
HAP	Helikite aerial photography
HOV	hold-out validation
ICP-MS	inductively couples plasma – mass spectrometer

IRCP	Inscrições romanas do Conventus Pacensis
LCS	La Codosera Synclinorium
LiDAR	Light Detection And Ranging
MGS	maximum grain size
MVS	multiview stereo
NAB	Nisa–Alburquerque Batholith
NSSDA	National Standard for Spatial Data Accuracy
OMZ	Ossa–Morena Zone
OpenCL	Open Computing Language
OSL	Optically Stimulated Luminescence
ppb	parts per billion
ppm	parts per million
RMSE	root-mean-square error
SCA	site catchment analysis
SfM	Structure from Motion
SGC	Schist–Greywacke Complex
SusDr	sustained draught

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Introduction and general aims

This PhD study on *The Provenance, Supply and Use of Stone Material at the Roman Town of Ammaia* is part of a broader geoarchaeological research project of Ghent University in and around the Roman urban site of *Ammaia* (São Salvador da Aramenha, Portugal). In 2001, the archaeological site of *Ammaia* was selected as the setting for the development of a better methodology for the study of the relationships and interdependencies of Roman towns and their exploitation territory.

To disclose the hidden historical landscape in and around Roman *Ammaia*, a multidisciplinary geoarchaeological approach was adopted. Essentially non-destructive survey methods were used to map and reconstruct ancient features underneath the modern landscape morphology (Vermeulen and De Dapper, 2000). Besides the development of a GIS-based spatial database of ancient and modern landscape data, a wide set of archaeological and geoscientific approaches (including aerial remote sensing, geophysical survey, geological survey, erosion modelling and artefact survey), as well as archaeometric methods were integrated within a historical questionnaire to answer questions concerning the topographic and stratigraphic development of the ancient urban site itself, as well as about the human exploitation of the palimpsest of natural resources lying within the town's exploitation territory. The project consists of several cornerstones, including the determination of the town's urban layout, a tentative reconstruction of the taphonomy of the site and its immediate surroundings, the study of water collection and distribution in and around the city, the location and evaluation of the exploitation of natural resources (e.g. stone building material and metals), and a study of the settlement dynamics (Vermeulen and Taelman, 2010).

The aim of this thesis is the study of the provenance, supply and use of building and ornamental stone at the Roman town of *Ammaia*, a small inland, provincial town in the westernmost province of the Roman world. The work partly builds upon the PhD research of S. Deprez (2009) that focused on the geomorphological aspect of the exploitation of three major natural resources in the territory of the town: water, granite and gold. The presented study goes deeper into the archaeological interpretation of the granite exploitation, but also investigates the provenance and supply of the other types of stones used for constructing and embellishing Roman *Ammaia*.

The investigated aspects of the stone economy of *Ammaia* are: (1) the nature of the use of building and ornamental stones, (2) the provenance of the different types of stones, and (3) the technology and organisation of the exploitation and trade of the various types of stone. For the building stones, the latter aspect includes foremost the study of the location of the quarries, why certain locations or stone resources were chosen for exploitation and others not, the method of extraction and stone working, and the organisation of the quarrying and transport. For the ornamental stones, the latter aspect primarily focuses on the trade mechanisms of ornamental stone in the Roman world. Moreover, the use and trade of ornamental stone in *Ammaia* are compared to that of other towns in the Iberian Peninsula.

In order to provide an answer to these research questions, a geoarchaeological and archaeometric approach is adopted that integrates methods, techniques and knowledge from archaeology, ethnography, geology, petrography, geography, geomatica, remote sensing, geomorphology and analytical chemistry.

The Romans employed stone for multiple purposes, the principal being building material (both structural as well as decorative). The importance of stone for Roman builders, combined with the durability of the material makes it an interesting research object for archaeologists.

Studies of the provenance, supply and use of stone material offer an insight into the level of technological development of a culture. Each stone type has its own specific working and carving properties. Stonecutters therefore need to be familiar with the stone that they are working (Fant, 1992; Moens et al., 1995; 1997; Waelkens et al., 1988). The characterisation and source tracing of stone material is therefore vital to understand the working properties of a particular rock. While studies of the provenance and supply of locally available stones inform us on the organisation of the local economy and the nature of the landscape exploitation, the study of imported stones reveals interesting information concerning ancient commercial relationships and trade routes and offer insights into the mechanisms of the general economy of the Roman world.

Until recently, the key focus of this archaeological questionnaire was on the larger Roman towns and within this framework, the emphasis was placed on the provenance determination and distribution of high-quality white marbles and coloured ornamental stones and the study of the Imperial quarries (e.g. *Mons Porphyrites* and *Mons Claudianus* in Egypt) (cf. Herz and Waelkens, 1988; Lazzarini, 2007; Maxfield and Peacock, 2001; Pensabene, 1998; and so forth; Ward-Perkins, 1992). Since the middle of the eighties of the 20th century CE, many advances in the techniques and methods used for the provenance determination of these stones have been presented at the *ASMOSIA* conferences (Association for the Study of Marble and Other Stones used in Antiquity). With some exceptions (e.g. *Sagalassos* in Turkey), studies of the provenance, quarrying and supply of local building stones are only rarely treated with the same consideration (cf. Degryse et al., 2008; Loots, 2001; Viaene et al., 1993). Likewise, the focus of the research for the Iberian Peninsula has long-time been – and still is – on the supply and trade of white marbles and coloured ornamental stones for the major urban centres such as *Tarraco* (Tarragona, Spain), *Italica* (Santiponce, Spain), *Emerita Augusta* (Mérida, Spain), *Caesaraugusta* (Zaragoza, Spain) and so on (cf. Àlvarez Pérez et al., 2009a; Àlvarez Pérez et al., 2009c; Àlvarez Pérez et al., 2009d; Àlvarez Pérez et al., 2012; Canto, 1977-1978; Cisneros Cunchillos, 1988; 1997; 2000; 2001; 2002; 2004; 2010; Cisneros Cunchillos et al., 2010-2011; Cisneros Cunchillos and Martín-Bueno, 2006; Lapuente, 1995; 1999; Lapuente and Blanc, 2002; Lapuente et al., 2002; Lapuente and

Turi, 1995; Lapuente et al., 1999; Lapuente et al., 2000; Mayer and Rodà, 1998; Nogales Basarrate et al., 1999; Nogales Basarrate et al., 2009). Investigations on the provenance, quarrying and supply of building stones are very scarce and include foremost the exploratory work of J.L. De La Barrera (2000) and A. Pizzo (2010a;b) concerning the granite quarries of *Emerita Augusta*. An important recent contribution is the detailed overview of the Roman quarries in the region of Cataluña in Spain by A. Gutiérrez-Garcia Morena (2009).

For building stones, physical properties and local availability or ease of procurement were primary concerns. The supply of building material, including building stone, was crucial for the development of an urban centre and the success of a construction project (DeLaine, 1992). As a result, this implies that the exploitation and supply of building stones happened in an economically efficient manner. The stone resources should be easily accessible and obtainable and the cost of their procurement should not exceed their intrinsic value (Fitchen, 1986). For these reasons, quarries or sources for building stones are normally located in the vicinity of the construction site.

Unlike the economy of building stones where local availability and profitable exploitation were primary concerns, the economy of ornamental stones was determined by other factors such as aesthetical properties, prestige, fashion and ideology. Where building stones were crucial in the development of an ancient town, ornamental stones were considered an expensive luxury good that symbolised prosperity, wealth and (economic) power (Fant, 1988). Long-distance trade of ornamental stone is no exception, especially form the Augustan–Tiberian period onwards, when an Imperial quarry and trade system had developed for ornamental stones and many large quarries became property of the Roman state or the Emperor (Ward-Perkins, 1992). It was, however, not until the late Julio–Claudian and Flavian period, when the demands from Rome and the cities in the Italic Peninsula were satisfied, that Imperial marbles reached the provinces in considerable quantities (Fant, 1988; 1993).

Chapter 1
Ammaia and its physical environment

1.1 Geographical location

The area of *Ammaia* and its ancient territory are situated south of the Tagus River. The study area extends on both sides of the Portuguese–Spanish border and roughly comprises the northeastern Alentejo region of Portugal and the central-western part of the Spanish Extremadura region.

The archaeological site of *Ammaia* lies just south of the modern village of São Salvador da Aramenha, about 10 km west from the present-day border between Portugal and Spain, in the heart of the Natural Park of the *Serra de São Mamede* (municipality of Marvão, district of Portalegre, Alentejo, Portugal) (Figure 1.1). The exact location of the site was for a long time the subject of discussion. Archaeologists and historians were persuaded that the ruins near São Salvador da Aramenha belonged to the Roman town of Medobriga. *Ammaia* was initially located in modern Portalegre (about 10 km to the south). In 1935, however, epigraphic evidence identified the ruins in São Salvador da Aramenha as Roman *Ammaia* (Mantas, 2000; Vasconcelos, 1935).

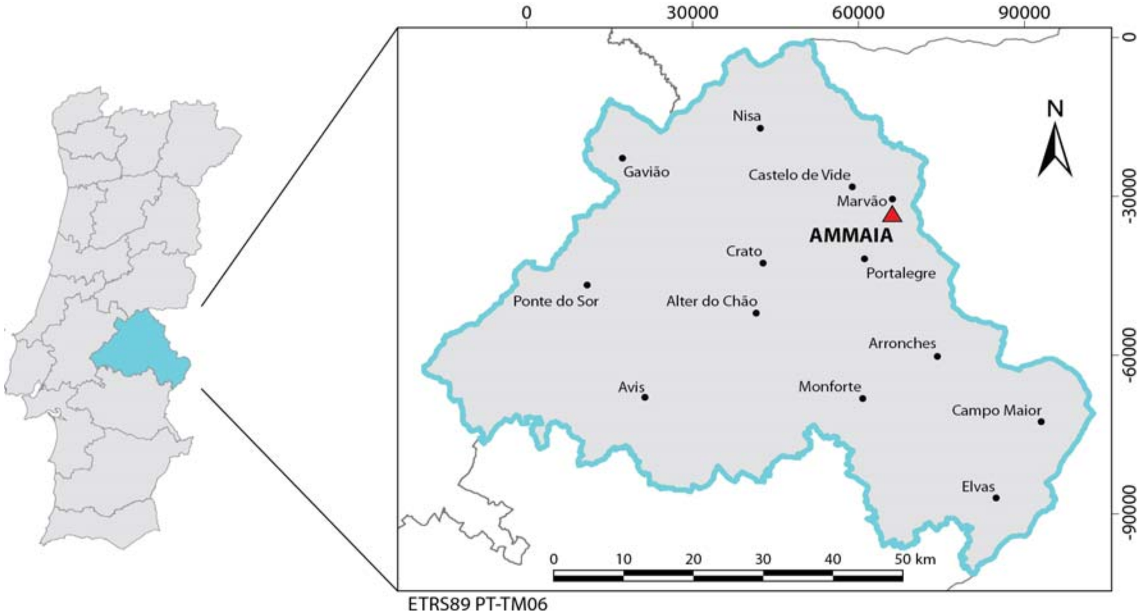

Figure 1.1 Geographical location of *Ammaia* with indication of the major towns in the present-day district of Portalegre (Portugal).[1]

1.2 Regional geology

From a geological point of view, the study area is located on the boundary of the *Central–Iberian Zone* (CIZ) and the *Ossa–Morena Zone* (OMZ), two zones of the Hesperian or Iberian Massif, a geotectonic domain that forms the oldest core of the Iberian Peninsula and occupies most of the modern Portuguese territory (Francisco Pereira et al., 2010) (Figure 1.2-A). The rocks of the Iberian Massif are of late Proterozoic and Paleozoic age and were deformed in late Paleozoic times during the Hercynian Orogeny (Menéndez et al., 2011). The CIZ crops out in the northern and central part of the study area, while the OMZ occupies the southern area. In the southwest, not the Iberian Massif forms the geological background, but Cenozoic formations of the *Tertiary Lower Tagus Basin* (Figure 1.2-B).

[1] ETRS89 PT-TM06 is the current projected coordinate system for continental Portugal. It is based on the European Terrestrial Reference System 1989 datum (which uses the GRS 80 ellipsoid).

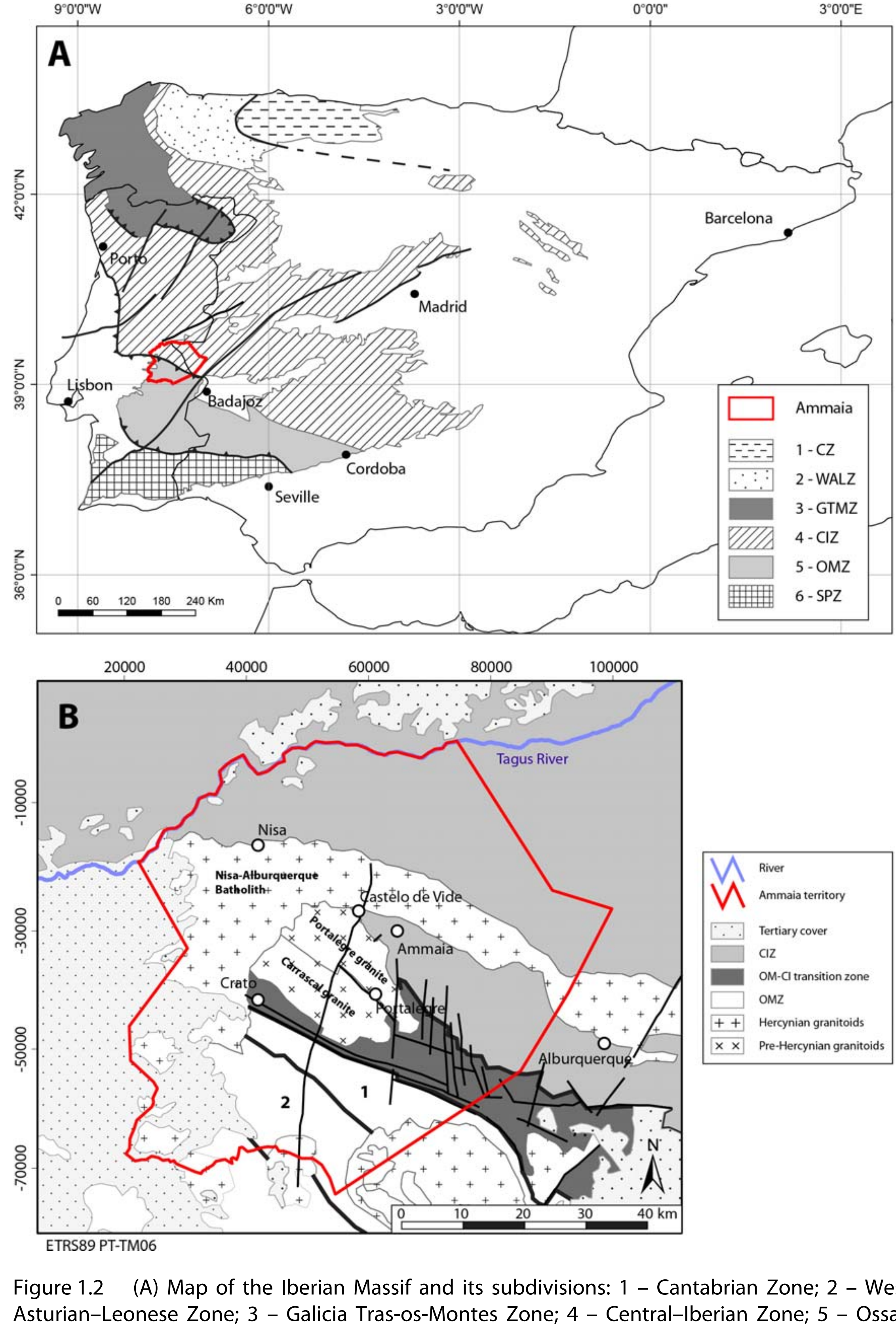

Figure 1.2 (A) Map of the Iberian Massif and its subdivisions: 1 – Cantabrian Zone; 2 – West Asturian–Leonese Zone; 3 – Galicia Tras-os-Montes Zone; 4 – Central–Iberian Zone; 5 – Ossa–Morena Zone; 6 – South Portuguese Zone (after Ribeiro et al., 1979). (B) Tectono-stratigraphic setting of the study area with indication of the OMZ-units: (1) Blastomylonitic Belt and (2) the Alter do Chão – Elvas Unit (after Alvaro et al., 1994; Menéndez et al., 2011; Oliveira et al., 1991).

The CIZ is characterised by a very thick formation with a flyschoid facies, known as the Schist–Greywacke Complex (SGC) (late Neoproterozoic – Lower Cambrian). Within the SGC, Precambrian slates and greywackes crop out in the southern part, while Lower Cambrian rocks essentially slates and greywackes with occasional conglomerates, acidic volcanic rocks and limestones make up the northern part. Only, the Precambrian rocks crop out in the study area (Rodríguez Alonso et al., 2004; Thadeu, 1977; Valladares et al., 2002). Towards the southern limit of the CIZ, the Precambrian rocks are overlain by an Ordovician to Devonian sedimentary sequence of the *La Codosera Syncline* (LCS) (Menéndez et al., 2011; Solá et al., 2009; Soldevila Bartolí, 1992). Here, the dominant rock types are shales and quartzites, with some dolomites and sandstones (Correira Perdigão and Peinador Fernandes, 1976; Limpo de Faria and Pinto de Mesquita, 1962; Lopéz-Moro and Murciego, 2007; Peinador Fernandes et al., 1973; Piçarra et al., 1999; Sanderson et al., 1991). Detailed information on the geology of the LCS is presented in Chapter 7.

The OMZ is a complex and diverse zone that consist of several units with a distinct stratigraphy and structure and ranging from the Precambrian to the Carboniferous (Lopes, 2003; Robardet and Gutiérrez-Marco, 2004). The Alter do Chão–Elvas Unit and the Blastomylonitic Belt are the only units represented in the study area (Figure 1.2-B).
The *Alter do Chão–Elvas Unit* is made up of (1) an late Proterozoic core of the *Mosteiros Formation* of the so-called *Black Series*, with black shales, black metacherts and greywacke; (2) the *Carbonate Formation* (Lower Cambrian), with essentially dolomites; (3) the Lower Cambrian *Vila Boim Formation*, with arenites and pelites and, towards the top, greywackes, micaceous quartzites and conglomerates with some intercalated acidic volcanic rocks and tholeiitic basalts; (4) the Middle Cambrian *Terrugem Volcano-Sedimentary Complex*, with pelites, siltstones, greywackes and some carbonates, with intercalations of acidic and peralkaline volcanic rocks, and alkaline basalts; (5) the *Fatuquedo Formation* (Middle Cambrian–Ordovician age), with arenites, pelites, and conglomerates; and (6) the Ordovician *Barrancos Formation* with mainly grey–black shales (Lopes, 2003; Oliveira et al., 1991).

The term *Blastomylonitic Belt* is used to denote the Portuguese part of the *Coimbra–Cordoba Shear Zone* (CCSZ), a major Hercynian intra-continental transcurrent zone located close to the northern limit of the OMZ. The stratigraphic sequence consist of: (1) the *Campo Maior Formation* (middle Calymmian age), with essentially gneisses, migmatites and amphibolites; (2) the *Morenos Formation* (late Calymmian age), with acidic metavolcanites, amphibolites, meta-arkoses, arenites, micaceous siliceous schists, calcareous and calc-silicate rocks and mica schists (sometimes garnetiferous); (3) the *Mosteiros Formation* (late Calymmian age), with black schists, greywackes, black cherts, calcareous rocks and amphibolites; (4) *Urra Formation* (Ectasian age), with porphyroids, turbidites and greywackes; and (5) the *Armorican Quartzite Formation* (Ordovician age), with mainly sandstones and quartzites (Oliveira et al., 1991).

The transition zone of the OMZ and CIZ lies just north of the CCSZ and an represents a 5–40 km wide and c. 280 km long band that extends from the Portalegre–Esperança Shear Zone in Portugal to the Obejo–Valsequillo–Puebla de la Reina domain in Spain. It is limited by the Alegrete–San Pedro de Mérida fault in the north and the Mosteiros–Hornachos fault (Francisco Pereira and Brandão Silva, 2001; Francisco Pereira et al., 2010; Solá et al., 2008). The OM–CI transition zone consists of three sedimentary and volcanic-sedimentary formations: (1) the *Mosteiros Formation* (late Proterozoic), typical of the OMZ; (2) the *Urra Formation* of the CIZ (Cambro–Ordovician); and (3) the *Armorican Quartzite Formation* of the CIZ (Arenigian). Rocks for the Mosteiros Formation include metagreywackes, metapelites and black metacherts; felsic volcanoclastic rocks, arkosic sandstones, conglomerates and rhyolites for the *Urra Formation*; and arkosic sandstones, quartzites and slates for the *Armorican Quartzite Formation* (Alvaro et al., 1994; Francisco Pereira et al., 2010).

Finally, important geological features of the study area are the large syn- to post-kinematic granite plutons, such as the Lower Ordovician Carrascal and Portalegre granites, that intruded the CCSZ, and the late Hercynian Nisa–Alburquerque Batholith (NAB), that intruded the OMZ, CIZ and the OM–CI transition zone (Francisco Pereira et al., 2010; Ramirez and Menéndez, 1999; Solá et al., 2010; Solá et al., 2009; Villaseca et al.,

2008) (Figure 1.2-B). The contact zone of these plutons with the surrounding geology is generally characterised by contact-metamorphic aureoles (Menéndez et al., 2011).

Late and post-Hercynian tectonic activity generated two principal sets of major, (sub)vertical fractures in the area. The first set has a direction generally between N20°E and N30°E and results from left–lateral motion along important, reactivated northeast–southwest faults (Messejana Fault (N35°–40°E) and Rio Sôr Fault (N30°–35°E)). These fractures are generally more than 10 m wide and exhibit little or no shearing. In a later period, the increasing importance of right–lateral movement along the N55°–60°W faults of Portalegre–Fortios caused the development of a new set of fractures, with a direction generally between N10°W and N30°W (Campos and Pereira, 1991; Deprez, 2009).

Aside from the above-described lithological diversity, the study area is rich in mineralisations that occur disseminated in rocks and quartz veins (composed of milky quartz, rock crystal or hyaline quartz). Mineralisations include chiefly gold, pyrite, uranium mineralisations, wolframite, cassiterite, barite, galena, apatite and sphalerite (Dekkers et al., 1989; Figueiredo et al., 2011; Limpo de Faria and Pinto de Mesquita, 1962; Ribeiro et al., 1965; Vriend et al., 1991).

1.3 Regional and site geomorphology

Ammaia is situated in the transitional zone of the Central Alentejo extensive plains (south) and the mountainous lands of the Beiras (north). Elevations range from 35 m amsl (above mean sea level) in the Tagus River valley to peaks rising as high as 1027 m amsl (*Pico de São Mamede*) in the *Serra de São Mamede*. The *Serra de São Mamede* is a 40 km long and 10 km wide, northwest–southeast oriented mountain range that stretches out on both sides of the present-day Portuguese–Spanish border (Feio and

Almeida, 1980) (Figure 1.3). Elevations in the *Serra de São Mamede* are generally higher than 600 m amsl; lower elevations, however, occur in the valley of the Sever River (c. 500 m amsl). Higher elevations occur as quartzite ridges that result from a higher weathering and erosion resistance (Feio and Almeida, 1980; Feio and Martins, 1993; Vermeulen et al., 2005) (Figure 1.3, Figure 1.4, and Figure 1.5-A). The southwestern part of the *Serra de São Mamede* has well-preserved fault scarps and is made up of two displaced granite planation surfaces: (1) the badly preserved Portalegre platform, (400–500 m amsl), and (2) the Alvarrões platform (680–700 m amsl) (Figure 1.4).

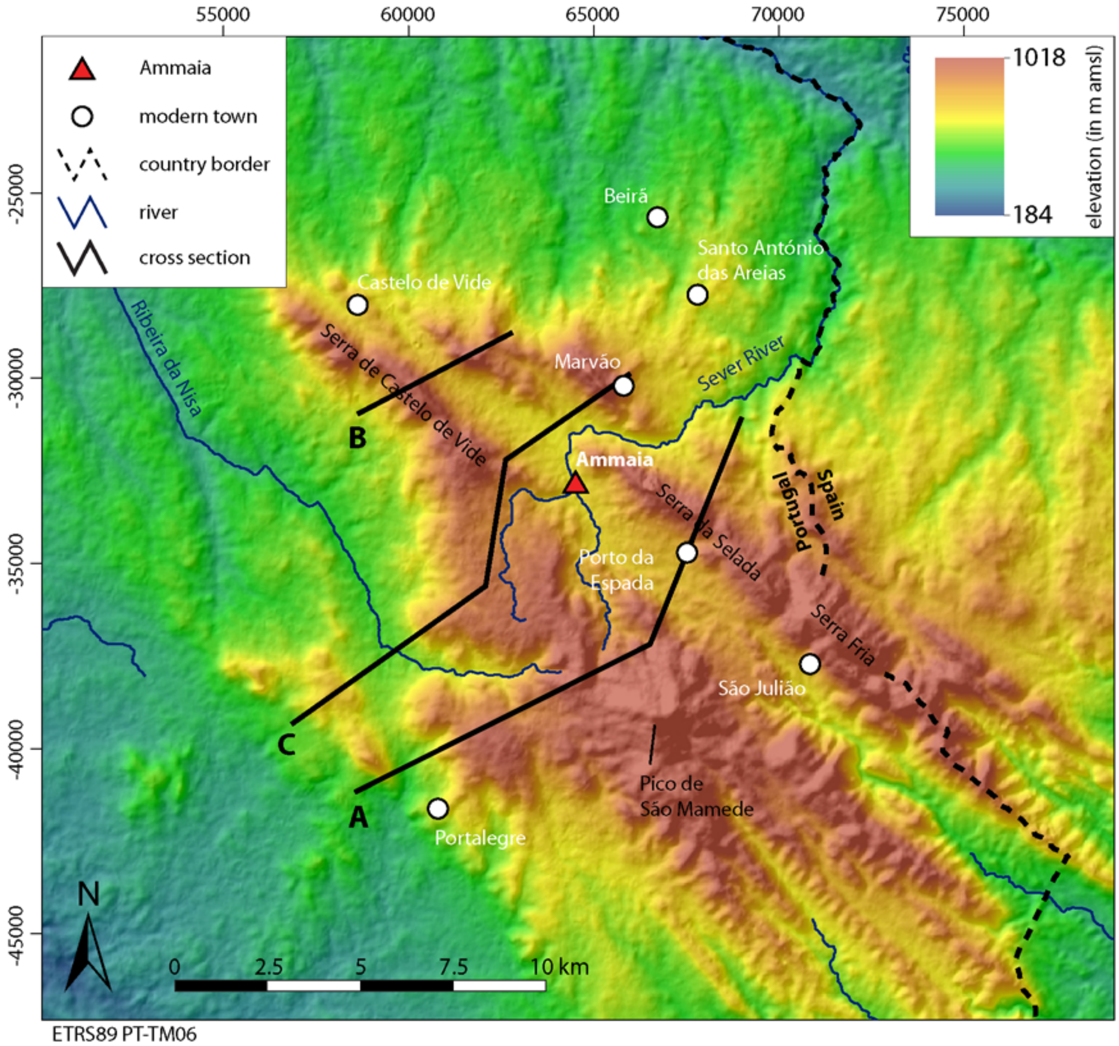

Figure 1.3 Relief of the *Serra de São Mamede* and the planation surfaces in its immediate surroundings. See Figure 1.4 for cross section A, B and C.

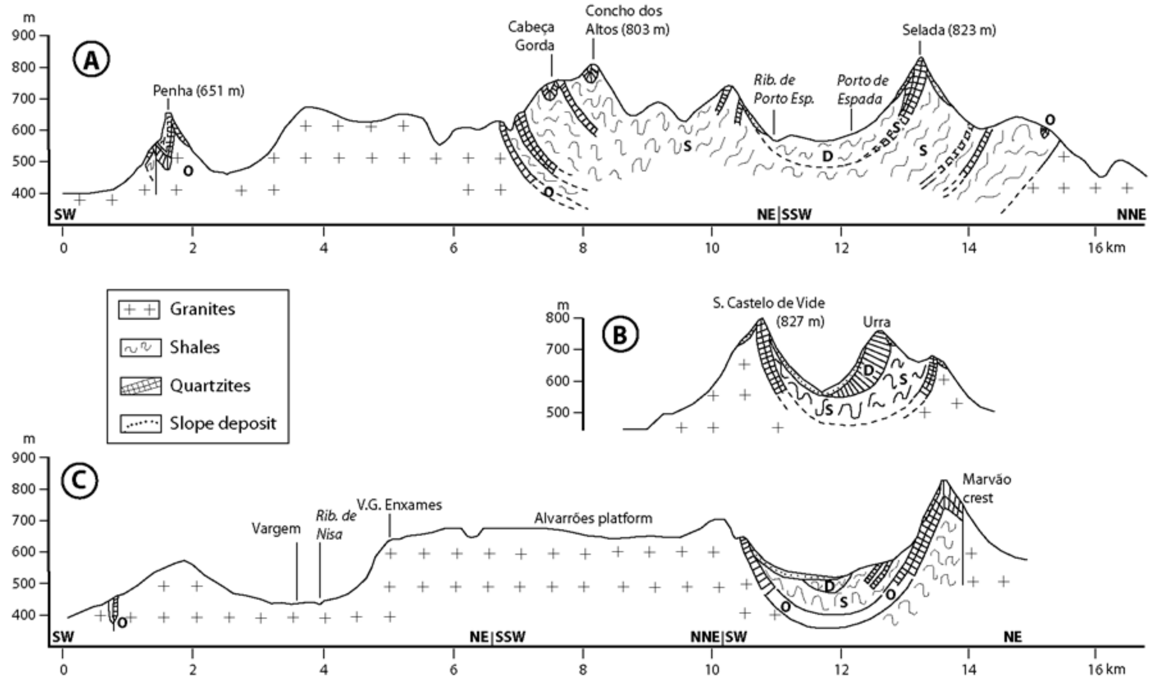

Figure 1.4 Cross sections through the *Serra de São Mamede* (O – Ordovician, S – Siluarian, D – Devonian). See Figure 1.3 for the location of the cross sections (vertical exaggeration = 5x) (after Feio and Almeida, 1980).

Surrounding the *Serra de São Mamede* is the so-called *Alto Alentejo Peneplain* (Figure 1.3), a desolate landscape of vast rolling planation surfaces in the Iberian Massif resulting from intensive erosion, mainly during the Mesozoic, which extends from the Tagus River in the north to the *Serra d'Ossa* in the south (Deprez, 2009; Feio and Martins, 1993). Generally, the bedrock lies at or close to the surface, resulting in poor soils (Vermeulen et al., 2005). Quaternary fluvial erosion has heavily dissected these plains in some areas, while neotectonic fault activity resulted in their displacement (up to hundreds of metres) (Deprez, 2009; Feio and Daveau, 2004; Feio and Martins, 1993). South of the *Serra de São Mamede*, elevations range between 300 m and 350 m amsl for the area north of Monforte–Veiros and around 250 m amsl near Sousel–Fronteira (Feio and Martins, 1993). Near Alter do Chão, the landscape is highly irregular as a result of the alternation of rocks with different weathering and erosion properties (Feio and Martins, 1993). North and west of the *Serra de São Mamede*, the peneplain is best preserved in the granite landscape of the NAB (300–320 m amsl) (Feio and Martins, 1993). One of the most distinctive geomorphological features of the granite landscape is the ubiquitous irregularly distributed weathered granite corestones, inselbergs, boulders and tors that result from selective subsurface weathering (De Dapper, 1994; Migon, 2006). Some larger ones attain up to 20 m in diameter (Deprez, 2009) (Figure 1.5-B). North of NAB, the planation surface lies around 20 m to 50 m higher. Towards the Tagus River, it is heavily dissected by fluvial erosion (Feio and Martins, 1993). Here, the Ródão double quartzite ridge that is cut by the Tagus River rises as a narrow syncline of Ordovician quartzites with peaks up to 460 m amsl.

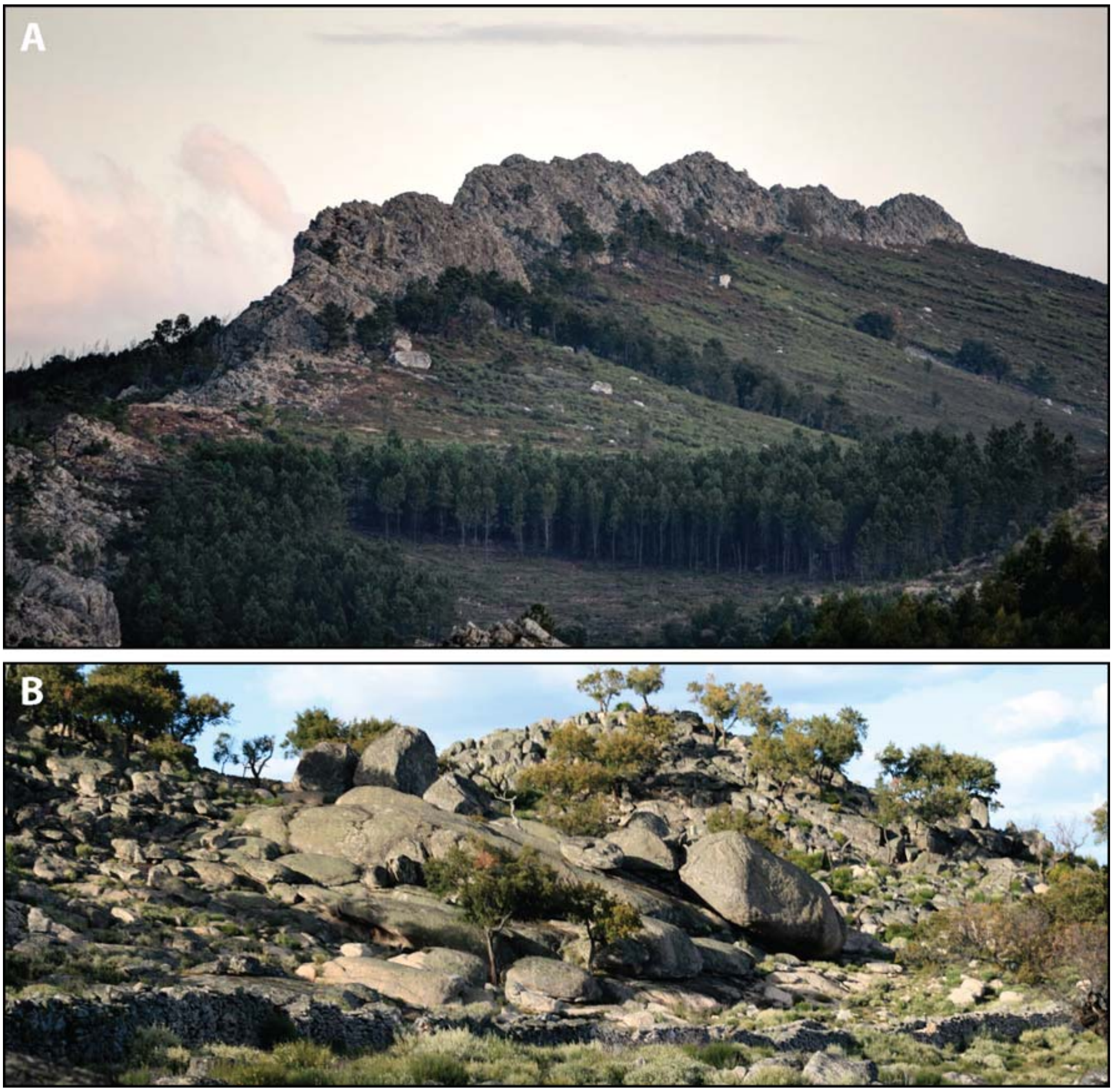

Figure 1.5 Landscape around *Ammaia*: (A) Typical high and steep quartzite ridges of the *Serra de São Mamede*, near Peñas de Puerto Roque on the present-day Portuguese–Spanish border (location: 39.360923° N, 7.319735° W (WGS84), view to the SE); (B) Granite boulder outcrops in the Nisa–Alburquerque Batholith (location: 39.370860° N, 7.315125° W (WGS84), view to the N).

All rivers in the study area rise in the *Serra de São Mamede* and drain towards the basins of the Guadiana River (to the south) and the Tagus River (to the north). The region has numerous small rivers and rivulets giving the northeastern Alentejo and western

Extremadura its particular appearance, certainly when compared with the drier areas to the south (Rodrigues, 1975). The main rivers are the Sever River, the Sôr River, the *Ribeira de Avis* and the *Ribeira da Nisa*, all tributaries of the Tagus River (Vermeulen et al., 2005).

The archaeological site of *Ammaia* is situated in the central lower part of the syncline that forms the *Serra de São Mamede*, and is flanked by high and steep quartzite ridges rising approximately 250–300 m above the site (Figure 1.3 and Figure 1.4). Around *Ammaia*, Silurian and Devonian terrains forming the inner part of the syncline reach a maximum width of about 1–2 km.

The site lies on the gentle slopes of a small hill immediately west of the Sever River, just south of the village of São Salvador da Aramenha. On-site elevation ranges from c. 525 m amsl near the river to c. 600 m amsl in the upper part of the town, which is an extension of the northwest–southeast oriented Malhadais hill. Emsian shales form most of the geological substratum of the town, except for the westernmost part where the substrate is composed of Silurian–Ordovician ferruginous sandstones (Correira Perdigão and Peinador Fernandes, 1976; De Dapper, 2011; Peinador Fernandes et al., 1973).

Geomorphological coring and archaeological observations demonstrate straightforward post-Roman stratigraphic site formation processes. Most of the site area was covered with (dark) brown, fine and loose, sandy silt colluvial sediments, deposited on top of the shale or sandstone bedrock. The steep foothill of the northwest–southeast oriented Malhadais hill was the source of the colluvial material. Fragments of the bedrock and archaeological material occur frequently in the colluvium. On average, the full stratigraphy is approximately 50 cm deep, with local maxima up to 120 cm. At some places, however, the bedrock is just below the earth surface, especially in the western part of the town (De Dapper, 2011; Verdonck and Taelman, in press). The upper parts of the bedrock are often transformed into saprolite as a result of deep bedrock weathering by chemical and physical processes. Near the Sever River, a 30 cm thick layer of fluvial sediments of subrounded gravel in a matrix of clayey silt were deposited by the Sever River on top of the shale bedrock. The alluvial deposits probably result from flooding events as it is clear that the river was not wandering of the valley bottom (De Dapper, 2011).

Today, most of the site is used as grassland and for olive cultivation, with some light woodland and abandoned field terraces on the upper parts of the town. Except for some farmhouses, one of which was recently transformed into the on-site archaeological museum, the site is free of modern buildings. A road connecting Portalegre and Marvão (EN359), however, cuts the former urban site into two unequal parts.

1.4 Present-day climate

The northeastern Alentejo and western Extremadura have a Mediterranean–Iberoatlantic climate with hot summers and moderate winters (Pope and Miranda, 1999). Precipitation occurs mainly during winter, and the summer months are usually extremely dry. Mean annual precipitation ranges from 500 mm to 700 mm; mean annual temperature is around 15 °C. During summer, temperature easily reaches over 40 °C (July–August); during winter (December–January–February), frost days are exceptional (Chazarra et al., 2011; Ratola Duarte, 2002) (Figure 1.6). In the *Serra de São Mamede*, the climatic situation differs somewhat as a result of higher altitudes and orogenetic rains. Mean temperature is slightly cooler and mean annual precipitation is significantly higher compared to the rest of the Alentejo (between 800 and 1000 mm). These wetter conditions result in numerous rivers and more fertile soils in the São Mamede region (Cerqueira, 2005; Daveau et al., 1977; Deprez, 2009; Vermeulen et al., 2005).

As a result of this lack of rain and the outcropping bedrock, the general Alentejo soils are shallow and unfertile with difficult crop cultivation. Agriculture in the region is dominated by cork and olive production and pasture (mainly goats and cows). This is in striking contrast with the *Serra de São Mamede* that has abundant water and features good agricultural soils, especially in the fertile valley of the Sever River that extends from Porto da Espada to Escusa (Cerqueira, 2005; Vermeulen et al., 2005).

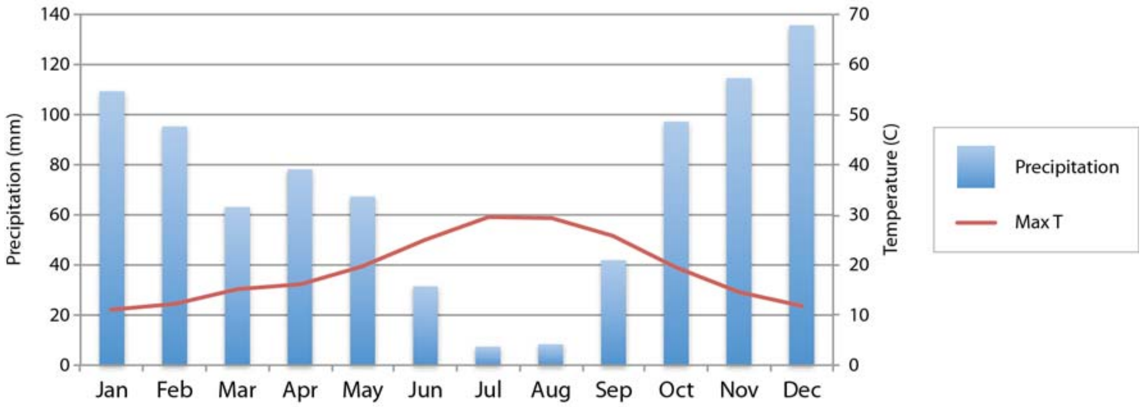

Figure 1.6 Ombrothermic diagram showing the mean precipitation (column graph) and mean maximum temperature (line graph) at Portalegre. Mean values are calculated over a 30-year period between 1971 and 2000 (after Chazarra et al., 2011).

Chapter 2
History of the *Ammaia* region

As a result of its geographical setting (see Chapter 1), the region in which *Ammaia* is situated forms a natural corridor connecting the inner Iberian Peninsula with the Atlantic coast (Mataloto, 2009). This has led to considerable human presence and abundant archaeological remains since the early Prehistory.
Despite this archaeological wealth, systematic archaeological research has developed only relatively recent. Few excavations and in-depth studies have been carried out and archaeological and historical information mainly originates from survey work. This has resulted in a fragmentary knowledge of the archaeological situation, especially regarding chronological information. These issues are especially valid for the Prehistoric and Protohistoric periods. The Neolithic and Copper Age is an exception thanks to the high visibility of the megalithic culture that developed in these periods.

2.1 Prehistoric occupation

Even though scientific interest in the early phases of human occupation in the study area started only recently, it is already clear that the area was densely populated in the

Paleolithic, especially in the Tagus River basin. Concentrations of sites have been discovered in the Arneiro and Ródão depressions (Almeida et al., 2007; 2008). Other locations are Gavião, Lajes, Crença, Vasco, Vidais and isolated finds near Elvas, Arronches and along the Sever River (Almeida, 2002; Almeida et al., 2007; 2008; Cunha et al., 2012; Pereira and Oliveira, 2005; Raposo, 1987).

The earliest human occupation dates to the Lower Paleolithic (pre-Acheulean or Oldowan) with worked pebbles without bifaces. Pre-Acheulean tools were found only at Crença and Vidais (Almeida, 2002). At both sites, as well as at other sites in the central part of the northeastern Alentejo region (e.g. around Castelo de Vide and at Gavião), Acheulean industries with bifaces, cleavers, scrapers and other lithic tools were found (Almeida, 2002; Carvalho, 1998; Cunha et al., 2012; Raposo, 1987) (Figure 2.1). An increase in Middle Paleolithic sites with Micoquian and Mousterian lithic industries using the Levallois stone knapping technique suggests considerable human presence in this period. Middle Paleolithic artefacts comprise Levallois cores, Micoquian handaxes, bifaces, scrapers, and denticulate flakes and blades (Almeida, 2002; Almeida et al., 2007; 2008; Cunha et al., 2012; Pereira and Oliveira, 2005; Raposo, 1987). In contrast to the Lower and Middle Paleolithic, the Upper Paleolithic is less documented and data are scarce and fragmentary. Some isolated finds of Magdalenian(?) industry were recovered at Gavião, Vilas Ruivas, Castelejo and Tapada do Montinho (Cunha et al., 2012; Pereira and Oliveira, 2005) (Figure 2.1).

The raw materials used for the Paleolithic tool assemblages were generally local quartzite and quartz (Almeida, 2002; Almeida et al., 2007; 2008; Cunha et al., 2012). Flint tools appear from the Middle Paleolithic onwards, for example at Tapado do Montinho and Foz do Enxarrique, and originate from more distant sources (Cunha et al., 2012).

Recent Optically Stimulated Luminescence (OSL) dates obtained from soil samples from excavations in the Arneiro and Ródão depressions date the Lower Paleolithic occupation of the area from c. 300 ka to 160 ka; the Middle Paleolithic from c. 160 ka to 32 ka; and the Upper Paleolithic industries from 32 ka onwards (Cunha et al., 2012).

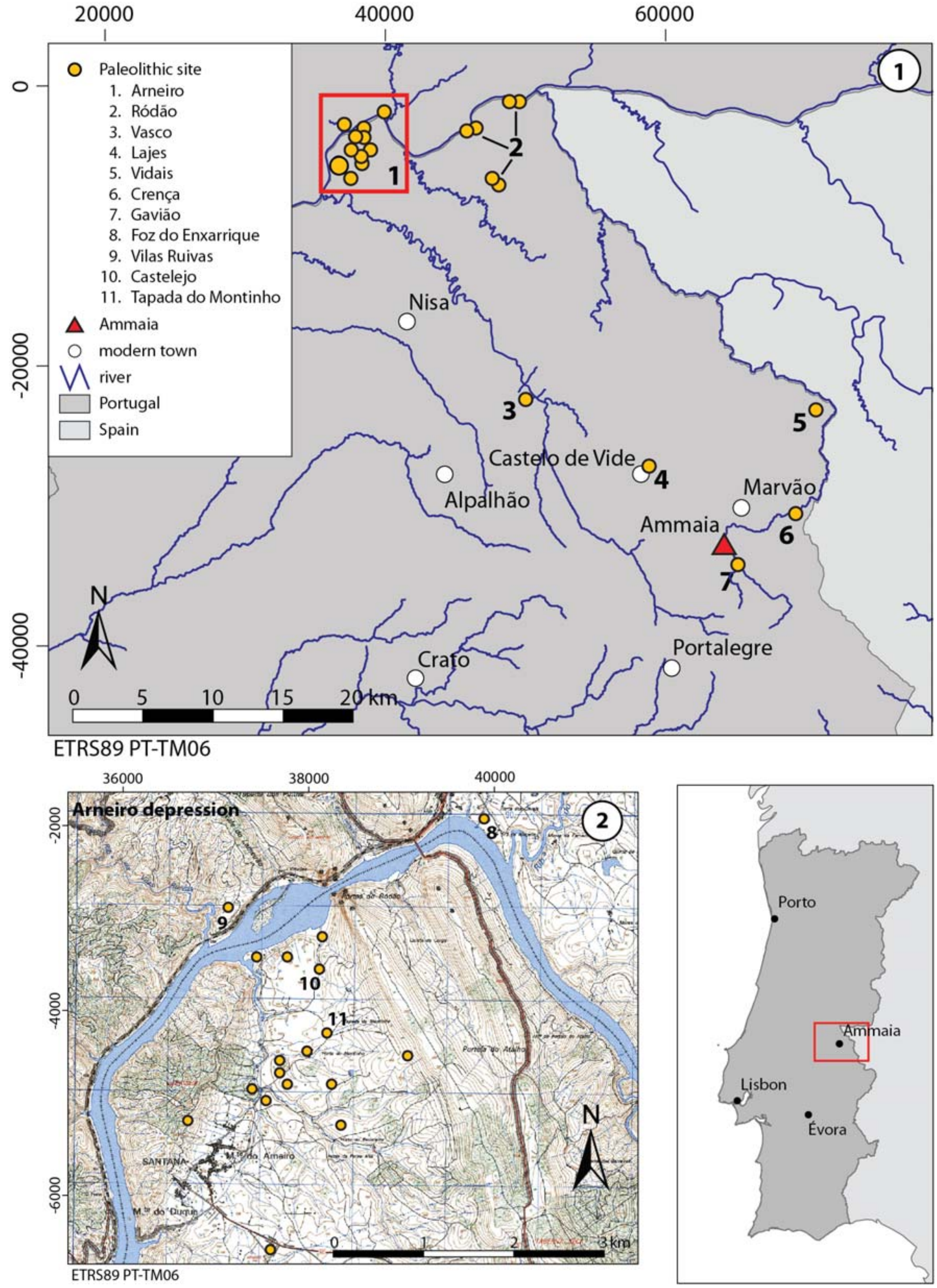

Figure 2.1 (1) Map with location of the Paleolithic sites mentioned in the text; (2) Detailed map of Arneiro depression with indication of the Paleolithic sites (after Cunha et al., 2012).

The Mesolithic in western Iberia is known mainly from about 50 sites associated with shell middens (Gutiérrez-Zugasti et al., 2011). These sites, which were predominantly oriented towards the exploitation of marine and fluvial–estuarine food resources, are concentrated essentially in the estuaries of the Tagus (e.g. Muge), Sado and Mira Rivers, and along the southern Alentejo and the western Algarve coast (e.g. Costa Vicentina) (Bicho, 1994; Carvalho, 2010; Gutiérrez-Zugasti et al., 2011). Traces of Mesolithic presence in the inner part of western Iberia, including the northeastern Alentejo and western Extremadura region, still remain scarce or absent (Carvalho, 2010).

The concentration of settlements in coastal and estuarine territories in the Early Mesolithic seems conditioned by economic and ecological factors. While food resources were readily available in the Paleolithic, settlement locations were primarily determined by the availability of rocks suitable for the production of high-quality lithic tools. As a result of changing climatic conditions in the Mesolithic (during the Preboreal and Boreal periods), settlement locations relate to the presence of food and water resources, and are concentrated essentially in coastal and estuarine environments with sufficient marine, fluvial–estuarine and terrestrial food resources (Bicho, 1994; Carvalho, 2010).

Paleorecords and archaeological data reveal that climatic and environmental changes resulted in an increased aridity, sea level changes, and a decrease in temperature and precipitation in the southern part of the Iberian Peninsula between 8.0 and 7.3 ka cal BP. These changes affected the composition of the terrestrial and marine faunas that were the primary food resources for the Mesolithic groups of the Algarve and Alentejo coast and the estuaries of the Tagus, Sado and Mira Rivers. The faunal impoverishment and the changing climate heavily impacted the Mesolithic coastal economies (Carvalho, 2010; Cortés Sánchez et al., 2012; Jackes and Meiklejohn, 2008). At the same time, the aridification of the Sahara area forced North African people with a Neolithic lifestyle to migrate to the southern Iberian Peninsula (Cortés Sánchez et al., 2012; Jackes and Meiklejohn, 2008). Radiocarbon dates place the beginning of the Neolithic in southern Portugal at 7.4 ± 0.1 ka cal BP (Cortés Sánchez et al., 2012). The number of sites increased and coastal areas that were previously unpopulated were occupied (Carvalho, 2010). The changed climatic and environmental conditions caused the gradual decrease of shell midden sites and encouraged the Mesolithic people to adopt a Neolithic lifestyle (Carvalho, 2010; Cortés Sánchez et al., 2012). The advent of the

Neolithic culture resulted in a considerable demographic growth in southern Iberia (Carvalho, 2010), and in a spread of the neolithisation towards the inner lands of western Iberia that were virtually uninhabited at that time (Bueno Ramirez et al., 2004; Jackes and Meiklejohn, 2008). Eventually, the sedentary lifestyle associated with Neolithic communities reached the northeastern Alentejo and western Extremadura region around the end of the 5th millennium BCE where a mixed agro-pastoral subsistence economy developed (Oliveira and Oliveira, 1999-2000; Oliveira et al., 2007).

The Neolithic and Copper Age settlement pattern consisted of relatively small sites that left few archaeological traces dispersed in the landscape (Andrade, 2011). Besides these habitation sites, the Tagus River valley and the areas around Arronches and Esperança are also rich in rock art (e.g. Lapa dos Gaviões and Abrigo Pinho Monteiro). The regional rock art depicts hunting and livestock farming scenes, but also schematic anthropomorphic and zoomorphic figures, as well as geometric motifs (Oliveira, 2008; Oliveira and Borges, 1998).

The Neolithic in the study area is, however, best known for its rich megalithic funerary culture that developed from the end of the 5th millennium BCE (Early Neolithic), with a peak during the second half of the 4th millennium BCE and the beginning of the 3rd millennium BCE and continuing into the first years of the Copper Age (in the second half of the 3rd millennium BCE) (Andrade, 2011; Boaventura, 2011; Boaventura and Langley, 2006; Bueno Ramirez et al., 2004; Duque Espino, 2002; Oliveira, 1998b; Pereira and Oliveira, 2005) (Figure 2.2). Some of the megalithic monuments were reused in later times, even until the Middle Ages (e.g. the Tapada de Matos dolmen and the Carvalhal menhir) (Oliveira, 1999-2000a; Oliveira and Oliveira, 1999-2000). More than 700 megalithic monuments are known from the study area. Most are circular, ellipsoid or rectangular–square dolmens; the remaining are single standing stones or menhirs.

Figure 2.2 Megalithic monuments around *Ammaia*: (A) Curral das Galhordas dolmen (location: 39.461756° N, 7.544275° W (WGS84)), (B) Meada menhir (location: 39.484415° N, 7.429261° W (WGS84)). Photo-B by E. Browaeys.

Burial gifts associated with the dolmens consist generally of pottery and lithic tools such as worked chips and flakes, hammerstones, polished axes and adzes, and arrowheads. Stone tools were mainly made from local stones; imported flint occurs only rarely (Andrade, 2011; Boaventura, 2006; 2011; Bueno Ramirez et al., 2004; Bueno Ramirez et al., 1998; Navacués and Carrasco Martín, 1999-2000; Oliveira, 1999-2000b; 2003). From the middle of the 3rd millennium BCE onwards, decorated slate plaques are also sometimes found (Boaventura, 2011; Lillios, 2002) (Figure 2.3). The plaques are generally between 10 cm and 20 cm high and 10 cm in width, and have a roughly trapezoidal shape. Rectangular and composite shapes sometimes occur. The plaques are normally engraved with geometric motifs such as triangles, checkerboard, zigzag and chevron motifs; anthropomorphic and zoomorphic decoration also exists, but only rarely. The top part is always perforated (Caninas and Henriques, 1994; Lillios, 2002). Their function remains unclear, but they could relate to heraldry (Lillios, 2002).

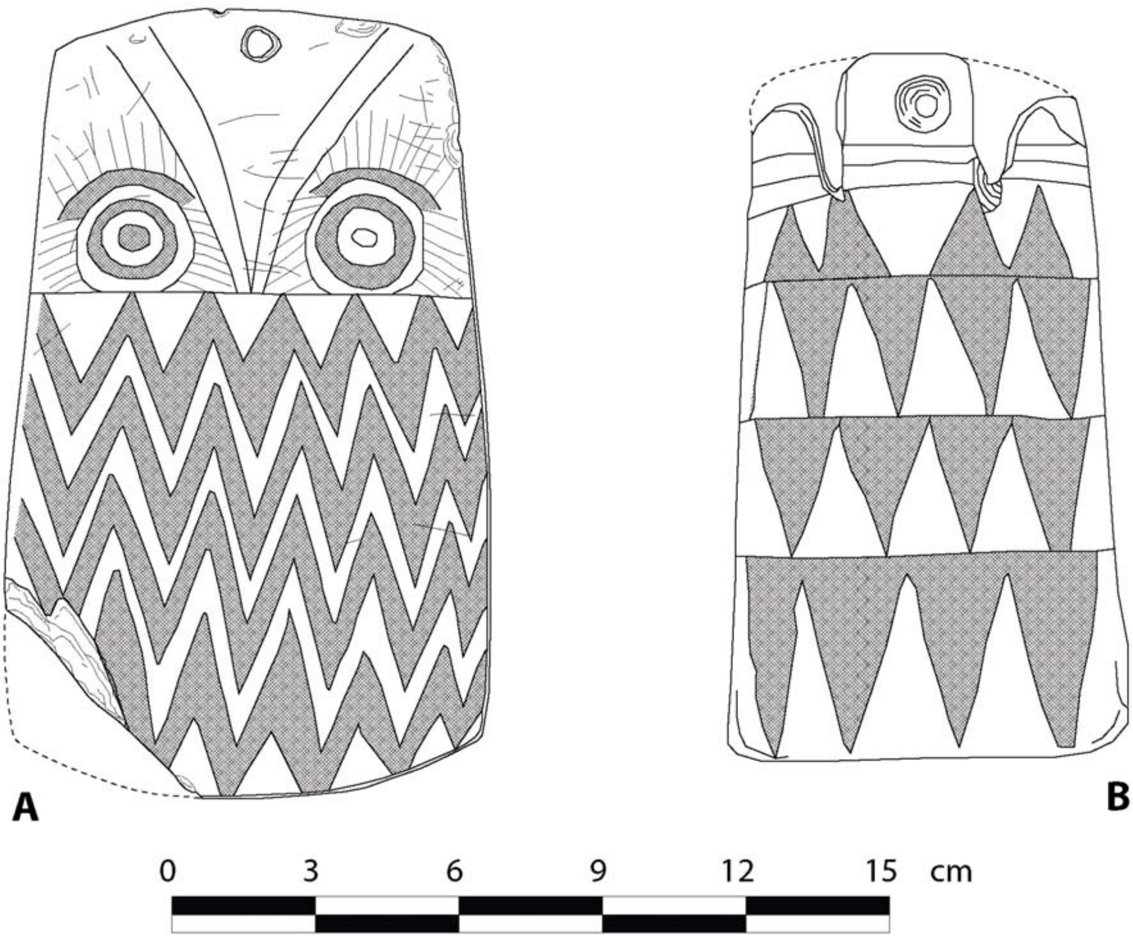

Figure 2.3 Decorated slate plaques with geometric motives from the Neolithic: (A) plaque found in the Alcogulo 2 dolmen (Castelo de Vide) (Caninas and Henriques, 1994); and (B) plaque found in the Pessilgais 2 dolmen (Fronteira) (Andrade, 2011).

The megalithic culture from the study area belongs to the so-called Nisa–Crato group that developed between the Tagus River and the *Serra d'Ossa*, a mountain range located just south of Estremoz (Andrade, 2011). Within this group, two subgroups can be distinguished that are more or less concentrated along the main rivers in the area: (1) the Sever River (on both sides of the Portuguese–Spanish border) reaching to Nisa, and (2) the Seda and Ribeira Grande rivers (around Crato, Fronteira, Ervedal, Figueira e Barros, Alter Pedroso, Vaiamonte and Monforte) (Andrade, 2009; 2011; Boaventura, 2006; Oliveira, 2000; Oliveira et al., 2011a). Based on raw material and geological setting, the Sever group is subdivided into two contemporaneous groups. The first group consists of dolmens located in the Nisa–Alburquerque Batholith and made from the local granite (Pope and Miranda, 1999); the second group are slate dolmens and are found more to the north in the Schist–Greywacke Complex. Large menhirs are situated at the northern boundary of the NAB granite outcrops and mark the transition between the granite landscape and the plains of the SGC. Examples are the menhirs of Meada, Carvalhal, Corregedor and Pombais (Oliveira, 1992; 1998a; Oliveira and Oliveira, 1999-2000) (Figure 2.2). Besides geological setting and raw material, the two dolmen groups also differ in average size of the monuments. Compared with the granite dolmens, the slate examples are significantly smaller (rarely over 50–100 kg per stone slab). The number of slate dolmens is, however, higher compared with the granite dolmens (Oliveira, 1998a). Finally, there is a clear distinction between the two groups regarding the richness of the burial gift assemblages. While ceramic vessels and grinding stones are found frequently in the granite dolmens, they are absent or occur only rarely in the slate monuments. Although imported flint artefacts and decorated slate plaques mainly occur in the granite monuments, (polished) lithic tools are far more abundant in the group of slate monuments. Other differences mainly concern the proportions of axes and adzes in the different monument types, with axes being predominant in the slate group and adzes in the granite group (Oliveira, 1998a; 2003; 2008). It is believed that these two different megalithic contexts are part of two different socioeconomic groups: (1) the granite group: a more complex hierarchically organised and sedentary society with a subsistence economy oriented towards agriculture, and (2) the slate group: a more individualistic and mobile society where pastoralism was predominant. The prime reason for this socioeconomic distinction is related to the higher soil fertility in the granite area. In the slate area, the constant search for good herding grounds hindered the development of a proper sedentary culture and people lived in smaller groups. This difference is also reflected by the presence of tools related to agricultural practices (adzes and grinding stones) and the presence of pottery in the granite monuments. As a result of the agricultural subsistence base, the people from the granite area were more sedentary and developed a stronger hierarchical organisation, in which it was easier to gather sufficient people to provide labour for the construction of larger megalithic structures (Oliveira, 1998a; 2000; 2003). This hierarchy is also visible by the presence of prestige goods in the granite burials (jewellery, decorated slate plaques, imported flint) (Oliveira, 1998a; 2003; 2008).

Around the middle of the 3rd millennium BCE, the introduction of copper technology and Campaniform pottery indicates the beginning of the Copper Age or Chalcolithic in the study area. In a first phase, copper objects were mainly used for decoration and as a symbol of wealth (Pereira and Oliveira, 2005). The megalithic funerary culture that had developed during the Neolithic also remained important.

Hitherto, research of the Copper Age has essentially focused on the area around Elvas (Portugal) and Badajoz (Spain), south to southeast of the study area, where a network of 3rd millennium BCE fortified settlements has been identified (e.g. Paraíso, Juromenha 1, El Lobo, Santa Vitória and Fontalva). Smaller sites are gradually abandoned and replaced by middle- to large-sized settlements located at strategic locations in the landscape, indicating a period of instability and hostility in the 3rd millennium BCE (Mataloto and Costeira, 2008).

Near *Ammaia*, only few Copper Age sites have been identified (Lapas dos Vidais in Beirã and Castelo Velho in Castelo de Vide). Although less pronounced, a similar image to that of the area around Elvas and Badajoz, with a more apparent social distinction and wealth accumulation in the hands of a small elite community, is also visible (Carvalho, 1998; Pereira and Oliveira, 2005).

2.2 Protohistoric occupation

Like in many parts of the western Iberian Peninsula, the Bronze Age in the study area did not fully develop until the late 2nd millennium BCE, when new Indo-European populations entered the Iberian Peninsula (Alarcão, 2001). Of these Indo-European people, the *Lusitani* tribes settled in the Beira region and parts of the Spanish Extremadura (between the 13th and 11th century BCE) and the *Conii* tribes settled in the Alentejo, the southern part of the Spanish Extremadura and the Algarve (during the late Bronze Age). The study area therefore exists within the zone of contact between the *Lusitani* and the *Conii* (Alarcão, 2001). Just as for the Copper Age, archaeological evidence for the Bronze Age in the northeastern Alentejo (Portugal) and western Extremadura (Spain) is scant, especially in comparison with the situation in the central and southern Alentejo where several late Bronze Age settlements have been discovered (e.g. Vaiamonte) (Carneiro, 2004; Carvalho, 1998; Oliveira et al., 2007; Pereira and Oliveira, 2005). The few known Bronze Age sites in the study area, for example Outeira de São Miguel, Tapada da Moita, Castelo de Gusmão, Vidais 2 and Sapateira Grande 2, suggest a continuation of the culture that developed in the Copper Age, characterised by hilltop settlements with good natural strategic–defensive properties and sometimes protected with defensive walls (Mataloto, 2005; Oliveira et al., 2007). The megalithic tombs are often reused (Mataloto, 2005). In the Final Bronze Age, a new settlement pattern with dispersed rural sites and an abandonment of the larger sites is observed (Mataloto, 2009).

The first arrival of the Celts around 500 BCE marks the beginning of the Iron Age; a second wave of Celtic immigrants is dated in the 3rd century BCE (Alarcão, 1988a). The beginning of the Iron Age coincides with an increasing Mediterranean influence, especially for the area south of the Tagus River that came into contact with the more developed Mediterranean cultures of the Tartessian, Phoenician, Greek and Carthaginian colonists that had settled along the southern Iberian coast (Alarcão, 1988a). Similar to the previous periods, sites are generally located at strategic positions in the landscape. Important was the proximity of water and good visibility of the surrounding landscape. From the 3rd century BCE, the first imported Mediterranean products appear (mostly Italic). Examples are Campanian pottery, Italic *amphorae*, Pompeian ware and Roman Republican coins. The 3rd century BCE also marks a change in the settlement pattern of the region. Existing settlements are gradually abandoned and replaced by larger, fortified towns as a response to the growing socioeconomic, politic and military instability, such as the military campaigns of the Romans in the Iberian Peninsula after the Second Punic War (Calderón Fraile et al., 2000). While for the central and southern Alentejo, several proper Iron Age towns are known (e.g. *Conistorgis* (north of Faro?, Portugal), *Mirobriga* (Chãos Salgados, Portugal), *Lacobrig*a (Lagos, Portugal) and *Ebora* (Évora, Portugal)) (Alarcão, 1988a), only smaller settlements have been identified in the study area. These include Vaiamonte, Vidais 2, Agua Formosa, Castelo do Corregedor, El Jardineiro, Crença and Murta 2. Especially Vaiamonte and Vidais 2 have been studied in detail. The archaeological data from Vaiamonte suggest an intensive occupation of the site from the middle of the 1st millennium BCE until the 1st century BCE (Boaventura and Langley, 2006; Mataloto, 2010; Pereira, 2009). The Vidais 2 site was occupied between the 4th and the 1st century BCE. Contact with the Roman conquerors is illustrated by the presence of Roman Republican coins and *amphorae* fragments (Dressel 7–11, 20). The site's subsistence was based on a mixed agro-pastoral economy with an important exploitation of minerals. Based on the excavated housing structures and the site's maximum food supply, a population of 60 to 84 persons is proposed (Correia, 1999-2000; Oliveira et al., 2007).

Recent research in the southern part of the study area has illustrated the existence of dense occupation of the rural landscape with small- to medium-sized sites oriented towards the exploitation of food and minerals (Mataloto, 2010).

2.3 The Roman period

The Roman conquest of the Iberian Peninsula is indirectly the result of the Roman victory over the Carthaginians in the Second Punic War (218 BCE – 201 BCE), after which the Roman presence in the coastal areas of the eastern and southern part of the Iberian Peninsula was definitively established (Collins, 1994). During the next two centuries, the Romans gradually annexed the entire Peninsula. For the *Ammaia* region, this must have taken place between 178 BCE, when the first Roman army under command of L. Postumius Albinus arrived in the region, and 138 BCE, when Decimus Junius Brutus conquered *Olisipo* (Lisbon, Portugal) and Moron (near Santarém, Portugal) and consolidated the Roman presence south of the Tagus River (Collins, 1994; Mantas, 1998). The definitive integration of the area south of the Tagus River in the

Roman Empire is dated in 72 BCE, after the Sertorian wars (Alarcão, 1988a; Collins, 1994; Mantas, 2000).

During the first decades of Roman control, the existing indigenous settlements continued to be inhabited and actual Roman presence was rather limited. A network of tower enclosures and fortified rural sites, erected around the middle of the 1st century BCE in strategic positions in the landscape illustrate an increased instability of the area at the end of the Republic and the beginning of the Imperial period, when the first Roman immigrants arrived (Alarcão, 1988a; Calderón Fraile et al., 2000; Fabião, 2002; Mataloto, 2010). Most sites have only a limited period of occupation and are abandoned at the latest at the end of the 1st century BCE – the beginning of the 1st century CE (Alarcão, 1988a; Fabião, 2002; Mataloto, 2006; 2010). These fortified sites probably functioned as a fundamental element for the Romans in controlling the newly conquered lands, prior to a proper territorial and political reorganisation by the foundation of proper Roman towns around the end of the 1st century BCE (e.g. *Ebora*, *Pax Iulia* (Beja, Portugal) and *Emerita Augusta*) (Calderón Fraile et al., 2000; Fabião, 2002). The abandonment of these sites is thus related to the foundation of a Roman political and territorial control system of the area with proper Roman towns (Mataloto, 2006). Like other towns in the province of *Lusitania*, *Ammaia* undoubtedly functioned as an urban and political–administrative centre from where the surrounding lands of the northeastern Alentejo and western Extremadura regions could be governed efficiently.

The town of *Ammaia* was founded between the late Augustan–Tiberian and early Claudian period. At this stage of the research, no traces of pre-Roman occupation on the site have been detected. Likewise, the material record clearly indicates that the town was not yet fully integrated in the Roman commercial system in the Augustan–Tiberian period (Pereira et al., 1999/2000; Quaresma, 2010-2011; 2011). The earliest certain evidence for Roman *Ammaia* is an honorific inscription of the town's citizens dedicated to the Emperor Claudius. The inscription dates the foundation before 44–45 CE (IRCP 615).

Like many other towns in *Lusitania*, *Ammaia*'s heyday began around 50 CE and lasted until the end of the 2nd century CE (Quaresma, 2010-2011; 2011). According to Stylow (2009), *Ammaia* evolved to a *municipium iuris latini* in the last quarter of the 1st century CE, when Vespasian granted the Latin right to all towns in the Iberian Peninsula. This new political status is reflected in the urban development of the town, with the dismantlement of several pre-existing buildings and the construction of monumental public complexes (see Chapter 4) (Pereira, 2002; 2005; 2009; Quaresma, 2011).
The end of the 2nd century CE was a turning point for *Ammaia*. Compared with the previous period, fine-ware imports from the 3rd and 4th century CE are relatively scarce (Quaresma, 2011), and epigraphic production and building activity virtually ceased. Numismatic evidence, however, suggests a continued occupation of the town at least until the third quarter of the 4th century CE (Ruivo J., personal communication). Between the late 4th and early 5th century CE, the town was gradually abandoned in favour of the countryside as a result of economic instability, demographic decline and reduced urban investment are some of the interlinked explanations for this evolution.
Sometime in the first half of the 5th century CE, the entire site was completely abandoned and covered by flood and slope deposits (Vermeulen and Taelman, 2010) (see also Chapter 1). The few material remains of the later 5th to 6th century CE, such as some Visigothic material, are not sufficient to justify a full occupation of the town in this period; some isolated habitation cannot be excluded (Quaresma, 2011). In the late 9th century CE, when the Muladi chieftain Ibn Marwân settled in the nearby and strategically well-situated stronghold of Marvão, the town of *Ammaia* had already degraded into ruins as suggested by the title of *Lord of the ruins of Ammaia* for Ibn Marwân (Sidarus, 1991).

As mentioned in Chapter 1, the Roman town of *Ammaia* was the capital of a territory of approximately 3950 km^2, situated south of the Tagus River and extending on both sides of the present-day Portuguese–Spanish border. Even though its exact boundaries are not known, it roughly comprised the northeastern Alentejo region of Portugal and the central-western part of the Spanish Extremadura region. The northern limit is likely to correspond to the course of the Tagus River. A plausible southern border is formed by the *Ribeira de Avis* and the line between Veiros, São Pedro de Almor, Monforte, Arronches, Esperança and La Codosera (Spain). Somewhere just north of Veiros, a meeting of the territories of *Ammaia*, *Ebora* and *Emerita Augusta* must have existed. The western and eastern border curved northwards towards the Tagus River at respectively Avis and La Codosera (Carvalho, 2002; Guerra, 1996; Mantas, 2000; Pereira, 2005; Plana-Mallart, 1995). Two main communication and trade routes that linked *Emerita Augusta*, the province capital of *Lusitania*, with *Olisipo*, the main harbour of the province crossing the territory were certainly a major asset for the development of the area (Carneiro, 2004; 2009) (Figure 2.4, see also Chapter 3).

Other population centres in the territory, such as *Abelterium* (Alter do Chão, Portugal) and *vicus Camalocensis* (near Crato, Portugal), mainly emerged on the main crossroads of the Lusitanian road network (António and Encarnação, 2009; Carneiro, 2004). Apart from these main settlements, an extensive network of rural sites was responsible for the exploitation of the landscape. Around *Ammaia*, these rural sites were relatively small and served to supply the town with the necessary goods for its daily subsistence (food, building stone, wood, lime, metal) (Taelman, in press). Outside the catchment area of *Ammaia*, many rural settlements developed into large villa estates, such as Torre de Palma, Tapada do Garriancho, Tapada da Pedreira, Mascarro, Pombais 1 and Mosteiros (André, 1997; Carneiro, 2004; Fernandes, 1985; Fernandes and Mendes, 1985; Fernandes and Oliveira, 1995; Huffstot, 1998; Maloney and Hale, 1996; Monteiro, 2011; Rodrigues, 1975) (Figure 2.4). Most of these large villa estates were founded immediately after the establishment of a proper Roman system of political and territorial control, and were often richly decorated with marble and mosaics and often incorporated bathing facilities in addition to residential and industrial or artisanal functions (Almeida, 2000). The abundant import material at most villas, the construction of the private paleo-Christian basilicas and baptisteries, such as at Torre de Palma (Huffstot, 1998; Maloney and Hale, 1996), and the investments in maintenance and reparation of the road between *Emerita Augusta* and *Olisipo* in the second half of the 3rd century CE (Carneiro, 2004), clearly indicate a flourishing rural exploitation system between the 1st and the early 4th century CE (Carneiro, 2004; Fernandes and Oliveira, 1995; Maloney and Hale, 1996; Oliveira et al., 2007; Rodrigues, 1975). After the 4th century CE, several signs point to a changing economic and political climate. The decline and final collapse of the Roman economic system and the invasion of Germanic people resulted in a ruralisation of the landscape and a gradual abandonment of the urban centres (e.g. *Ammaia*). On the other hand, the large villas maintained their status and gradually accumulated all land, regardless of signs of a reduced wealth (Almeida, 2000; Carneiro, 2004; Huffstot, 1998; Maloney and Hale, 1996).

Besides crop cultivation and livestock farming, the main economic activity in the study area was the mining of mineral resources, mainly iron and lead. Remains of these extractive activities are plentiful in the territory of *Ammaia*. More valuable minerals such as gold and rock crystal for glass and jewellery manufacturing were mined as well. Evidence of gold mining was found at Mosteiros (Oliveira et al., 2007) and particularly at Conhal, on the left bank of the Tagus River (Deprez et al., 2009; Deprez et al., 2007). Here, large volumes of Tagus River sediments were exploited on an industrial scale (Deprez et al., 2009; Deprez et al., 2007). The importance of rock crystal for the town's economy is illustrated by two references to the presence of the mineral in the hills around *Ammaia* by Pliny the Elder (*Naturalis Historia 37.24 and 37.127*) (Guerra, 1995) (see Chapter 3). Industrial-scale ceramic production was discovered at the villa of Mosteiros (Monteiro, 2011), and large oil and wine presses were found, for example, at Torre de Palma and several other locations (Maloney and Hale, 1996). Finally, the importance of horse breeding needs to be mentioned. *Lusitania* was famous for its horses in Roman times (Centeno, 1983). The discovery at Torre de Palma of mosaics depicting horses illustrates that the region probably played an important role in racehorse breeding (Alarcão, 1988a; Mantas, 1999).

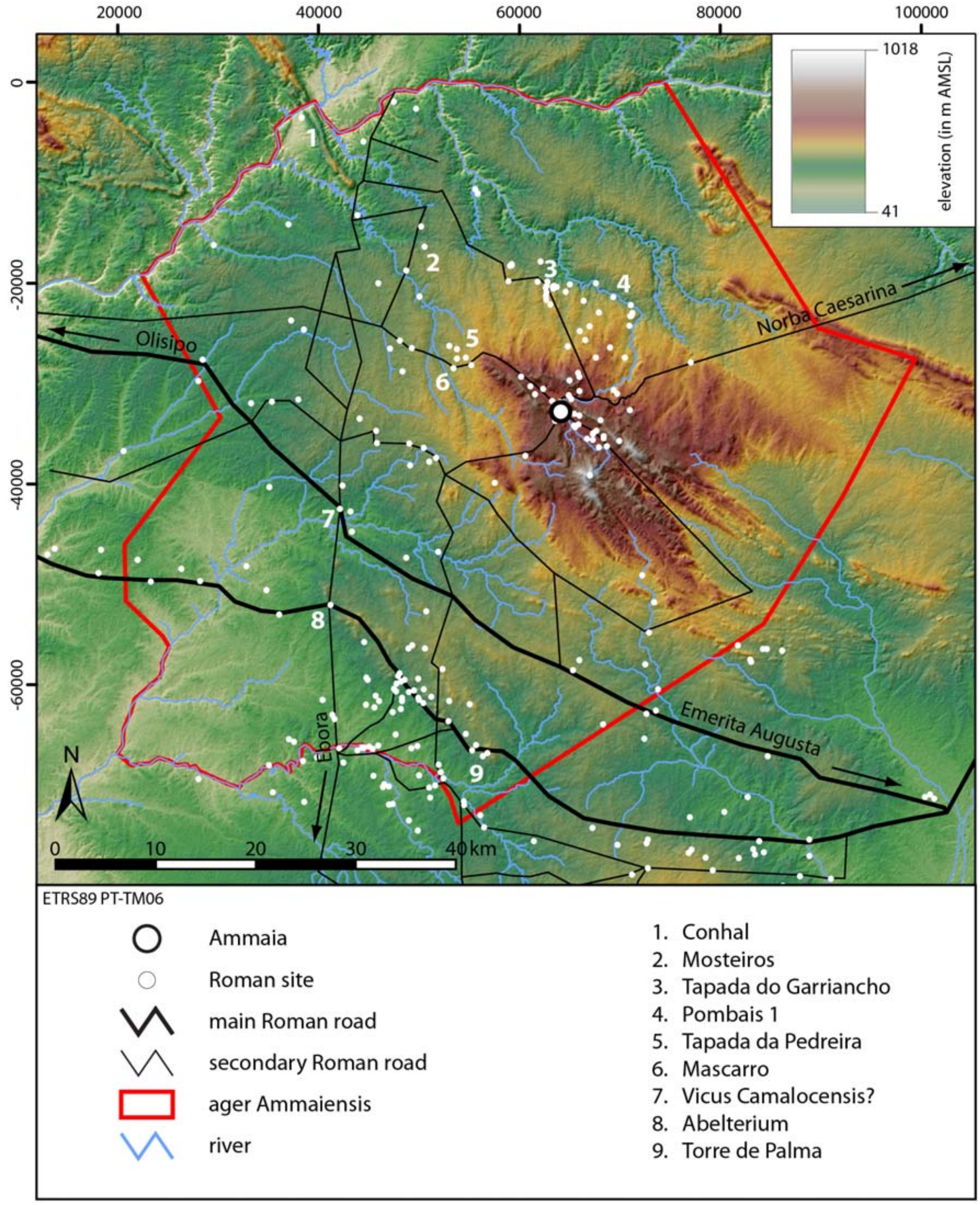

Figure 2.4 Map of the known Roman sites in the territory of *Ammaia* (after Alarcão, 1988b; Carneiro, 2004; Langley, 2006; Oliveira et al., 2007; Oliveira et al., 2011b; Rodrigues, 1975), with indication of the Roman road network (after Alarcão, 1988a; Almeida et al., 2011; Carneiro, 2009; de Saa, 1956).

2.4 The post-Roman situation

Around the turn of the 5th century CE, a series of foreign invasions by Sueve, Vandal and Alan people initiated the end of the Roman control of the Iberian Peninsula. The Sueves and the Hasding Vandals settled in *Gallaecia* (northwestern Iberia), the Alans in *Lusitania* and the Siling Vandals in *Baetica* (Alarcão, 1988a; Centeno, 1983; Richardson, 1998). The Sueves soon defeated the Hasding Vandals and extended their territory as far as Mérida. Meanwhile, the Visigoths made their first appearance and gradually expanded their influence. Ultimately, in 585 CE, they incorporated the entire Peninsula in their kingdom (Alarcão, 1988a; Centeno, 1983; Collins, 2006). As a result of internal conflicts among the reigning Visigothic classes, the kingdom was heavily weakened at the end of the 7th century CE. Moorish invaders, that reached Iberia across the Straits of Gibraltar, defeated the Visigoths and conquered most of the peninsula in less than ten years.

Sometime between 712 CE (conquest of Mérida) and 715 CE (conquest of Évora), the northeastern Alentejo and western Extremadura was reached (Collins, 1994; 2006; Oliveira et al., 2007). For the area around *Ammaia*, however, no direct indications of political and military instability exist. Local people probably continued their Roman(ised) lifestyle (Oliveira et al., 2007). Nevertheless, some severe changes took place from the late 4th century CE onwards, notably in the settlement system, as a result of the decline and final collapse of the Roman economic system. Urban centres, like *Ammaia*, are gradually deserted and a ruralisation of the landscape can be observed. Larger rural estates acting as local centres progressively acquired more land at the expense of the smaller rural sites, and gradually evolved into ‘proto-villages’, where religious, funeral, social and economic aspects of society are concentrated. Occupation of these sites generally continued well into the Middle Ages (Almeida, 2000; Carneiro, 2004). Besides food production, the economies of these sites probably consisted largely of oil and wine production as can be seen from the numerous presses that have been found on these sites (Oliveira et al., 2007). Typical around *Ammaia* for this period are the inhumation graves cut into the granite outcrops (Oliveira et al., 2007) (Figure 2.5).

Figure 2.5 Early Medieval rock-cut inhumation graves: Vale do Cano VI (length of hammer: 30 cm) (location: 39.470611° N, 7.407182° W (WGS84)).

Between the 8th and 12th century, the situation in the study area remains somewhat unclear. The main evidence for a Moorish presence are the hilltop fortifications such as Marvão and Arronches (Figure 2.6). These fortifications played an important role during the crisis periods of the 9th–10th century CE, the 11th century CE and the 12th century CE, when the region was the scene of the war between Afonso Henriques, lord of Coimbra, and the Moors (Rei, 1998). During this period, the area of *Ammaia* and Marvão was conquered from the Moors and incorporated into the Portuguese kingdom. Around the middle of the 13th century CE, the town of Portalegre was founded and has since gradually taken over the position as regional capital in the area (Balesteros, 1998). At the end of the 15th century CE, the area around *Ammaia* served as a refugee zone for the Jews expelled by the Catholic monarchs of Spain, Ferdinand II from Aragon and Isabella I from Castille. Many remains of this Jewish presence are still visible in Castelo de Vide and Marvão (Balesteros, 1998). After the 15th century CE, the area remained the scene for battles between Portugal and Spain, including those during the Portuguese War of Restoration.

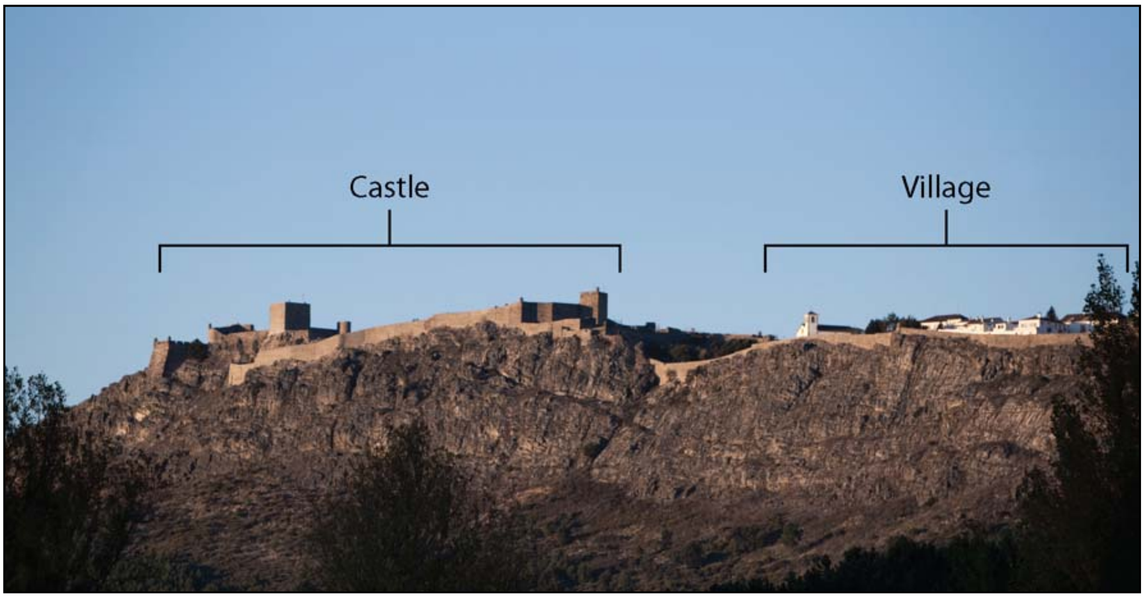

Figure 2.6 Hilltop fortification of Marvão. The castle is visible on the left, the late Medieval and Early Modern village on the right.

Chapter 3
Archaeological research in Roman *Ammaia*

3.1 Frameworks for the *Ammaia* research

3.1.1 Early studies

In the 16th century CE, the site of *Ammaia* first attracted the attention of Portuguese and Spanish historians, one of which was Amador Arrais who, in 1589, mentions the discovery of several Roman columns, marble funerary inscriptions, coins and gemstones, as well as the presence of numerous towers and bridges over the Sever River, and several mines in the hinterland of the town (Arrais, 1974; Pereira, 2009). More scientific archaeological and historical studies are noted from the middle of the 19th century CE onwards. José de Viu (1852) describes the shipping of 20 large marble statues and several other artefacts to England; and several new inscriptions, coins and other artefacts were discovered and described. In the second half of the 19th century CE and the beginning of the 20th century CE, the first excavations revealed some of the town's necropoleis (Pereira, 2009). Many intact Roman burial gifts that were found during these digs are still displayed in the site's museum and in the *Museu Nacional de Arqueologia* in Lisbon. An interesting reference is given in Laranja Coelho's book from 1924 on the history of the region. Besides other archaeological and historical information on the site, he mentions the transfer of the South Gate of *Ammaia* in 1710 to Castelo de Vide, where it stayed in use until 1891 (Coelho, 1988; Mantas, 2010; Stylow, 2009) (Figure 3.1-A).

Figure 3.1. (A) Photograph taken around 1890 in Castelo de Vide of the so-called *Aramenha* Gate or South Gate from Roman *Ammaia*. A typical 18th century CE sentry box can be seen on top of the gate (Coelho, 1988; Mantas, 2010). (B) Inscription dedicated to the Emperor Claudius in 44–45 CE (IRCP 615), found in *Ammaia* in 1935 (MNAE E 7267, *Museu Nacional de Arqueologia*, Lisbon) (Mantas, 2000).

Until this moment, archaeologists and historians believed that the ruins near São Salvador da Aramenha belonged to the Roman town of Medobriga and that *Ammaia* was located in Portalegre, about 10 km to south. It was not until 1935 when Leite de Vasconcelos (1935) published a paper on the discovery of an honorific inscription dedicated to the Emperor Claudius (IRCP 615) that the Roman remains near São Salvador da Aramenha were identified as *Ammaia* (Figure 3.1-B).

In the beginning of the second half of the 20th century CE, mainly epigraphic studies were carried out. The foremost were the works of Encarnação (1984), Mantas (2000; 2002) and Jalhay (1947). The site was declared a National Monument in 1949 and became an archaeological park in 1994.

3.1.2 Excavations and material studies

Systematic archaeological research on the site started only in 1994. From 1997 onwards, these works have been organised by the *Fundação Cidade de Ammaia*, in close collaboration with the universities of Évora and Coimbra. Foreign universities such as Ghent (Belgium), Louisville (USA), Cassino (Italy) and Dublin (Ireland) participated in the works since the beginning. Initial excavations have focussed essentially on areas where visible ruins indicated the presence of subsurface Roman remains. These areas included parts of the city wall and the South Gate with associated monumental square and residential buildings, parts of a public bathhouse, and parts of the forum complex where the mortar core of the temple podium was still visible. In addition, a residential area underneath the 18th–19th century CE farmhouse, that now hosts the on-site archaeological museum, and a suburban area between the town and the Sever River were fully excavated. Some preliminary material studies (mainly epigraphy, gemstones, numismatics and fine-ware pottery) mainly aimed at reconstructing the general historical and chronological evolution of the town.

3.1.3 Geoarchaeological research

In 2001, the Geography (under the direction of Prof Dr Morgan De Dapper) and Archaeology (under the direction of Prof Dr Frank Vermeulen) departments of Ghent University (Belgium), in close collaboration with the University of Cassino (Italy), initiated a broad geoarchaeological survey project in and around the Roman urban site of *Ammaia*. The aim of the project was – and still is – to investigate the complex interaction between the Roman provincial town and its territory. The main research topics concern the urban layout, the geomorphological setting of the town and its surrounding landscape, the exploitation of mineral resources (e.g. gold, iron, granite and quartz), the water provisioning system, and the ancient road system. To reconstruct the cultural landscape around *Ammaia*, a multidisciplinary geoarchaeological approach was adopted combining techniques from archaeology and the geosciences (essentially geomorphology and geology) (Vermeulen et al., 2005). A thorough study of the geological and geomorphological setting of *Ammaia* and its territory and extensive field survey formed the basis for interpreting the archaeological landscape of *Ammaia*. Field data were incorporated in a geographical information system (GIS), in which ancient and modern landscape data were integrated. Apart from field work and the development of GIS-based spatial databases, laboratory analyses such as thin section petrography and geochemical analysis were carried out to answer questions regarding the highly structured and heavily exploited rural landscape around Roman *Ammaia*.

This PhD thesis on *The Provenance, Supply and Use of Stone Material at the Roman Town of Ammaia* is part of this interdisciplinary geoarchaeological project.

3.1.4 Radio-Past – Radiography of the past

In 2009, the archaeological site of *Ammaia* was selected as a field laboratory for the project 'Radiography of the Past – Integrated non-destructive approaches to understand and valorise complex archaeological sites', in short *Radio-Past* (coordinator Prof Dr C. Corsi), within the framework of the European Union funded Marie Curie/People framework 'Industry–Academia Partnerships and Pathways' program. The partners of the project are the University of Évora (Portugal), Ghent University (Belgium), the University of Ljubljana (Slovenia), 7Reasons Media Agency (Austria), the British School at Rome (United Kingdom), Past2Present (The Netherlands) and Eastern Atlas (Germany). The project aims at integrating non-destructive survey approaches for the study, valorisation and management of complex archaeological sites. The methodology to achieve these aims includes fieldwork, data collection, data processing, archaeological interpretation and visualisation of the results. For this, fieldwork research in *Ammaia* is linked to several reference projects of Roman urban sites where the partners have been active for many years. The techniques used are an integrated set of remote sensing techniques (low-altitude aerial photography, LiDAR, geomagnetometry, ground-penetrating radar (GPR) ,survey and electrical resistance survey), topographic survey, geomorphological survey, systematic artefact survey, targeted ground-truthing, GIS-based analysis, photogrammetry, laser scanning and scientific visualisation tools (van Roode, 2009; van Roode et al., 2012).

In an initial stage of the geophysical research (2008), a GPR survey was done on the forum area mainly to evaluate the geophysical potential of the archaeological site, after which a full coverage magnetometer survey was done (Corsi et al., in press). Certain urban zones were further investigated with GPR and electrical resistance. Ground-truthing to evaluate the geophysical survey results was carried out on the forum complex (2010 and 2011) and the bathhouse just south of the forum (2008, 2009 and 2011). These digs mainly aimed at providing information on the structural, stratigraphic and chronological evolution of these areas of the town. For a better understanding of the site formation processes and to improve the geophysical interpretation, a systematic geomorphological coring campaign and tests with systematic and targeted artefact surveying were organised in the summers of 2010 and 2011. Finally, several suburban areas were selected for magnetometer survey in 2011 to investigate the relationship between the Roman town and its immediate surroundings, and to locate possible suburban production and burial zones.

3.2 Archaeological research in and around *Ammaia*

3.2.1 Urban layout

Excavations, geophysical survey results and geomorphological observations have illustrated that the Roman urban site of *Ammaia* was surrounded by a walled enclosure of about 1750 m in length. The town wall was partly identified along the northeastern side, where it coincides with the facade of the museum and a modern field boundary, and along the southeastern side, where the South Gate is located (Vermeulen et al., 2005). A second gate, the so-called River Gate was identified in the northeastern side of the enclosure (Corsi et al., in press; Eastern atlas, 2010). Along the northwestern side, clear evidence for the trace of the wall remains absent as a result of the construction of a modern road and some houses that severely altered the natural topography. A small paleovalley was, however, probably not incorporated in the urban area. Geophysical data suggest the possible presence of a gate opposite the South Gate (Corsi et al., in press; Vermeulen et al., 2005). Towards the west, the urban area probably included a steep foothill of the northwest–southeast oriented Malhadais hill as a kind of *acropolis* or strategic lookout (Vermeulen et al., 2012; Vermeulen et al., 2005). Taking this proposal of the town wall, the town, which approached some 19.8 ha, was regularly designed with an elongated extension towards the southwest. It was strategically positioned on a gently-sloping terrain, parallel to the Sever River and was bordered to the north and the south by two narrow paleovalleys connected with the Sever River (Vermeulen et al., 2005).

The built-up area comprised essentially the central and eastern part of the town. Artefact and coring surveys at the Malhadais foothill revealed no architecture in this area, probably because of the outcropping or near-surface bedrock and the steep slopes of the Malhadais foothill (between 11° and 17°) (Vermeulen et al., 2012). Contrary to this extension, the remainder of the urban area was densely occupied with buildings designed according to an orthogonal plan organised along a series of parallel and perpendicular streets and with a centrally located forum. The streets organised the town into a total of 43 roughly rectangular building blocks. The main northwest–southeast street or *cardo maximus* passed just northeast of the forum and connected the South and North Gate. The main northeast–southwest street or *decumanus maximus* passed the forum on its southeastern end and reached the River Gate. At several locations, building modifications have severely changed the initial regular town layout. For example, some streets were reduced to narrow alleys of only 2–3 m wide. Judging from the plan of the building blocks, most of the urban area was occupied by residential areas (*domus* and *insulae*). At first sight, public buildings were limited to the forum complex, a bathhouse just south of the forum and a possible religious complex in the northeastern part of the town. Buildings for public leisure, such as a theatre and amphitheatre, have not been detected yet. Commercial areas were identified as rows of *tabernae* along the central sectors of the main streets, a possible *horreum* near the River Gate and a market place associated with the South Gate (Corsi et al., in press) (Figure 3.2).

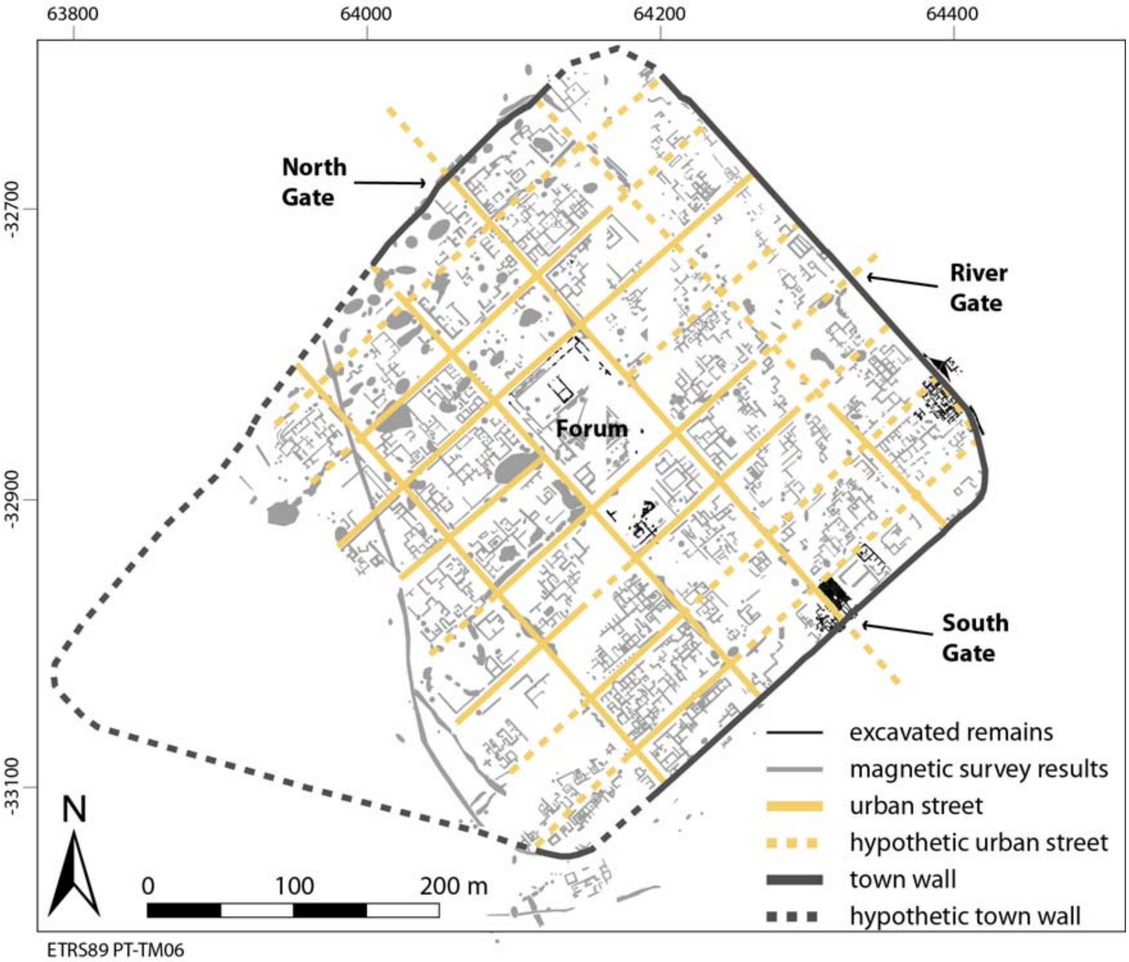

Figure 3.2 Map of the excavated remains overlain with the results of the intra-mural magnetometry survey (Corsi et al., in press; Johnson, 2010).

Although small workshops may have occurred inside the walled area, surveys in the town's *suburbium* suggest significant industrial and artisanal activity here. Apart from workshops, agriculture must have been an important economic activity in the suburban area. Finally, several necropoleis have been detected northwest, northeast and southwest of the town, along the main roads leaving from the town gates (Barata and Mantas, 2006; Coelho, 1988; Corsi et al., in press; Eastern atlas, 2010; Pereira, 2009) (Figure 3.4).

3.2.2 Material studies

Ceramic

Hitherto, ceramic studies have focused solely on fine-ware pottery, i.e. thin-walled wares, lamps and *terra sigillata*.

In general, the pottery record indicates a start of the commercial activities in *Ammaia* in the Augustan period, and going to full development around the middle of the 1st century CE (Quaresma, 2010-2011). In this first phase, thin-walled wares (mainly Mayet 37, 38 and 43) and lamps (mainly volute lamps: Dressel 11–14, and disc lamps: probably Dressel 20) show intensive commercial contact between *Ammaia* and *Emerita Augusta* (Quaresma, 2010-2011). From the beginning, *Ammaia* was clearly part of the economic sphere of *Emerita Augusta*, with the capital acting as a (re)distribution centre for, for example, Emeritan lamps and Hispanic *terra sigillata* from La Rioja (Quaresma, 2010-2011). Considerable quantities of fine-ware imports reached *Ammaia* well into the 2nd and beginning of the 3rd century CE. A period of import decline is noted in the 3rd and 4th century CE with, for example, only a small amount of lamps, African red slip C from Byzacene and African red slip D from Zeugitania, Hispanic *terra sigillata*, and Late Hispanic *terra sigillata* from the Douro region. Imported fine-ware products are noted again from the middle of the 4th century CE onwards. After the 5th century CE, the fine-ware record illustrates a gradual abandonment of the site (Quaresma, 2010-2011; 2011).

Numismatics

Thus far, around 3000 coins are known from the urban area of *Ammaia*, of which only a small portion has been studied.

Apart from few Late Republican and Early Imperial coins, the first numismatic evidence dates to the Claudian period. Two main periods dominate: (1) from Claudius to Marcus Aurelius (middle 1st– late 2th century CE), and (2) the middle of the 3rd century CE to c. 370 CE (Ruivo J., personal communication). The most recent coin is from Arcadius and dates to 392–395 CE (Pereira et al., 1999/2000).

Epigraphy

Of the 25 epigraphic monuments originating from *Ammaia*, most bear funerary inscriptions (13), followed by religious inscriptions (8) and commemorative inscriptions (2). Two inscriptions were not preserved sufficiently to be classified.

Onomastically, the inscriptions illustrate a predominant indigenous population in *Ammaia*. Latinised indigenous names include, for example, *Anceitus*, *Aranta* and *Tongus* (Mantas, 2000; Mantas, 2002). Apart from these clearly indigenous names with a Roman suffix, individuals with the *tria nomina* illustrate the presence of a proper Roman elite. Common *gentes* are *Aelia*, *Iulia*, *Cornelia*, *Pomponia*, *Calventia* and *Sentia* (Mantas, 2000). When the *tribus* is mentioned, this always refers to *Quirina*. Without a doubt one the most important persons from the town was C. Iulius Vegetus (CIL II 160, IRCP 617), a provincial *flamen* of the imperial cult (Archivo Epigráfico de Hispania, 2007; Encarnação, 1984; Mantas, 2000; Stylow, 2009).

As for religion, the epigraphic collection from *Ammaia* shows the importance of the Jupiter cult. Four of eight religious inscriptions are dedicated to Jupiter. One inscription mentions the name of Ocrimira, a local goddess that might be related to the nearby Sever River. Two inscriptions refer to the *genius* of the town. On one inscription, the name of the honoured deity was not preserved. Finally, the presence of the imperial cult at *Ammaia* was already mentioned regarding the provincial *flamen*.

More information on the epigraphic monuments proper is presented in Chapter 5.

Gemstones

With 30 pieces, the gemstone collection from *Ammaia* is one of the largest in *Lusitania*. Of these 30 pieces, only 10 were discovered during excavations, seven of which were found in the sewer channels of the town's bathhouse. About 75 % of the gems are of the microcrystalline group (mainly nicolo and carnelian, but also banded agate, onyx and sardonyx). This high number is remarkable and probably relates to the abundant regional availability of quartz raw material and possible local workshops specialised in mining and engraving the local quartz (Cravinho, 2010; Cravinho and Amorai-Stark, 2006; Taelman et al., 2009).

The iconography is miscellaneous, but can generally be dated in the 1st and 2nd century CE, with few going into the 3rd century CE. Two gemstones have an iconography that can be dated in the late 1st century BCE (Cravinho, 2010). Most gems depict mythological or religious scenes, mainly related to the cult of Jupiter and Mars. Depictions of cattle and horses testify the importance of animal raising in and around *Ammaia* (Cravinho, 2010). Especially interesting are two gems showing a Menorah and a lyre, typical Jewish themes. These intaglios point to an important Jewish presence in *Ammaia* in the 2nd–3rd century CE and form the oldest secure glyptic evidence of Jews in the Western Roman Empire (Cravinho, 2004; Cravinho and Amorai-Stark, 2006) (Figure 3.3).

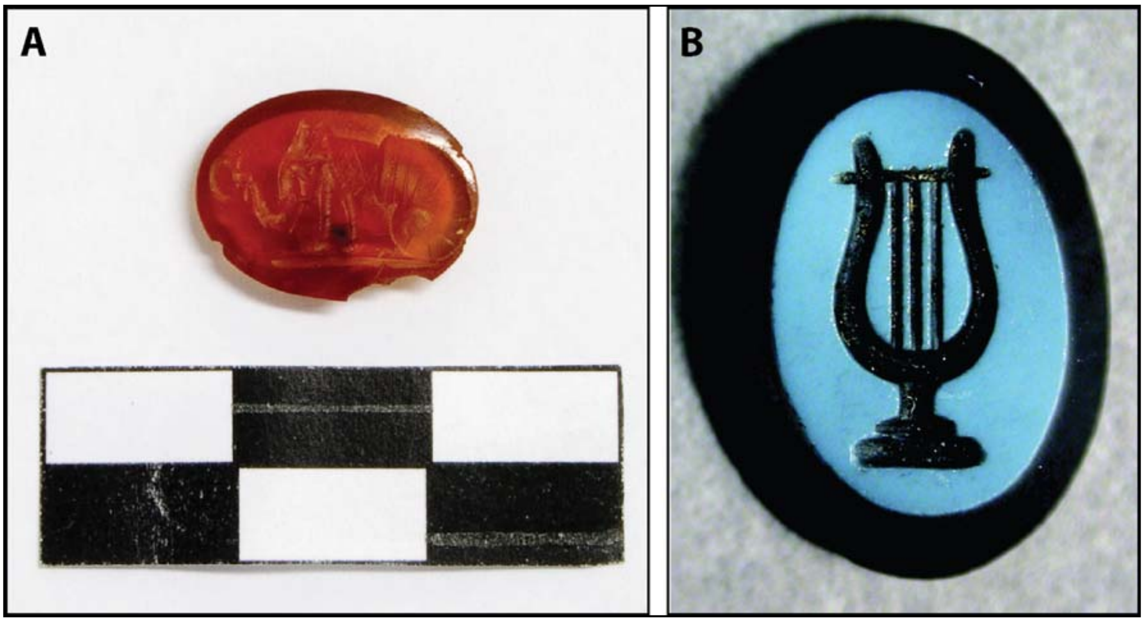

Figure 3.3 (A) Carnelian intaglio depicting a mythological animal, hybrid between elephant and sea-snail (end of 1st – begining of 3rd century CE (Henig, 1984)); (B) Nicolo intaglio depicting a lyre (Jewish) (2nd – 3rd century CE). Photo B by G. Cravinho.

3.2.3 The regional and local road network

Partly because the only ancient source available on the Lusitanian road network, the *Itinerarium Antonini*, does not mention any road connecting with *Ammaia*, only few detailed studies have explored the Roman road network of *Ammaia* and its territory. General studies for the province of *Lusitania*, in which *Ammaia* and its environs are

discussed only briefly, include the work of M. de Saa (1956) and J. de Alarcão (1988a). More in-depth studies on the road network of *Ammaia* and the northeastern Alentejo and western Extremadura region were carried by M.J. Almeida (2000), Almeida et al. (2011), A. Carneiro (2004; 2009), J. Carvalho (2002) and C. Corsi & F. Vermeulen (2007).
In general, the trajectory of the Roman roads is determined through the location of known Roman urban and rural centres, bridges, milestones and preserved stretches of road. In addition, the local topography and an interpretation of vertical aerial photographs sometimes provide important clues on the trace of the roads.

According to the *Itinerarium Antonini*, *Emerita Augusta* was connected with *Olisipo*, its main harbour, through three different roads – the *via XII*, *via XIV* and *via XV* (Alarcão, 1988a; de Saa, 1956). The first part of these three routes runs in east–west direction on, more or less parallel to and on both sides of the Guadiana River. At the confluence of the Guadiana and the Xévora Rivers, probably in Plagaria (Talavera de la Reina, Spain), the *via XII* splits off from the *via XIV* and *XV,* and continues in southwestern direction towards *Ebora*, crossing on its course the important marble quarries of the Estremoz Anticline (see Chapter 9). After *Ebora*, the road runs towards the estuaries of the Sado and Tagus Rivers, where important fish sauce or *garum* production centres were located, and further to *Olisipo* (Almeida et al., 2011; Carneiro, 2009).
While the *via XII* continues in southwestern direction at Plagaria, the *via XIV* and *XV* turn off in northwestern direction towards the Tagus River crossing the southern part of the territory of *Ammaia* (Figure 2.4). Both roads continue along the same course probably as far as *Ad Septem Aras* (Degolados?, Portugal), passing the *vicus* of *Butua* (Bótoa, Spain), where they split in a more or less parallel northern and southern trajectory. For the *via XIV*, the *Itinerarium Antonini* lists further *Matusaro* (?, Portugal), *Abelterium* and *Aritium Praetorium* (Abrantes?, Portugal). Along its trace, the road passes over the preserved Roman bridges of *Ponte de Monforte*, *Ponte de Sor* and *Ponte Vila Formosa*. The *via XV* passes places like *Montobriga* (near Arronches?, Portugal), *Fraxinum* (?, Portugal) and *Tubucci* (Cazal de Várzea, Portugal). Both roads cross the Tagus River near *Scallabis* (Santarém, Portugal). The final part of both roads, from *Scallabis* to *Olisipo*, follows the same course as the important north–south axis in *Lusitania* that connects

Olisipo with *Bracara Augusta* (Braga, Portugal) in Hispania *Tarraconensis* (Almeida et al., 2011; Carneiro, 2009). Along the trajectory of both roads in the territory of *Ammaia*, a dense rural occupation with important Roman villas and *vici* has been identified. Sites include, for example, *Abelterium*, the *vicus Camalocensis*, the villa of Torre de Palma, the villa of Quinta do Pião and many others (Carneiro, 2009) (Figure 2.4).

Despite two major Lusitanian roads crossing the territory of *Ammaia*, none directly connect to the town proper. Nevertheless, a dense network of secondary or regional roads linked *Ammaia* with its hinterland and with the major roads and main Roman towns in the southern part of *Lusitania* (Carneiro, 2009) (Figure 2.4 and Figure 3.4). These secondary roads and routes are essential in structuring the rural landscape and for the economic development of the towns.

Recent excavation and geophysical survey data, field observations in the surrounding countryside of the town and the study of vertical aerial photographs have allowed suggesting plausible hypotheses for the location of the major roads connecting the town with its hinterland and wider territory.

A first road runs from the South Gate in southwestern direction and connects to the *via XV* just south of Crato. At about 100 m west of the town, the road crosses the *Ribeira do Porto da Espada* at the *ponte de Madalena* where parts of an ancient Roman bridge have been preserved. After crossing the river, the road continues in the direction of Carris and Alvarrões. It partly follows the valley of the *Ribeira da Nisa* and passes near Fortios before reaching the *via XV* somewhere between Crato and Assumar (Carneiro, 2009; Carvalho, 2002; Corsi and Vermeulen, 2007). This road was surely one of the main communication axes for the town and was essential for its development as it not only linked *Ammaia* with one of the main roads between *Emerita Augusta* and *Olisipo*, but also formed a direct connection with the Roman town of *Ebora* and the important marble quarries of the Estremoz Anticline (see Chapter 11) (Carneiro, 2009).

A second road also leaves the town at the South Gate and runs in southeastern direction towards *Emerita Augusta*. The road follows the Sever River Valley, passing along modern villages like Porto da Espada, São Julião and La Codosera (Spain). Near Alburquerque, the road turns southwards, runs along the Xévora River and connects with main road to *Emerita Augusta* probably at *Butua* (Carneiro, 2009; Carvalho, 2002; Corsi and Vermeulen, 2007). Results of the geophysical surveys in the immediate extra-mural part of the town illustrated the presence of a large necropolis just outside the town, with several funerary monuments bordering the road.

A third road follows a northwestern orientation and connects *Ammaia* with *Aritium Vetus* (Alvega?, Portugal) where an important crossing of the Tagus River must have been located. The first part of the trajectory follows the Escusa valley as far as Castelo de Vide, after which it turns westwards and passes through a zone with several Roman villas and rural sites (Carvalho, 2002; Corsi and Vermeulen, 2007). More or less halfway between *Ammaia* and *Aritium Vetus*, a crossroad must have existed with a side-road continuing in northern direction towards the Tagus River. Somewhere near Ródão, the river might be crossed with a ferry after which the route goes on in the direction of *Civitas Igaeditanorum* (Idanha-a-Velha, Portugal) (Carneiro, 2009). Excavations in the area just north of the town, alongside the first part of this northwestern road have revealed an important Roman necropolis near the modern church of São Salvador da Aramenha (Barata and Mantas, 2006; Coelho, 1988; Corsi et al., in press; Eastern atlas, 2010; Pereira, 2009).

A final road also leaves the town in northern direction, but soon turns eastwards following the left bank of the Sever River as far as *Ponte Velha*. Here, the road divides into a northern and an eastern trajectory. The northern trajectory passes through a zone of intensive rural exploitation with many Roman villas and smaller rural sites. Further to the north, the road might connect with the road going to Tagus River in the direction of *Civitas Igaeditanorum* (Carneiro, 2009; Carvalho, 2002). The eastern trajectory probably continues to the town of Valentia (Valencia da Alcântara?, Spain) and *Norba Caesarina* (Caceres, Spain), the neighbouring *civitas* capital, following more or less the same course as the modern road between Marvão and Caceres (Carvalho, 2002; Corsi and Vermeulen, 2007).

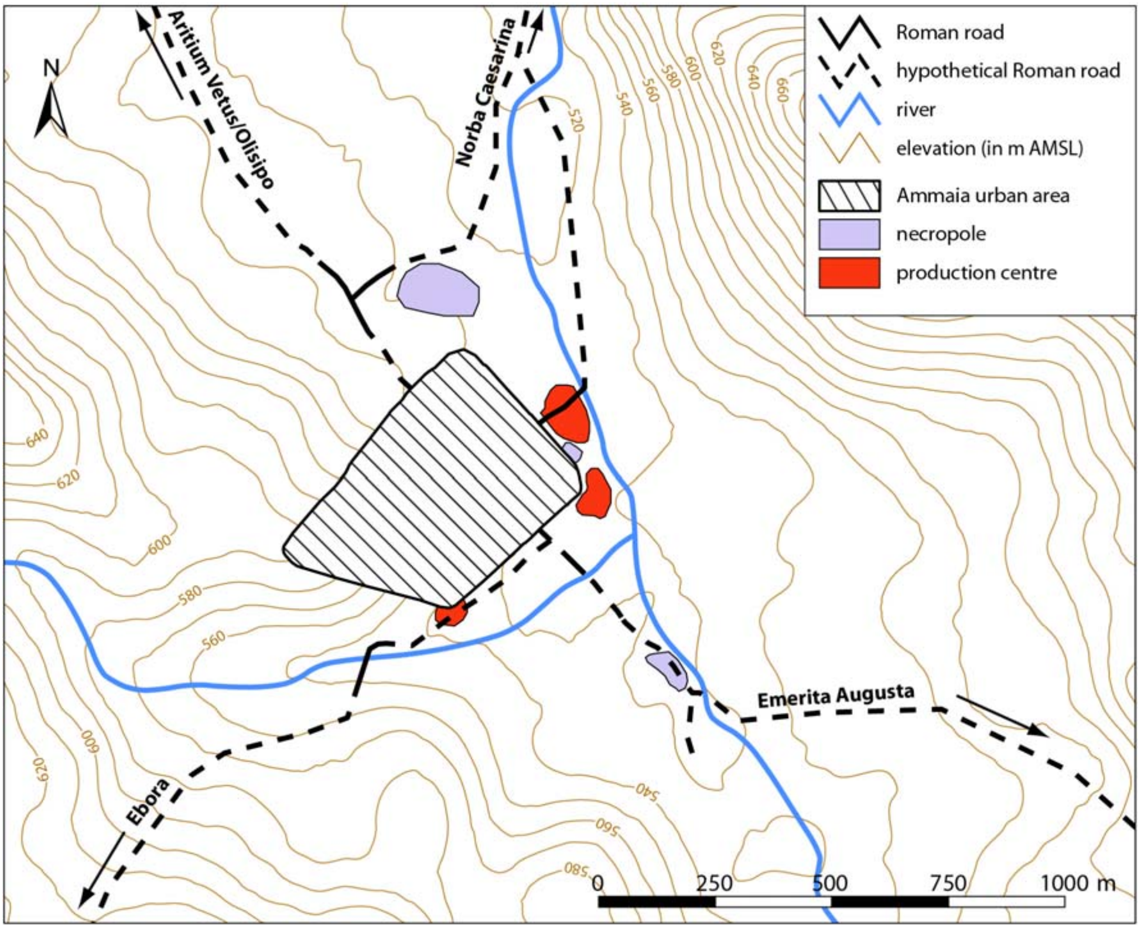

Figure 3.4 Local road network around *Ammaia* with indication of the identified necropole areas and industrial production centres.

3.2.4 Natural resources and landscape exploitation

In the site selection process for new towns like *Ammaia*, the availability of food resources was certainly a primary concern. The good agricultural location of the town in contrast to the surrounding Alentejo lands was already shortly mentioned in Chapter 1. Besides food resources, water and building materials and mineral resources such as metals and limestone for mortar were crucial for the development of a town.

Water supply

The location of the town of *Ammaia* was surely conditioned and at least partly determined by the numerous natural springs in the area of the *Serra de São Mamede*.

The perennial Sever River and *Ribeira dos Alvarrões* were without a doubt the key water sources for the town inhabitants. Likewise, at several smaller water sources, such as the one just south of the town, water could be collected easily (Deprez, 2009).

Besides these sources, two aqueducts were constructed to transport water into the urban area for supplying bathhouses, fountains, latrines and so forth. The best archaeological evidence is provided by the so-called Western Aqueduct or Malhadais Capture (Figure 3.5). Remains of a river capture and a typical Roman *specus* aqueduct constructed with a series of U-shaped granite ashlars (c. 1.5 m in length) were found on the southern flanks of the Malhadais hill, just above the winterbed of the *Ribeira dos Alvarrões*. Further towards *Ammaia*, the aqueduct continued as a rock-cut conduit and could be traced over a length of approximately 700 m; only the last 100 m, where the aqueduct entered the town, has not been discovered yet. Inside the urban area, the aqueduct can be connected with the remains of a similar granite *specus* aqueduct found in situ in the field west of the forum area (Figure 3.5) (Corsi and Vermeulen, 2012; Deprez, 2009; Deprez et al., 2006; Taelman et al., 2011; Vermeulen et al., 2005; Vermeulen and Taelman, 2010) (Figure 3.5).

A second water source is part of the aquifer system of the Escusa dolomitic limestones that stretches out between Castelo de Vide and the Spanish border, following the flanks of the *Serra de São Mamede* (Almeida et al., 2000). At Olhos de Agua, on the opposite side of the Sever River, some 300 m east of *Ammaia*, remnants of Roman water capture structures were discovered (Figure 3.5). Even today, this spring still acts as an important water source for the nearby town of Portalegre. The spring lies about 8 m higher than the eastern urban area of the town; it could therefore supply only the lower parts of the town. Even though nothing of the ancient Roman aqueduct has been preserved, probably because it was destroyed during the construction of a modern mill, it can reasonably be suggested that it followed more or less the same trace as the 19th century CE aqueduct that was constructed to supply the *Olhos de Agua* mill (Deprez, 2009; Deprez et al., 2006; Vermeulen et al., 2005).

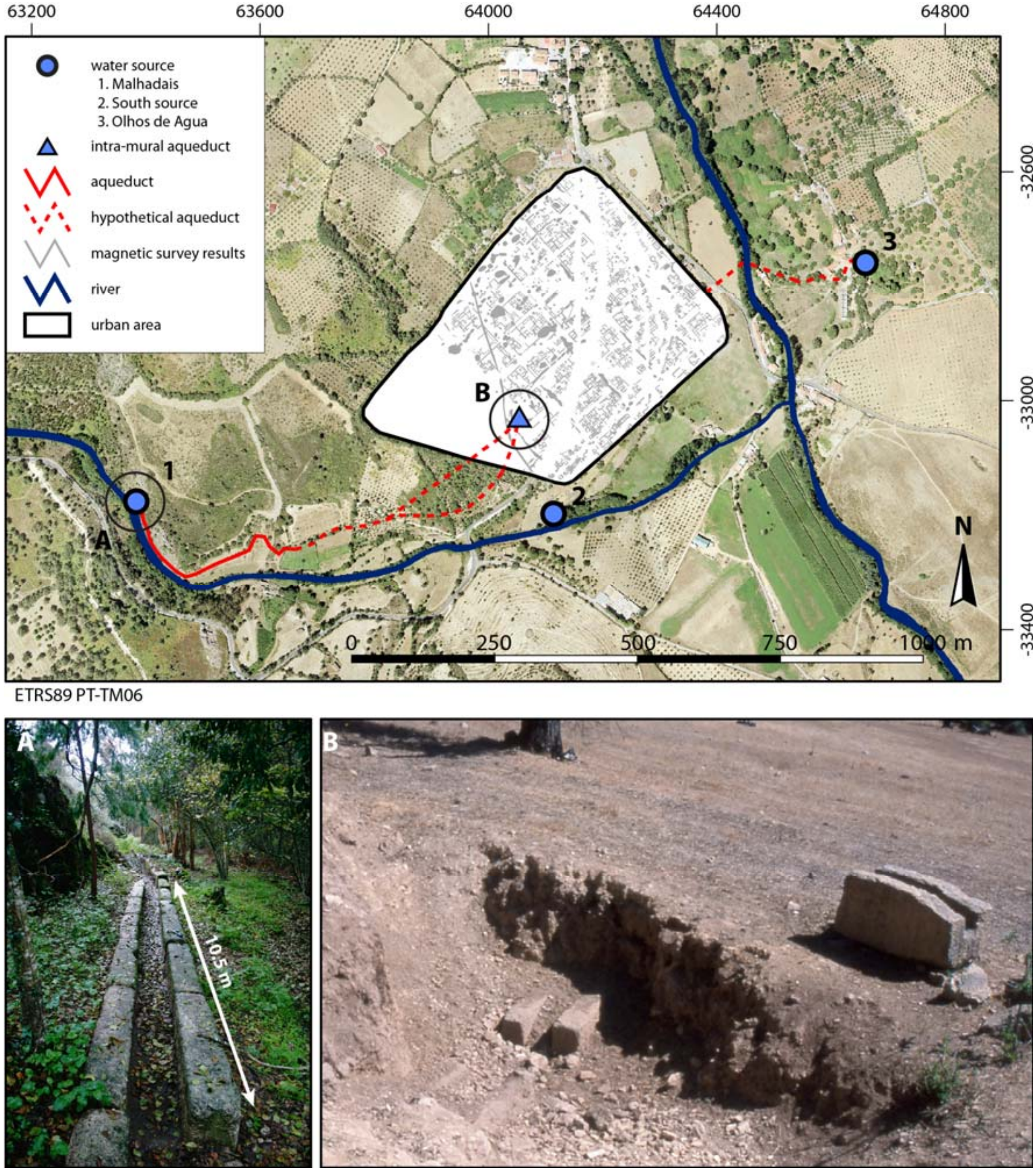

Figure 3.5 Water supply of Roman *Ammaia*, showing the main water sources and confirmed and hypothetical aqueducts: (A) Aqueduct consisting of U-shaped granite ashlars near the Malhadais capture (location: 39.367207° N, 7.397861° W (WGS84)); (B) Specus of U-shaped granite ashlars found inside the urban site (location: 39.368035° N, 7.389708° W (WGS84)). Photo-B by M. De Dapper.

Mineral exploitation

The mineral richness around *Ammaia*, as illustrated in Chapter 1, undoubtedly greatly appealed to the Roman settlers.

An important gold mining site was discovered at *Conhal*, on the left bank of the Tagus River (Cardoso et al., 2011) (Figure 3.6). Large volumes of river sediment were systematically exploited. Over a surface area of 0.6 km^2, the topography was lowered by 10–15 m, corresponding to a volume of 6 to $9*10^6$ m^3 auriferous river sediment processed (Deprez, 2009; Deprez et al., 2009).

The large quantity of pebble heaps (*muria*) composed of quartzite stone, the numerous water channels visible in the landscape, and the large water storage basins indicate the use of the *arrugia* technique, where gold particles were separated from other sediments based on the difference in relative density using large volumes of water (Bird, 1984; Domergue, 1986; 1990; Sánchez-Palencia, 2000) (Figure 3.6).

Even though the actual involvement of the *Ammaia* people in this exploitation process remains difficult to evaluate, the presence of the gold mine was surely an important asset for the economic development of the region.

Figure 3.6 Overview of the historical gold mine of the Conhal. The *muria* are visible in the centre of the image, the Tagus River flows on the right (location: 39.641650° N, 7.685528° W (WGS84), view to the SW).

Between the 19th century CE and the seventies of the 20th century CE, limestone extraction and mortar production were the main economic activity in the Sever Valley (Coelho, 1988; Mena, 1992; Oliveira et al., 2007). Two large exploitation fronts (about 200–300 m in length and 30–40 m in height) and numerous lime kilns still testify the importance of this economy in Escusa and just north of Porto da Espada (Coelho, 1988) (Figure 3.7).

Identifying the sources for the lime and mortar used in Roman *Ammaia* is difficult as most traces of ancient extraction have disappeared as a result of the industrial-scale lime production in the 19th and 20th century CE. Some smaller quarry fronts (2–20 m in length and maximum 4 m in height) and small limestone waste heaps in the hills east of *Ammaia* might illustrate preindustrial limestone extraction (Figure 3.8). Even though no exact chronology is available for these exploitations, the heavily weathered state of the quarry faces and the debris blocks suggests an exploitation prior to the 19th and 20th century CE. Ancient kilns for burning the lime have not been discovered, but these were probably located close to the Sever River where sufficient amounts of water could be obtained (Taelman, in press).

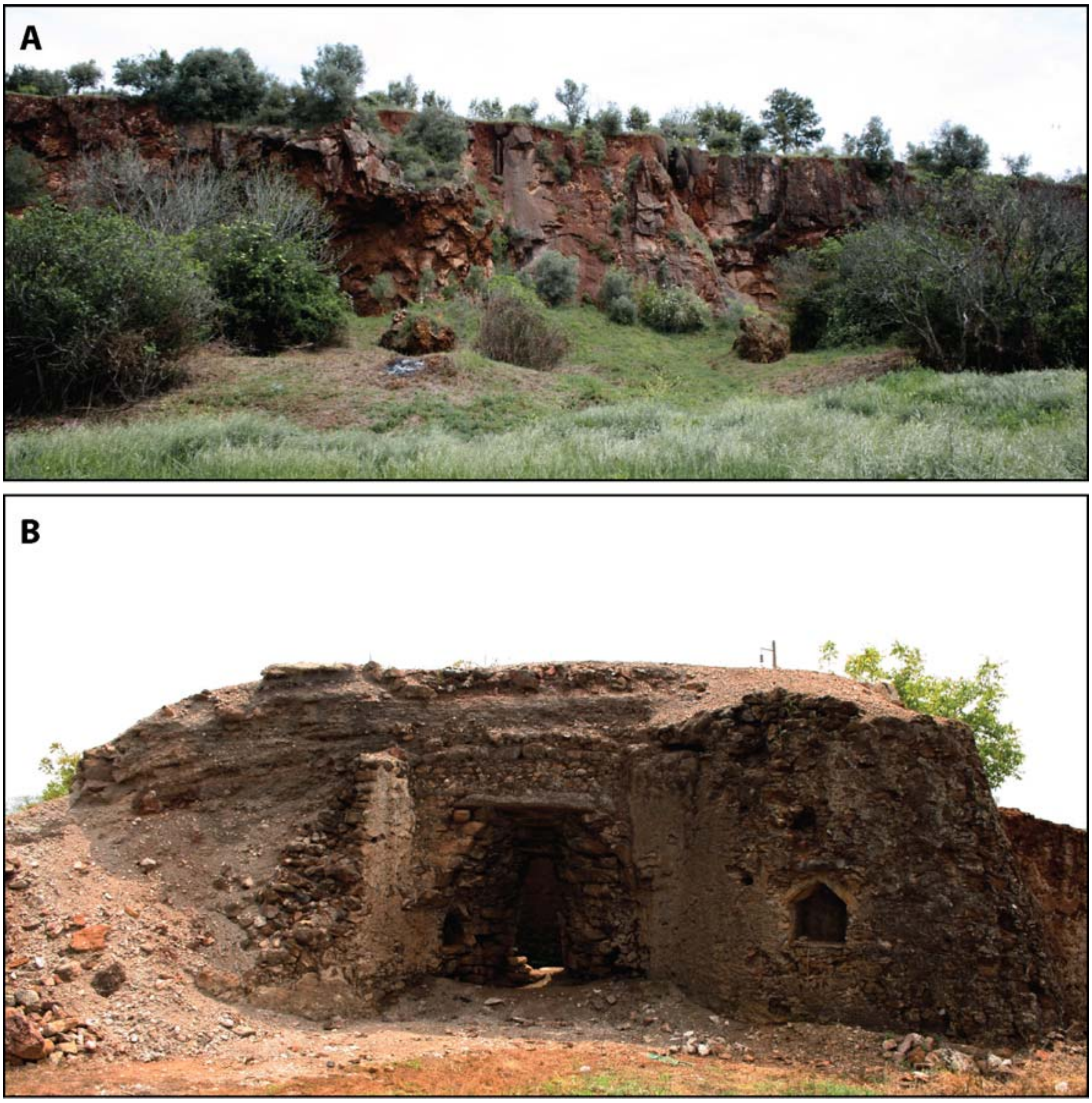

Figure 3.7 Remains of twentieth-century CE lime and plaster production in Escusa: (A) Abandoned limestone quarry (location: 39.387405° N, 7.399235° W (WGS84), view to the N); (B) Abandoned lime kiln (location: 39.387689° N, 7.399971° W (WGS84)).

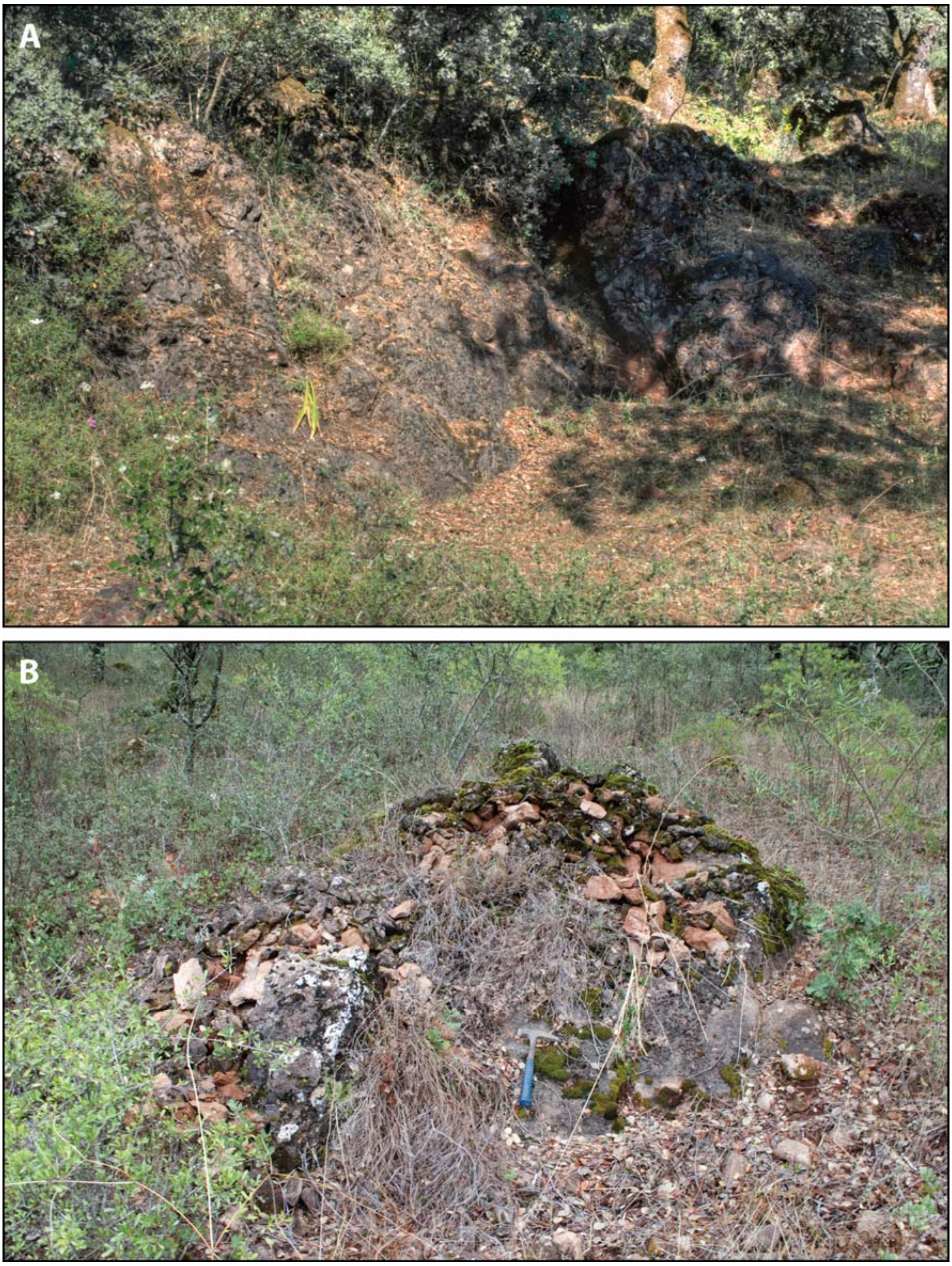

Figure 3.8 Remains of possible preindustrial limestone quarrying near *Ammaia*: (A) Extraction front (location: 39.369591° N, 7.377013° W (WGS84)); (B) Limestone debris heap (location: 39.368439° N, 7.376496° W (WGS84)).

The richness in metals of the area around *Ammaia*, especially iron and lead, is already known for a long time, and mining activities have formed an essential part of the region's economy certainly since the late Middle Ages (Pestana, 1992). In the town's immediate hinterland, several ancient iron and lead mines have been discovered. Most mines are, however, difficult to date as a result of the conservative nature of mining techniques and the lack of datable archaeological material at most sites. An exception is the Roman *Cova da Moura* mine that consists of three main halls and nine smaller galleries (Coelho, 1988; Oliveira et al., 2007).

Finally, *Ammaia* is also rich in quartz and rock crystal, of which the importance in Roman times is illustrated by two references to the presence of the mineral in the mountains around *Ammaia* by Pliny the Elder (*Naturalis Historia 37.24 and 37.127*) (Cardoso et al., 2011; Guerra, 1995). Finely grinded rock crystal and quartz were often mixed with molten glass substance for the production of glass artefacts. In addition, the mineral could have served as raw material for gemstones and luxury vessels (Stern, 1997; Vickers, 1996).
The region of *Ammaia* is characterised by two sets of major, (sub)vertical fractures, resulting from late and post-orogenetic fault activities. These fractures were filled by quartz, forming large veins that are distributed throughout the granite landscape (see Chapter 1). In the centre of these veins, pure quartz or rock crystal can often be found.
Mines were the mineral was extracted have been discovered at Naves (c. 4 km southeast of *Ammaia*), at the Pitaranha granite quarry (c. 6.5 km east of *Ammaia*), along the modern road from São Salvador da Aramenha to Marvão (c. 3.5 km north of *Ammaia*), and at Vale do Cano (c. 11 km north of *Ammaia*) (Taelman et al., 2011; Taelman et al., 2009; Vermeulen and Taelman, 2010) (Figure 3.9).

Figure 3.9 Evidence of rock crystal mining in the hinterland of *Ammaia*: (A & B) Quartz debris heap at the quartz and rock crystal mining site of Naves (scale: 10 cm) (location: 39.344747° N, 7.356124° W (WGS84)); (C) Quartz debris with iron mineralisations, collected at the mining site of Pitaranha (scale diameter: 5 cm) (location: 39.371815° N, 7.314243° W (WGS84)).

Chapter 4
The architectural and archaeological remains

Systematic archaeological research in *Ammaia* began in 1994 and focused essentially on five areas: parts of the town wall and the South Gate complex with a monumental square, the forum temple and parts of the forum portico, a public bath building just south of the forum, a residential area in the southeastern corner of the town (*insula 38*), and parts of the suburban area between the town and the Sever River (Pereira, 2005; 2009; Vermeulen and Taelman, 2010) (Figure 4.1). The information presented in this chapter is derived from the existing excavation reports, new excavations done between 2008 and 2011, systematic geophysical surveys carried out since 2008, and small-scale, targeted ground-truthing performed by Ghent University in close collaboration with the University of Évora since 2008. The available plans were complemented with a full topographic survey of the standing and excavated remains and with a detailed photographic documentation. In situ observations of the site stratification, building techniques and stone use were carried out. Finally, a major effort was realised for a full three–dimensional and orthophotographic documentation.

Given that only about 4500 m^2 of the town area has been excavated, corresponding to c. 2–3 %, the presented overview of the *Ammaia* architecture, construction techniques and stone use is far from complete. The data, interpretations and conclusions are only preliminary and subject to change as archaeological research continues. Nevertheless, it is believed that the presented data provide a good overview since the studied areas include public, monumental and private complexes that were occupied throughout the entire Roman history of the town, i.e. from the 1st century CE to the 4th–5th century CE.

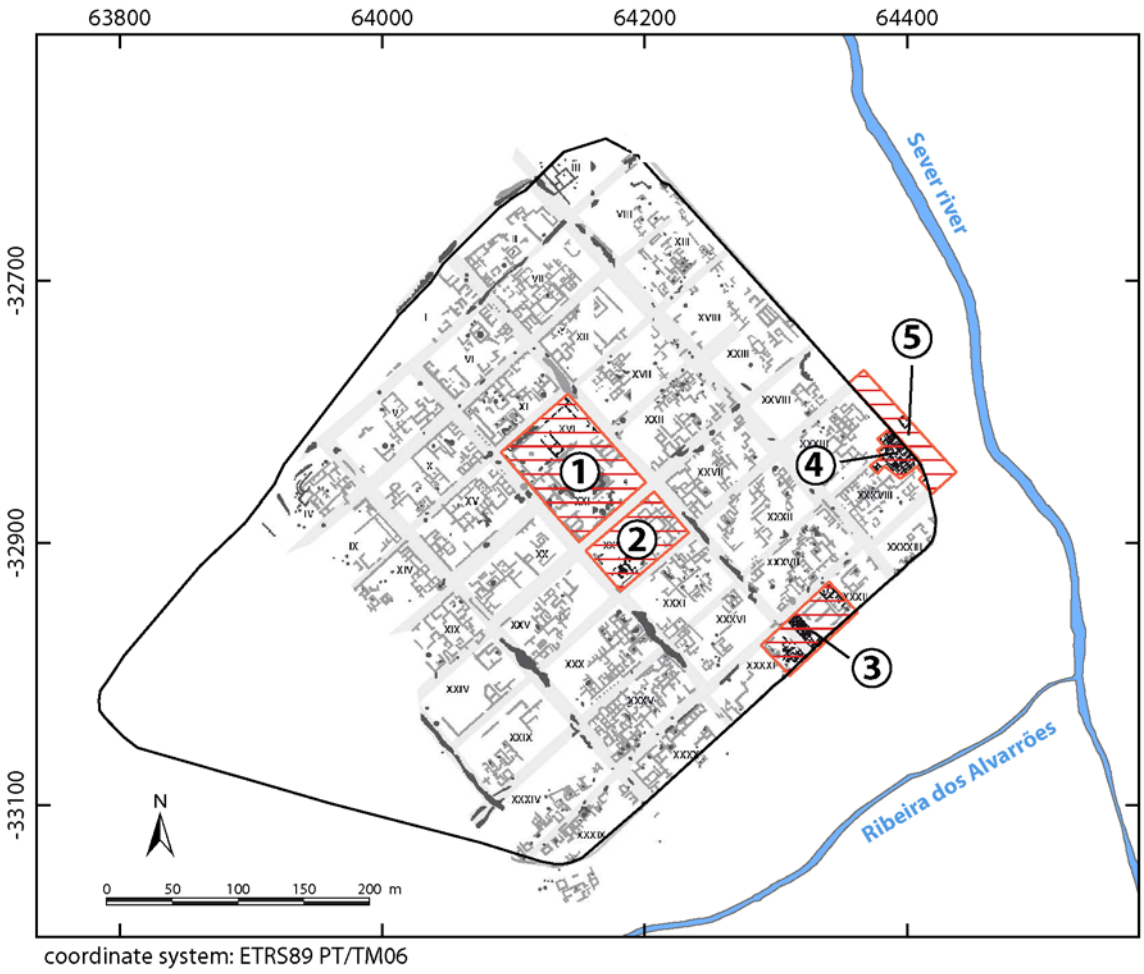

Figure 4.1 Plan of Roman *Ammaia* based on the excavation and magnetometry data. Excavated sectors are indicated: (1) forum complex, (2) bathhouse, (3) South Gate complex, (4) the residential area of *insula 38*, and (5) suburban area.

It needs to be noted that stratigraphic recording for the earlier excavations was rather limited. Documentation was often incomplete – generally only the grid of the box excavation method was registered – resulting in difficulties assigning the provenance of the archaeological material. Moreover, it must be realised that stone material has often been spoliated for reuse already in Roman times, but surely in post-Roman times. As for ornamental stone, the highly valued and rare marbles were probably the first to be reused. In addition, marble and limestone were frequently used as raw material for lime production in later times.

4.1 The forum complex

Excavations of the forum complex were first carried out by the *Fundação Cidade de Ammaia* between 1995 and 2002 (Navascúes et al., 2000; Oliveira et al., 1995; Oliveira et al., 1996; 1997; Oliveira et al., 1998; Oliveira et al., 2002; Pereira, 2009). These earlier excavations mainly aimed at determining the general layout and orientation of the complex and focused on the aboveground preserved temple podium and on the northern portico. In 2010 and 2011, a team from the universities of Évora (Portugal), Ghent (Belgium) and Cassino (Italy) organised new digs in front of the forum temple and in the northeastern portico area to establish the full stratigraphic sequence in the northern part of the forum area (Corsi and Vermeulen, 2010; Mlekuz, 2010; Persichini and Corsi, 2011). In addition, the relationship between the forum square, the portico and the forum temple was studied (Mlekuz, 2010; Vermeulen et al., 2012).

The forum complex was also geophysically studied using magnetometry, electrical resistance and ground–penetrating radar (2008–2011) (Corsi et al., in press; Johnson, 2010; Strutt, 2009; Verdonck and Taelman, in press; Verhegge, 2010; Vermeulen et al., 2012).

4.1.1 Building configuration

The forum complex is centrally located in the orthogonal street pattern of the town and is enclosed by two more than 11 m wide *cardines* (Corsi et al., in press) (Figure 4.1 – n°1). The outside perimeter of the complex measures 65 m by 88 m. Instead of the simple rectangular plan assumed by V. Mantas (2000), recent archaeological and geophysical observations have shown a more complex, tripartite configuration for the forum with a religious, commercial and administrative–political part (Figure 4.2).

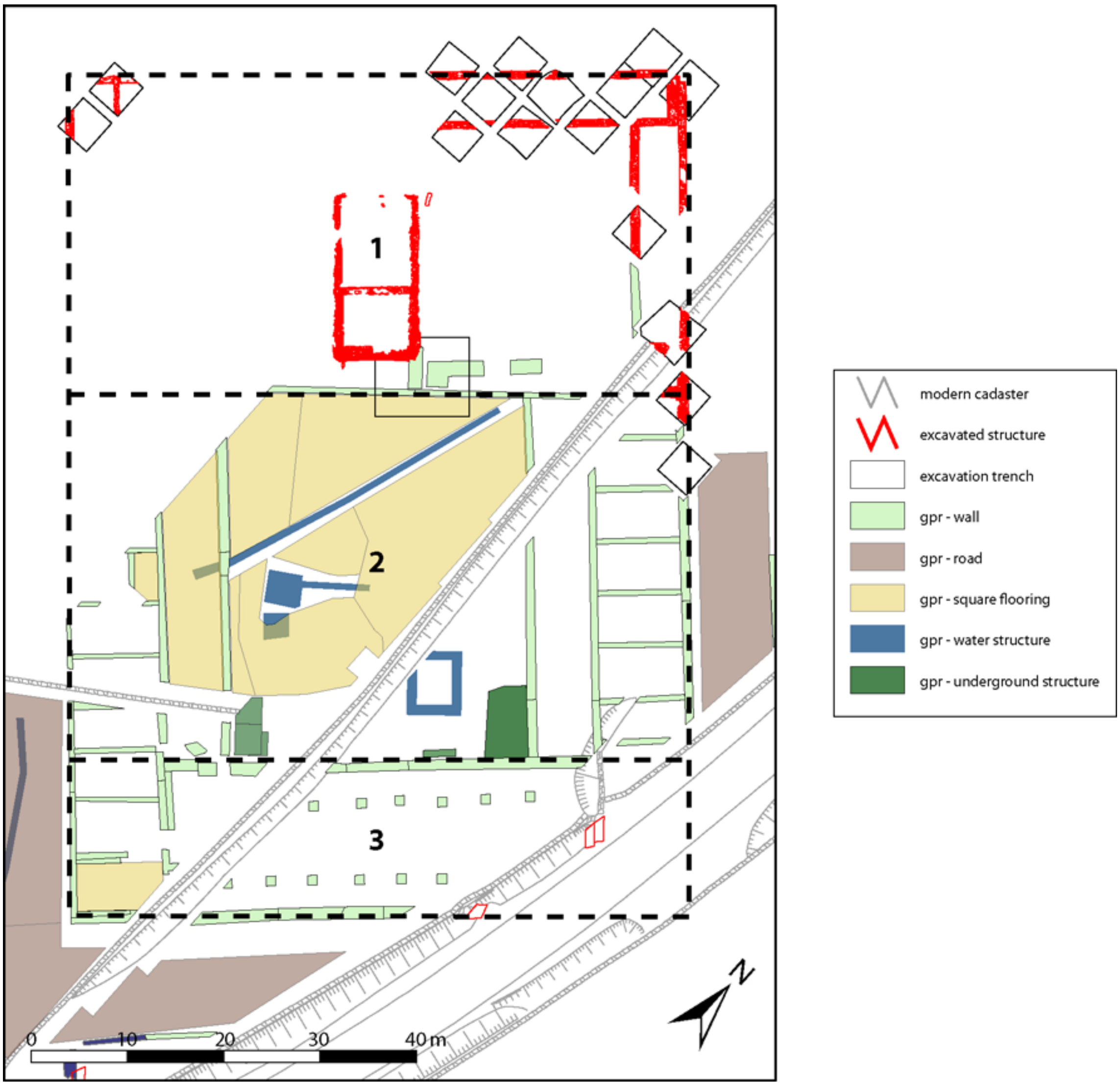

Figure 4.2 Plan of the forum complex with interpretation of the excavated structures and the GPR data: (1) religious part with the forum temple, (2) commercial part, (3) administrative–political part (Verdonck and Taelman, in press; Verdonck et al., 2008; Vermeulen et al., 2012).

The northern, religious part consists of a portico surrounding a centrally and axially positioned temple that dominates the square. The forum temple of 17.5 m by 8.9 m (i.e. dimensions of the podium) was approached from the south through a 6.5 m wide and 3.5–4 m long frontal staircase flanked by two projecting stair wings and monuments (Persichini and Corsi, 2011; Vermeulen et al., 2012) (Figure 4.3). The *cella* has a length of 10.8 m; the front porch is 6.70 m long. The interior of the *cella* measures approximately 65.6 m^2 (Figure 4.10). The original height for the podium was approximately 2.65 m (Figure 4.9). At present, only the core of the temple podium is preserved as a result of recent disturbances in search of a presumed gold treasure or golden bull statue that was buried in the temple according to a local legend. The staircase was destroyed only very recently as local farmers still recall its existence in the 1960s. As a result of these disturbances and stone recuperation, little is known of the upper configuration of the building. On the basis of temples with similar dimensions and judging from the preserved remains, a tetrastyle, pseudoperipteral temple can be suggested (Mantas, 2000). Only the front wall of the podium was wide enough to support a row of columns. The forum temple of *Ammaia* matches closely to the forum temple in *Civitas Igaeditanorum* regarding dimensions (17.4 m by 9.2 m) and style (tetrastyle, pseudoperipteral) (Carvalho, 2009). Similar small tetrastyle temples are typical in fora of smaller Roman towns in *Lusitania* (Hauschild, 2002).

A solid drainage floor of subrounded and rounded gravelstones immediately adjacent to the temple may be related to a water basin or a fountain (Figure 4.3). Similar water-related features have been discovered at other Lusitanian fora, for example, *Ebora*, *Conimbriga* (Condeixa-a-Velha, Portugal), *Civitas Igaeditanorum* and *Emerita Augusta* (Mierse, 1999; Reis, 2009). Surrounding the temple on three sides is a portico and cryptoportico. The distance between the southwestern and northeastern portico wing is 53.5 m; the width of the three portico wings is between 4.2 m and 4.4 m. A transverse wall separates the northern part of the forum complex from the central commercial area. The separation of the sacred area from the commercial and administrative–political area and the surrounding of the sacred area with a portico and cryptoportico system is a feature typically observed in Lusitanian fora, for example at *Ebora*, *Emerita Augusta* and *Conimbriga* (Hauschild, 2002).

Figure 4.3 Area southeast of the temple podium showing the base of a monument (left), the drainage floor of a possible water basin composed of subrounded and rounded gravelstones (middle) and one of the projecting stair wings (back) (scale: 1 m) (Vermeulen et al., 2012). Photo by C. Corsi.

The commercial part is essentially made up of a row of seven small rooms on either side of the forum, likely *tabernae*, facing out onto the streets passing the forum and have approximately the same dimensions: 8.95 m by 4.9 m (Verdonck and Taelman, in press). It should be noted that the *tabernae* to the northeast would have been considerably lower than the forum square and than the *tabernae* on the southwestern side, as a result of the natural slope of the terrain. An inner portico of c. 6 m wide surrounds the inner square of the commercial zone that measures 31 m by 53.5 m. The discovery of a keystone in one of the trenches in the northeastern corner of the commercial part suggests a lateral, arched entrance to the complex. Within the inner area of the forum, several structures were observed, possibly podia, statue bases or other types of monuments. Other features may have been part of the town's or the building's water provisioning system (e.g. aqueducts, fountains and basins). Recent observations indicate a surface of beaten earth mixed with small stones for the forum square (Verdonck et al., 2008; Vermeulen et al., 2012).

Towards the southern end of the complex, a three-aisle basilica serves the political purpose of the forum. Its dimensions are approximately 45 m by 17 m. The basilica is divided into an 8 m wide central nave and two 3–3.5 m wide side aisles by a double row of each eight columns. The distance between the columns is about 4.5 m. The main entrance to the basilica is probably situated centrally in its northern wall and opens onto the forum square. A small secondary doorway to the western portico of the commercial part is identified near the western end of the northwestern basilica wall. On the southwestern side of the basilica, the three rooms might have served an administrative function (Vermeulen et al., 2012). Because of the destruction caused by the EN359 road, an interpretation of the rooms along the northeastern end of the basilica is impossible.

Preliminary observations of the material recovered during the excavations propose a building chronology starting around the middle of the 1st century CE, with some adaptations to the forum temple in the Flavian period. A sequence of floor levels in the northeastern cryptoportico and material dating between the middle of the 1st and the 4th century CE suggest a continued occupation throughout the Roman history of the town (Mlekuz, 2010; Navascúes et al., 1999; Vermeulen et al., 2012) (Figure 4.4). A cow or calf skeleton suggests a reuse of the buildings as stables in the Late Roman period. In this phase, the forum lost its role as civic and religious centre. Until now, archaeological evidence of major modifications to the building's configuration is limited to the construction of a dividing wall in the northeastern portico wing and an associated mortar floor. Two successive collapse layers of roof tiles in most trenches of the portico indicate a rebuilding in the final occupation phases of the building. Soon after the rebuilding, the forum was permanently abandoned and exposed to post-Roman erosion and colluvation (Mlekuz, 2010; Vermeulen et al., 2012) (Figure 4.4).

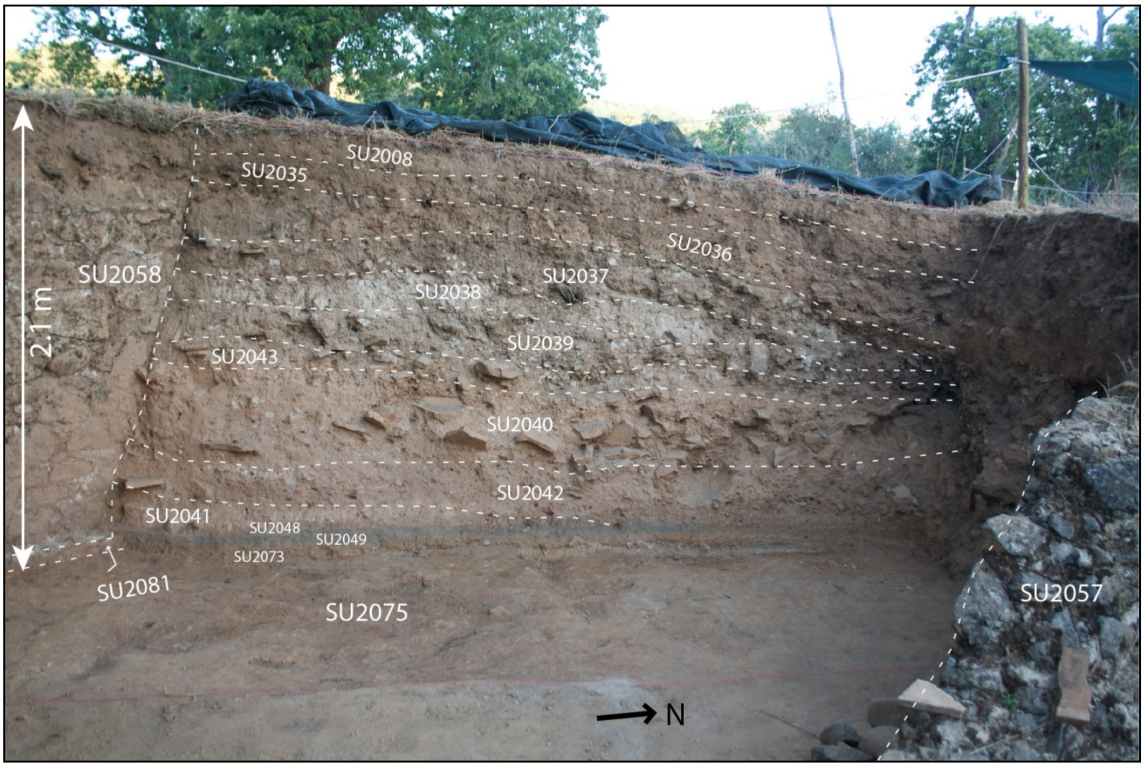

Figure 4.4 Photograph of a section in one of the trenches of the northeastern portico wing with indication of the excavated stratigraphic units: SU2057 = outer wall of the northeastern portico wing; SU2058 = inner wall of the northeastern portico wing; SU2035–SU2038 = colluvium; SU2039, SU2043, SU2040 = roof collapse; SU2048 = earthen floor; SU2049 = mortar floor. Photo by D. Mlekuz.

4.1.2 Construction technique and stone use

Excavations and systematic geomorphological coring revealed that the forum complex was built on sloping terrain. Terrain preparation, therefore, required considerable terracing and levelling. In a first stage, the space for the portico wings was excavated and the portico walls were built. The soil that became progressively available was used for levelling the forum square. Once the forum square was created, the forum temple was erected. The portico walls not only served to mark the forum building, they also acted as retaining walls for the entire complex. Their retaining function can be observed especially in the northern corner of the northeastern portico wing, where an internal abutment indicates large pressure on the walls as a result of the original southwest–northeastern slope (Vermeulen et al., 2012). The construction sequence of the portico walls and the nature of the wall structures enforce this hypothesis. First, the outer walls were erected, followed by the internal wall of the southwestern portico wing, the inner wall of the northwestern portico wing and finally the inner wall of the northeastern portico wing (Figure 4.5). The portico walls have an average width of 75 cm, except for the inner wall of the southwestern portico wing which measures only 50 cm and the inner wall of the northeastern portico wing which measures 90 cm. This difference in width is undoubtedly related to presence of the levelled forum square. While the inner wall of the northwestern portico wing did not support any weight of the square, the inner wall of the northeastern portico wing had to support the entire volume of the forum square. The deeper foundations of the northwestern and northeastern portico wing and the thicker walls suggest that these parts of the building were designed as a cryptoportico, a two-storey building with an underground floor perhaps opening onto the streets outside the forum. The northern *cryptoporticus* built according to the same orientation as the main slope of the terrain was, however, soon discarded and filled with sediments. The archaeologically sterile soil, similar to the material used to level the forum square suggests an anthropogenic event immediately after or even during the construction (Vermeulen et al., 2012). This hypothesis is further strengthened by the absence of a floor level and of wall and roof collapse material inside the cryptoportico. Again, stability problems resulting from the original slope may have been the main reason for this infilling.

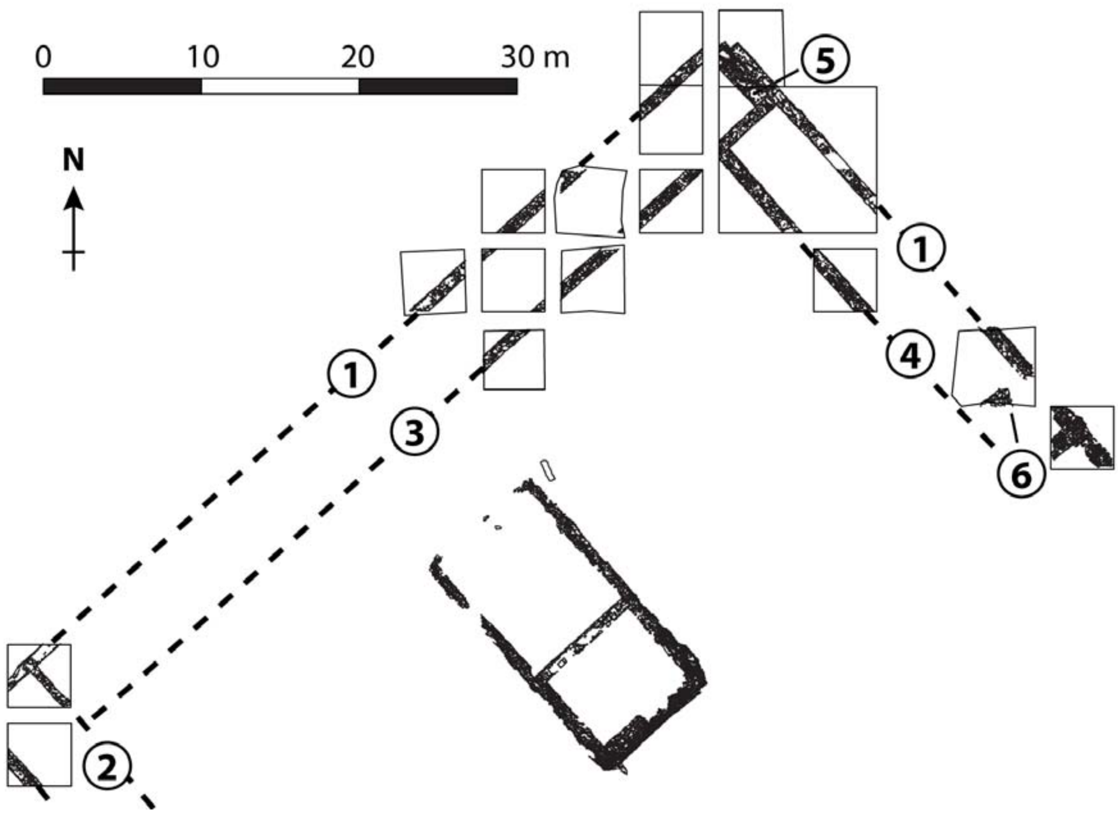

Figure 4.5 Map of the northern part of the forum complex. Numbers indicate the building sequence.

The walls of the portico and cryptoportico have survived to a maximum height of almost 2 m along the northwestern and northeastern end of the forum. The walls consist of roughly dressed facing stones (*opus incertum*) set into a mortared core of unworked stones (*opus caementicium*). Stones are nearly all granite (> 95 %), with some rare gravelstones, sandstone and shale. The used mortar is a pale brown–whitish lime mortar (Cardoso, 2011; sn, 2010; 2011). The facing stones are usually between 20 cm and 30 cm across; some larger stones can attain up to 40 cm. The smaller stones are between 5 cm and 10 cm. Shale slabs are generally 3 cm thick and up to 25 cm long and were used for creating horizontal courses (Figure 4.6). The buttress in the northeastern corner of the forum portico (Figure 4.5 – n°5) is characterised by a coarser building construction with roughly hewn granite, sandstone and quartzite blocks. The wall constructed in the final phase of the northeastern portico is a badly constructed wall composed of granite blocks, bricks and tiles bonded by a low-quality mortar (Figure 4.5 – n°6). The stones are very roughly hewn and predominantly between 10 cm and 30 cm diameter. During the construction of the EN359 road that partly destroyed the forum, a small part of the southeastern and of the double northeastern basilica wall was exposed. Compared with the walls of the northwestern portico, the basilica walls are significantly thicker (150 cm for the southeastern basilica wall and 90 cm for both northeastern walls). This was required to support the full weight of the basilica building, but also of the upslope-lying structures of the forum complex. More information on the basilica walls is not available, as only a small portion was exposed.

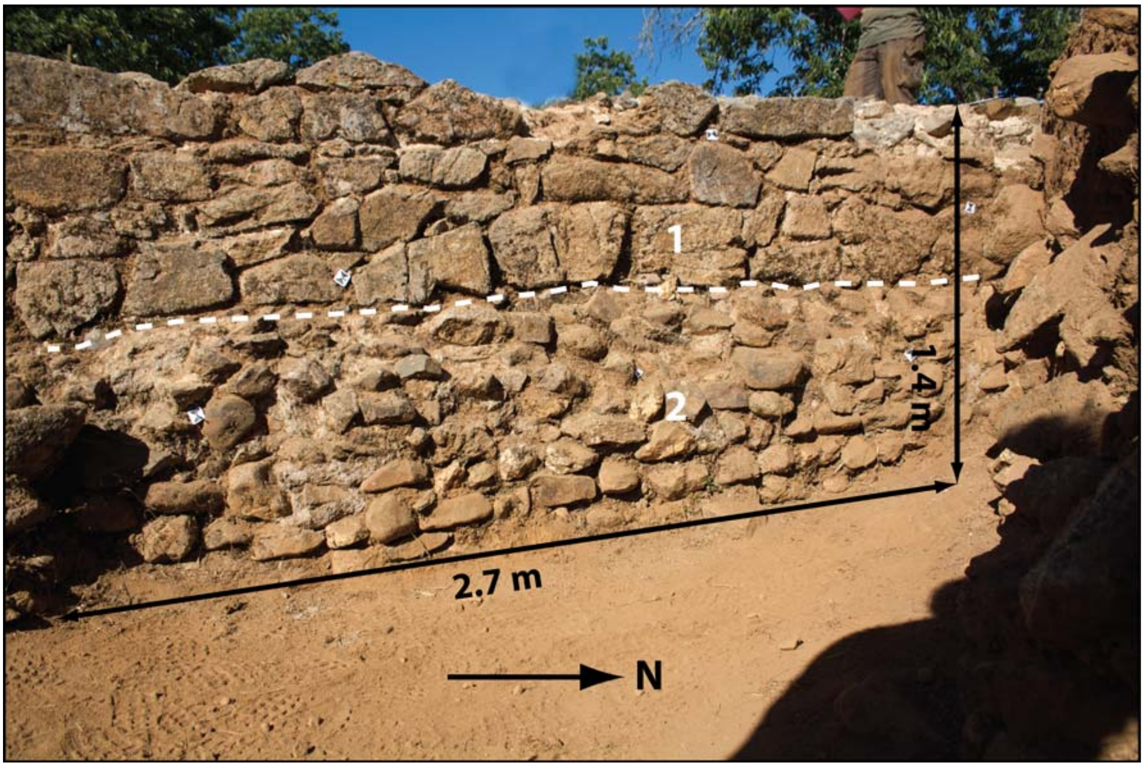

Figure 4.6 Outer wall of the northeastern portico wing, facing the streetside: (1) Wall composed exclusively of granite facing stones; (2) Foundations with rounded and subrounded gravelstones.

Where foundation levels have been reached, they are in *opus caementicium* with unworked river cobbles and some rare pieces of granite, sandstone, quartz and quartzite. The stones are predominantly between 5 cm and 20 cm diameter, with some rare larger blocks attaining more than 30 cm (Figure 4.6). The foundations are trench-built with foundation trenches having vertical edges (Mlekuz, 2010). The width of the foundations is 90 cm, slightly wider than the upper wall structures. Foundations are constructed following the natural slope of the terrain.

In most wall structures, the horizontal courses observed have a vertical spacing of 45–50 cm. For the central part of the northern portico walls, the spacing is only 30–40 cm.

This could indicate that different teams were at work, that the slope required closer spacing between the courses, or a combination of both. Putlog holes for scaffolding have been observed on the exterior of the inner wall of the northwestern portico (two putlog holes) and on the interior of the inner wall of the northeastern portico (three putlog holes). In both walls, only one row of putlog holes was preserved. Generally, they are associated with the horizontal courses, occurring just above them (Figure 4.7). The height above foundations is 1.50 m (measured to the centre of the putlog holes) for the northwestern portico, and 1.40 m for the northeastern portico (measured to the centre of the putlog holes). Horizontal spacing is 2.10 m and 2.60 m, respectively. The shape of the putlog holes is rectangular and measures roughly 15 cm by 25 cm. The fact that a proper scaffolding system was used for the construction of the northwestern and northeastern portico proves that the building reached higher elevations and confirms the hypothesis of a cryptoportico with a second floor.

Figure 4.7 Orthorectified image of the northeastern face of the inner wall of the northeastern portico wing. Horizontal courses are indicated by a white dashed line.

The forum temple is constructed on a solid foundation of dry masonry of mostly unworked gravelstones (10 cm to 25 cm diameter). On top of this core, the exterior wall of the podium, a dividing wall between the *cella* and the front porch and a transverse wall for stability in the *cella* were erected. The exterior wall was constructed in horizontal courses of about 45 cm in height. The first two courses were projecting slightly outwards (c. 20 cm) and were faced with rusticated granite ashlars of alternating headers and stretchers (Figure 4.8 and Figure 4.9). The ashlars measured approximately 50 cm (H) by 60 cm (W) by 40 cm (D). Only few granite blocks have been preserved in situ, but the negative traces of several blocks are still observable. This technique is very similar to the construction technique used for the Augustan–Tiberian temple of the provincial forum of *Emerita Augusta* (Pizzo, 2010b). The following courses of the exterior wall of the temple podium have a facing of roughly dressed and irregular granite stones. The core of the podium walls is composed essentially of roughly dressed or unworked blocks of granite and sandstone with a diameter between 5 cm and 20 cm. All walls used a pale brown–whitish lime mortar (Cardoso, 2011; sn, 2010; 2011). The thickness varies from 55 cm for the transverse wall of the *cella*, to 75 cm for the internal wall separating the *cella* and the front porch and approximately 90–95 cm for the outer walls. The front wall of the podium that had to support four massive columns is about 30 cm wider and measures 125 cm.

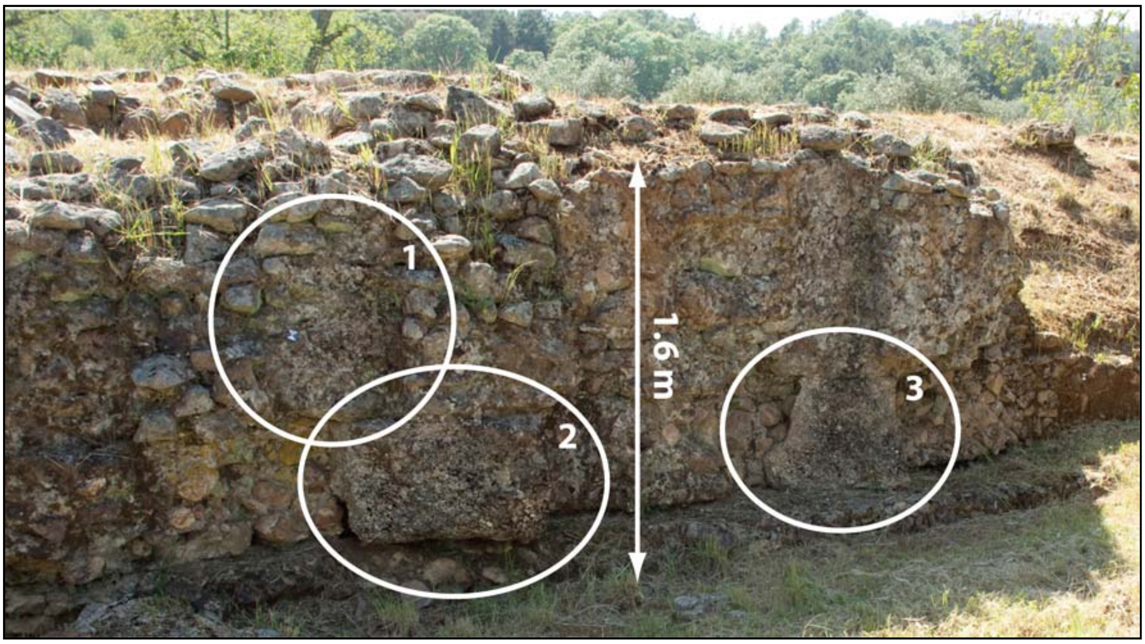

Figure 4.8 Detailed view of the spoliated ashlars from the northeastern wall of the temple podium.

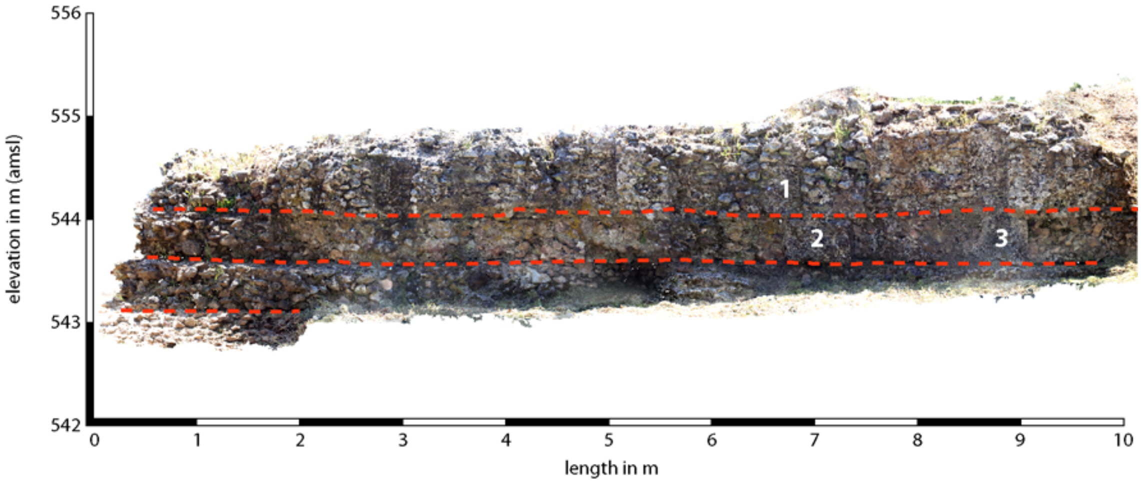

Figure 4.9 Orthorectified image of the southern part of the northeastern wall of the temple podium. The front side of the temple is on the left. Horizontal courses are indicated by a red dashed line. Remains of spoliated ashlars are indicated by numbers.

The podium fill consisted of a compact sterile deposit, similar to the deposits used to fill the northwestern portico and for the levelling of the forum square. First, a preparatory layer of large cobbles and small boulders (30 cm to 40 cm across), mixed with shale slabs and smaller pebbles was deposited. This was followed by a 10–15 cm thick *opus signinum* floor or floor preparation (Figure 4.10). In the *cella*, the paving consisted of large ceramic tiles of 30 by 40 cm (Oliveira et al., 1999; Pereira, 2009); no archaeological information is available for the paving of the *cella*. Of the superstructure of the temple, no remains have been preserved. Likewise for the staircase, no archaeological evidence is preserved except for the foundations and the core of the staircase's projecting foreparts. The absence of architectural elements found nearby shows that the temple was heavily spoliated in later times.

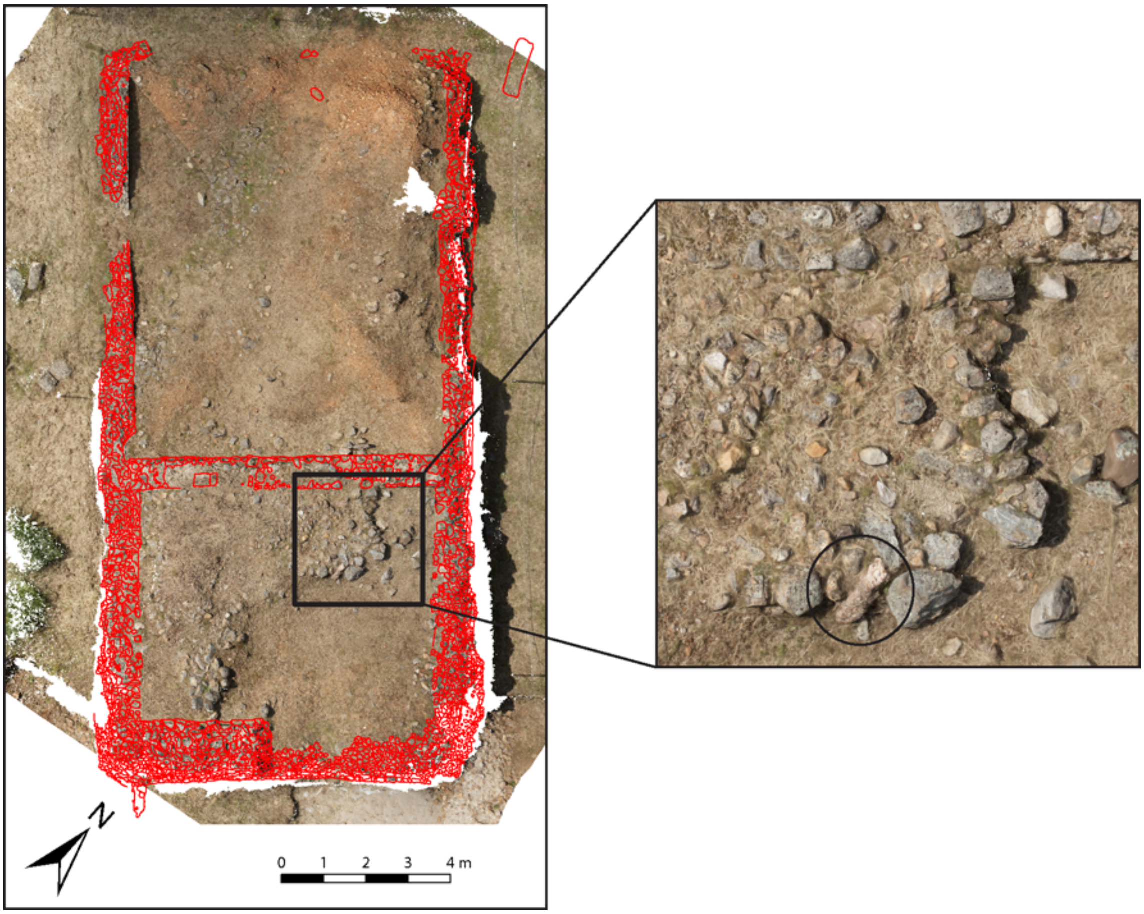

Figure 4.10 Orthoimage of the forum temple overlain with the excavation plan. Inset shows a detail of the preparatory layer of large gravelstones for the flooring of the front porch. Encircled is a large fragment of *opus signinum*.

Although no decorative elements remain in place today, a study of the ornamental stones recovered during excavations enables to propose some hypotheses on the decoration of the forum. In total, 590 fragments or some 131 kg of ornamental stone were recovered. Most ornamental stone comes from the forum portico, about 64 kg (231 pieces), while about 26 kg (309 pieces) was recovered in the temple area. The remaining 41 kg (50 pieces) come from the forum area, but their excavation context was not registered.

Among the ornamental stones, four different types can be identified: (1) a pure white or white, veined marble, (2) a grey–white marble, (3) a pink limestone and (4) a marble breccia. The white or white, veined marble forms by far the principal type of ornamental stone at the forum (62 % of the total weight). Grey–white marble (21 %) and pink limestone objects (16 %) also occur in considerable quantities, while the marble breccia occurs only marginally (1 %). Except for a small fragment of an inscription, all pieces are either part of floor or wall revetment or were difficult to classify because of weathering or small size. In most cases, however, these fragments are likely to be part of veneer panels. Judging from the thickness of the slabs, generally smaller than 2 cm, wall revetment is more likely.

Figure 4.11 Ornamental stones used to decorate the forum complex: (A) Grey–white marble veneer panel from the forum temple; (B) White marble moulding from the northeastern portico wing. Photo-B by J. Carvalho.

Regarding the quantification of the ornamental stone use in the forum complex, the incomplete excavation of some trenches needs to be stressed. Nevertheless, as the higher volumes of material were also found in trenches that were only partially dug, the presented image regarding the use of ornamental stones probably reflects the actual situation in Roman times.

Even though no in situ evidence has been found, it is possible to propose a reliable hypothesis for the temple decoration. The forum temple probably had a multicoloured wall decoration of predominantly white or white, veined marble (62 % of the total volume) and pink limestone (28 % of the total volume) veneering. Grey–white marble and marble breccia were less common (together 10 % of the volume) (Figure 4.11-B).

For the forum portico, the situation is slightly different, with a more explicit predominance of white or white, veined marble (79 % of the volume). Besides the white or white, veined marble, pink limestone was used in considerable quantities (20 % of the total volume). The remaining 1 % consists of marble breccia.

Most fragments were found in the excavation trenches on the inside of the forum square (about 20 kg) and in the trenches on the outside of the forum complex, facing the streets (about 43 kg). About 23 kg of this material was recovered in the trench where the entrance to the forum complex was situated (Navascúes et al., 1999). It can be concluded that ornamental stone was used essentially to embellish the walls facing the streets on the outside of the complex, to give the complex a more monumental appearance for passers-by, and the walls facing the forum square. Like for the temple, most fragments are parts of wall decoration (veneer panels and mouldings) (Figure 4.11-B).

It needs to be noted that the forum portico was not only embellished with ornamental stone decoration. A large amount of fragments of wall plaster, plaster architectural elements (cornices etc.) and painted stucco fragments recovered during the portico excavations indicates that the building was decorated with a combination of marble revetment, painted stucco and plaster architectural elements (Mlekuz, 2010; Oliveira et al., 1997).

4.2 The forum bathhouse

Excavations of the forum bathhouse (Figure 4.1 – n°2) were organised non-continuously between 1996 and 2003 by the *Fundação Cidade de Ammaia*. These first archaeological digs were concentrated on a small area of about 200 m^2 around the aboveground preserved remains of an *opus caementicium* construction (Barata and Mantas, 2003; Borges, 2002; Oliveira et al., 1996; 1997; Oliveira et al., 2001; 2002). A team of the universities of Ghent and Évora started a new excavation program in the summer of 2008 (Corsi and Vermeulen, 2011; 2012; Quaresma, 2008; Vermeulen and Corsi, 2008; Vermeulen et al., 2009). The original box excavation strategy was abandoned in favour of an open area excavation and the excavation trench was enlarged to c. 350 m^2. Besides a stratigraphic study, a major effort was realised for a full topographic survey of the excavated and standing remains, as well as for a geophysical survey of the whole bathhouse area using magnetometer, electrical resistance and

GPR, including the area of the EN359 road (Johnson, 2010; Verdonck and Taelman, in press; Verhegge, 2010).

4.2.1 Building configuration

The forum bath complex occupies the western half of the building block immediately southeast of the forum; the eastern half is a courtyard house or *domus* of roughly 39.8 m by 31.7 m. The latter building is composed of a central, open *atrium* with surrounding rooms of which the functions are not entirely clear from the geophysical results. Several smaller rooms opening onto the *cardo maximus* to the northeast may represent shops or *tabernae*. The *insula* is enclosed by the *cardo maximus* to the northeast, the *decumanus maximus* to the northwest and a secondary *cardo* and *decumanus* to the southwest and southeast respectively (Figure 4.12).

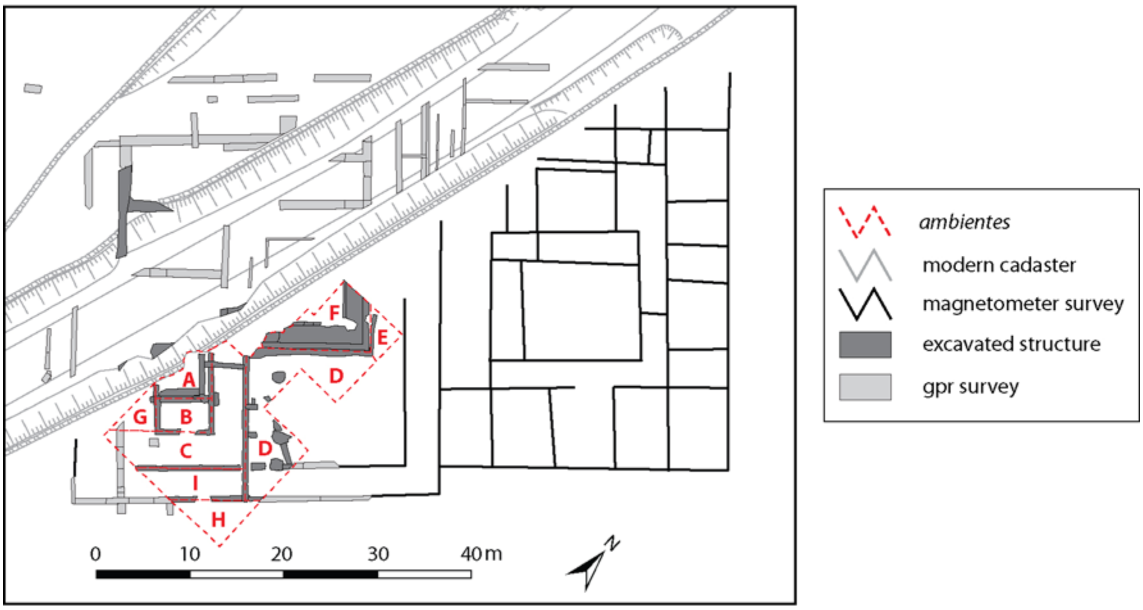

Figure 4.12 Plan of *insula 26* showing the bathhouse on the left and the *domus* on the right.

Thus far, the bathhouse has been excavated only partly. Preliminary studies of the material from these excavations propose a building chronology starting around the middle of the 1st century CE (Claudian–Neronian), when the area was probably occupied by a residential building, similar to the *domus* of the other part of the *insula*. Remains of this first phase are limited to four structures in *ambiente B, C* and *D*, and some destroyed flooring in *opus spicatum* (Corsi and Vermeulen, 2012). Reused and spoliated material in the later bathhouse such as marble revetment panels and column elements suggest a rich *domus* (Figure 4.13).

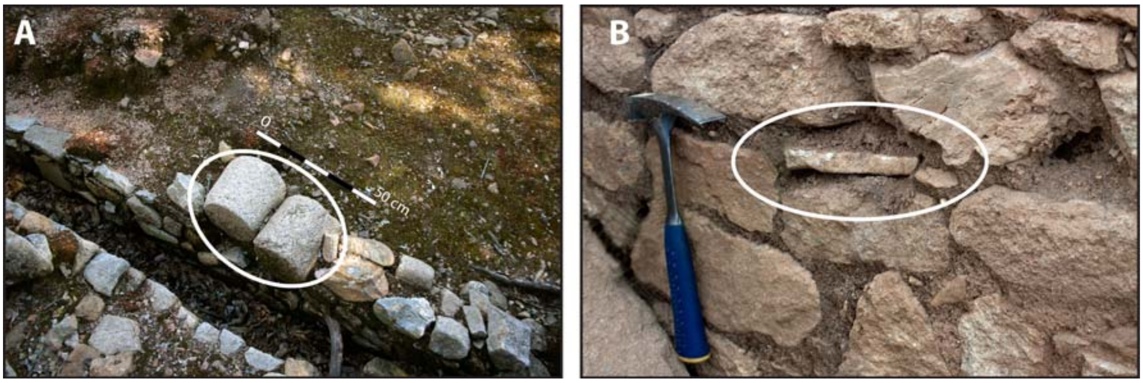

Figure 4.13 Reused elements for the construction of the Flavian bathhouse: (A) Column drums reused for the construction of drain 2; (2) Fragment of a marble veneer panel reused for the construction of the southeastern outer wall (SU88–89) (length hammer: 30 cm).

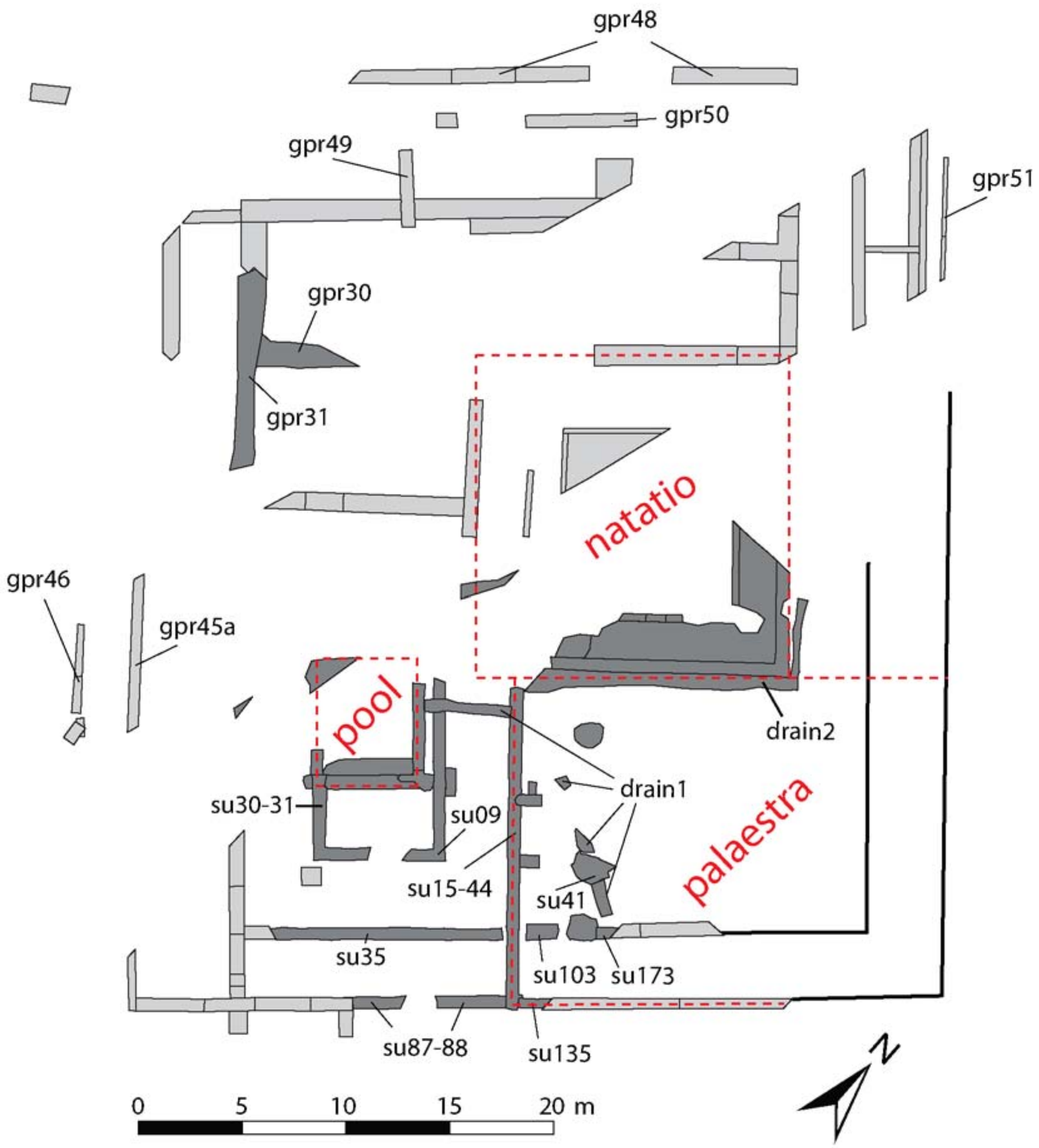

Figure 4.14 Plan of the western half of *insula 26* corresponding to the bath complex. The main structural features mentioned in the text are indicated.

In the Flavian period, the building occupying the western part of *insula 26* was entirely dismantled and replaced by a monumental bath building with the same general orientation as the earlier building (Corsi and Vermeulen, 2011; 2012). The construction of the bath building might be related to the elevation of the town to a *municipium iuris latini* by Vespasian in the last quarter of the 1st century CE. The most striking features that permit the identification of the complex as a bathhouse are a bath facility in *ambiente A* and parts of a massive, well-preserved *natatio* in the centre of the complex in *ambiente F* (Borges, 2002) (Figure 4.14).

The pool in *ambiente A* initially measured 6.1 m by 5.4 m. Two reinforcements were built on either side of the southeastern wall of the *piscina*. The inside area of the basin measures c. 4.3 by 4.8 m, totalling 20.6 m^2. Later modifications include a new entrance stairway in the northwest consisting of three steps and a sitting bench or a wall to reduce the capacity of the basin in the southeast. In the northeastern wall of the basin, a small outlet connects with a drain channel that could be followed through *ambiente C* and *D*; in the latter, the channel was, however, severely destroyed by later building (Oliveira et al., 2002). Material found in the channel illustrates an operation of the pool essentially between the late 1st century CE and the late 2nd century CE. As no heating system (hypocaust or wall heating) has yet been discovered in the basin or in adjacent rooms, a shallow, unheated pool as part of the *frigidarium* seems most likely. Moreover, the remains of a broken out and spoliated hypocaust system in a different part of the building and the absence of spoliation in the pool make it highly unlikely that the pool belonged to the *caldarium* or *tepidarium*.

The centrally located *natatio* is partially exposed and partially observed in the GPR results of the EN359 road survey. The room reserved for the *natatio* measures 14.4 m by 14.3 m (206 m^2). Surrounding the actual pool is a corridor with a width of 3 m along the northwestern side and 1.8 m along the northeastern and southeastern side (Figure 4.15). For the southwestern corridor, the situation is less clear and could measure either 2.3 m or 3.9 m. Here, a possible stepped entrance might have been located. The actual dimensions of the swimming area are 9.3 m by either 10.2 m or 8.6 m (80 m^2 or 95 m^2), depending on the assumed width of the southwestern corridor. The difference between the floor of the pool and the walking level of the corridor is approximately 1.9 m. Even though the pool has been excavated only partly, the absence of roof tiles in the infill of the pool may suggest that the room was originally unroofed. A large drain channel of about 60 to 75 cm deep runs along the southeastern and northeastern side of the *natatio* room and contained material pointing towards a main operation period from the end of the 1st century CE to the end of the 2nd century CE, with a reduced use in the 3rd and 4th century CE (Quaresma, 2008).

Figure 4.15 (A) General view of the *natatio* with the granite ashlar facing and corridor; (B) Cross section of the corridor surrounding the *natatio* pool as preserved in the bank of the EN359 road.

Besides the *natatio* and the bath facility of *ambiente A*, the excavated structural features include a northwest–southeast oriented wall (SU15–44) of 15.5 m long that divides the complex in two main parts and the southeastern outer wall (SU87–88–135). The continuation of the latter is detected in the results of the geophysical survey (Johnson, 2010; Verdonck and Taelman, in press; Verhegge, 2010). In comparison with the Claudian–Neronian house, this wall significantly enlarged *insula 26* and took up about 2.5 m of the street. Further, the corner of SU87–88–135 with the western outer wall of complex (GPR46), as well as a parallel wall (GPR45a), has been observed. In the field west of the EN359 road, two perpendicular walls belonging to the bath complex are still visible aboveground. GPR30 is preserved to a height of c. 3.9 m above the present-day walking surface and runs in southwest–northeastern direction (Figure 4.16). Wall GPR31 is perpendicular to GPR30 and is visible over a distance of 9.7 m in the road bank. The difference in elevation between the top of GPR30 and the bottom of GPR31 is c. 4.8 m. The GPR data of the road survey also shows the continuation of GPR31. On the southwestern side, the building was enlarged and occupied part of the street.

Figure 4.16 Aboveground preserved wall GPR30 in the field west of the EN359 road.

In the area between the western outer wall of the complex and the *natatio*, as well as along the northern side of the building, several structures and rooms can be distinguished (Verdonck and Taelman, in press). Some of these features (e.g. GPR48) are possible conduits underneath the surface of the *decumanus*, while others (GPR49, 50, 51) were structures that probably belong to the bath building itself. The exact identification of every room is, however, not possible from the results of the GPR survey. Nonetheless, if we assume that the main entrance of the bath complex was on the *decumanus* between the forum and *insula 26*, the rooms in the northern part possibly include a *vestibulum*, a hallway for access to the different rooms and an *apodyterium*. Comparing the excavated remains of *ambiente A* and the GPR data with excavated examples elsewhere in *Lusitania*, the *frigidarium*¸ *tepidarium* and *caldarium* have to be situated in the western part of the building and organised in a simple linear sequence. The location of these rooms in this area, especially of the hot rooms, can certainly be expected given the southwest to west orientation of these rooms to profit from the sunlight in the afternoon and evening as Vitruvius (*De Architectura V,10,1; VI,4*) describes (Peters, 2008). Service areas related to the bathing facilities can also be expected in this area.

The area of enclosed by the SU15–44, the northeastern limit of the complex with the neighbouring *domus* and the outer wall of the bath complex (SU135) – am*biente D* – formed a courtyard or *palaestra* of c. 200 m^2. The absence of roof collapse and the reduced width of the outer wall (SU135), that was too limited to support a massive superstructure, indicate that the area was unroofed. An inner perpendicular wall constructed without a proper foundation (SU173) can be interpreted as a low wall for a portico surrounding the *palaestra*. The large ashlars that are partly built into wall SU44 probably belonged to a doorway between the *palaestra* and the actual bath building.

In two exposed sections in *ambiente D*, a compact white mortar layer on top of a thin foundation of river pebbles represents part of the original flooring or a floor preparation layer of the *palaestra*. Wall collapse (large stones, ceramics, regularly cut large blocks and ceramic building material) in the deposits on top of the drain channel in *ambiente E* and the remains of a broken out hypocaust on top of the thick mortar layer confirm this hypothesis. A layer of small subrounded to rounded pebbles deposited on top of natural soil in the southern part of *ambiente D* probably served as a base for the drain channel of the *piscina* in *ambiente A*. The circular pebble layer in the northwestern corner of *ambiente D* might have had the same function. The construction of two massive pillars, as well as the dump of a broken out and spoliated hypocaust system have severely destroyed the trace of the channel.

Finally, the hall northeast of the open area could serve as a passageway with direct access to the *decumanus* to the north of the *insula*. Some rooms along this passage are possible locations for service rooms.

Summarising, the bath complex of *Ammaia* occupies the western half of *insula 26* and operated from the last quarter of the 1st century CE to the end of the 2nd century CE, but a continuation into the 3rd and beginning of the 4th century CE cannot be excluded. The configuration of the building is partly determined by the layout of the earlier building. The southeastern, northeastern and southwestern perimeter walls of the complex seem relatively certain from the excavation and geophysical data, while the precise extent along the northwestern side still remains doubtful. Depending on the assumptions made (wall GPR49 or GPR50), the complex measures 39.3 m by 39.5 m (1552 m^2) or 43.3 m by 39.5 m (1710 m^2) (Verdonck and Taelman, in press). Because of the limited area available for the bathhouse, a simple linear sequence of *frigidarium–tepidarium–caldarium* seems most obvious. Other notable features are the large *natatio* and the (porticoed) *palaestra*.

Regarding size, plan and chronology, the best parallel for the *Ammaia* forum baths is the Flavian *Termas da Muralha* of *Conimbriga*. As in *Ammaia*, these public baths are characterised by a simple linear *frigidarium–tepidarium–caldarium* sequence. Moreover, the importance of large open-air areas in the *Termas da Muralha* is obvious given the *natatio* and the large – partly porticoed – *palaestra* (Correia and Reis, 2000; Reis, 2004) (Figure 4.17). A division of the bath complex into a male and female area, as seems the case for the *Termas da Muralha*, could not be identified from the available data for the forum baths of *Ammaia*.

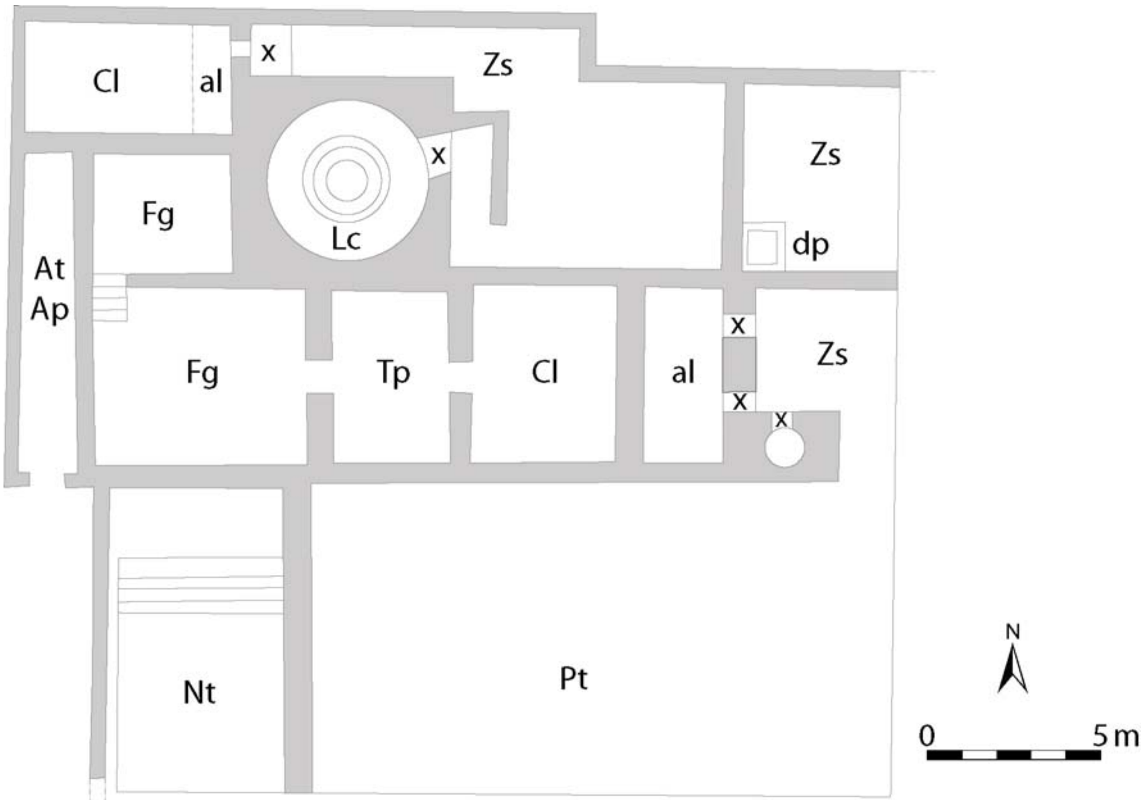

Figure 4.17 Plan of the *Termas da Muralha* in *Conimbriga* (al = *alveus*, Ap = *apodyterium*, At = *atrium*, Cl = *caldarium*, dp = deposit area; Fg = *frigidarium*, Lc = *laconicum*, Nt = *natatio*, Pt = *palaestra*, Tp = *Tepidarium*, Zs = service area, X = *praefurnium*) (Correia and Reis, 2000; Reis, 2004).

4.2.2 Construction technique and stone use

Although it is difficult to determine the natural topography of the terrain, the street level of the *decumanus* to the southeast and the elevation of the foundations of the earliest building illustrate that the *insula* was located on a sloping terrain, similar to that of the forum. As a result, the northwestern part of *insula 26* lies considerably higher than the southeastern part. Severe modifications were therefore required to prepare the terrain for building. Although these modifications can already be seen in the Claudian–Neronian building, for example different elevations for foundations, large-scale levelling and terracing effort was mainly carried out for the construction of the Flavian bathhouse.

While the street to the southeast and the structures of the early building are built on top of a layer of pre-Roman colluvium with foundations built into trenches dug into the pre-Roman colluvium, the main supporting wall structures of the Flavian bathhouse have significantly deeper foundations and are dug directly into solid natural soil to ensure a firm support for the massive bath building. A compact clay soil mixed with some pebbles and almost void of archaeological material was brought to the site and deposited on top of the pre-Roman colluvium to create a level platform in the inside of the bathhouse. This resulted in a significant elevation of the surface in certain areas of the building compared with the Claudian–Neronian phase. Judging from the staircase and the rough facing of one of the walls, the pool of the possible *frigidarium* was dug into this new platform and the surrounding floors must have been at least 75 cm higher (Figure 4.18-A). A similar situation for the other pools can be assumed. Also, as a result of this levelling, the floor level on the inside of the building was significantly higher than that of the *decumanus* to the southeast. The few preserved indications of floor levels in the building suggest a difference of 35 cm to 45 cm for the *palaestra* and c. 2 m for the rooms in the southeastern corner of the building. The partially exposed mortar floor or floor preparation in the *palaestra* shows that no levelling or terracing was done in the courtyard, as the level corresponds to the level of the pre-Flavian structures, some 1.55 m to 1.65 m lower than the level on the inside of the building.

Figure 4.18 (A) Southeastern wall (SU23) of the pool in *ambiente A*. The rough facing indicates its buried nature. (B) Structures of the Flavian phase (SU23, SU28 and SU55) partially built on top of the structures of the Claudian–Neronian phase (SU30).

Walls of the early phase are between 58 cm and 60 cm wide with foundations being 15–20 cm wider. The foundations of SU35 are 40 cm wider, probably because this wall formed the outer perimeter wall of the Claudian–Neronian building. Walls consist of roughly dressed granite facing stones set into a mortared core of rounded gravelstones and some quartz (*opus caementicium* with *opus incertum* facing). Rounded gravelstones and shale slabs were used for wall facing only rarely. The stones range from 15 cm to 40 cm across for the facing stones and maximum 15 cm for the stones of the wall cores. Some large facing stones may attain up to 50 cm diameter. The foundations are essentially made up of rounded gravelstones between 5 cm and 25 cm across. Some granite, sandstone, shale and quartz is also used (Figure 4.18-B).

Compared with the Claudian–Neronian structures, only few changes can be observed in the construction technique and the selection of stones for the Flavian bathhouse. The walls are a rubble and mortar construction (*opus caementicium* with *opus incertum*). The facing consists of roughly dressed stones with well-smoothed exposed sides. The blocks are generally between 15 cm and 25 cm in diameter. Some larger blocks are up to 45 cm. Over 95 % of the material used for facing is granite. Shale slabs (up to 25 cm long), brick and fragments of recycled marble veneer are occasionally used for creating horizontal courses. The mortared cores are generally constructed with rounded to subrounded gravelstones; sandstone, quartz and shale are used only in few cases. The size of these stones varies between 5 cm and 25 cm.

Throughout the excavated area, mainly in *ambiente C* where the first occupation phase of the building is best preserved, small heaps of stone debris underneath the levelling deposits suggest that reusable stones were separated from the unusable stones during the dismantlement of the earlier buildings. The first ones were reused for the construction of the bath building, while the latter ones were discarded. Their waste heaps were left in place and used as part of the infill for the new rooms (Figure 4.19).

Figure 4.19 Waste heap of unusable stones, left in place during the filling of *ambiente C*.

Three in situ preserved granite ashlars on the corner of SU87, SU44 and SU135 illustrate that the rubblework architecture of the main supporting walls of the building are protected by piers of alternating headers and stretchers. Dimensions of the ashlars are 130 cm x 63 cm x 40 cm, 120 cm x 70 cm x 40 cm and 125 cm x 75 cm x 45 cm, respectively weighing 865 kg, 887 kg and 1113 kg, as calculated using an average mass density for granite of 2640 kg/m^3 (Hunt et al., 1995) (Figure 4.20).

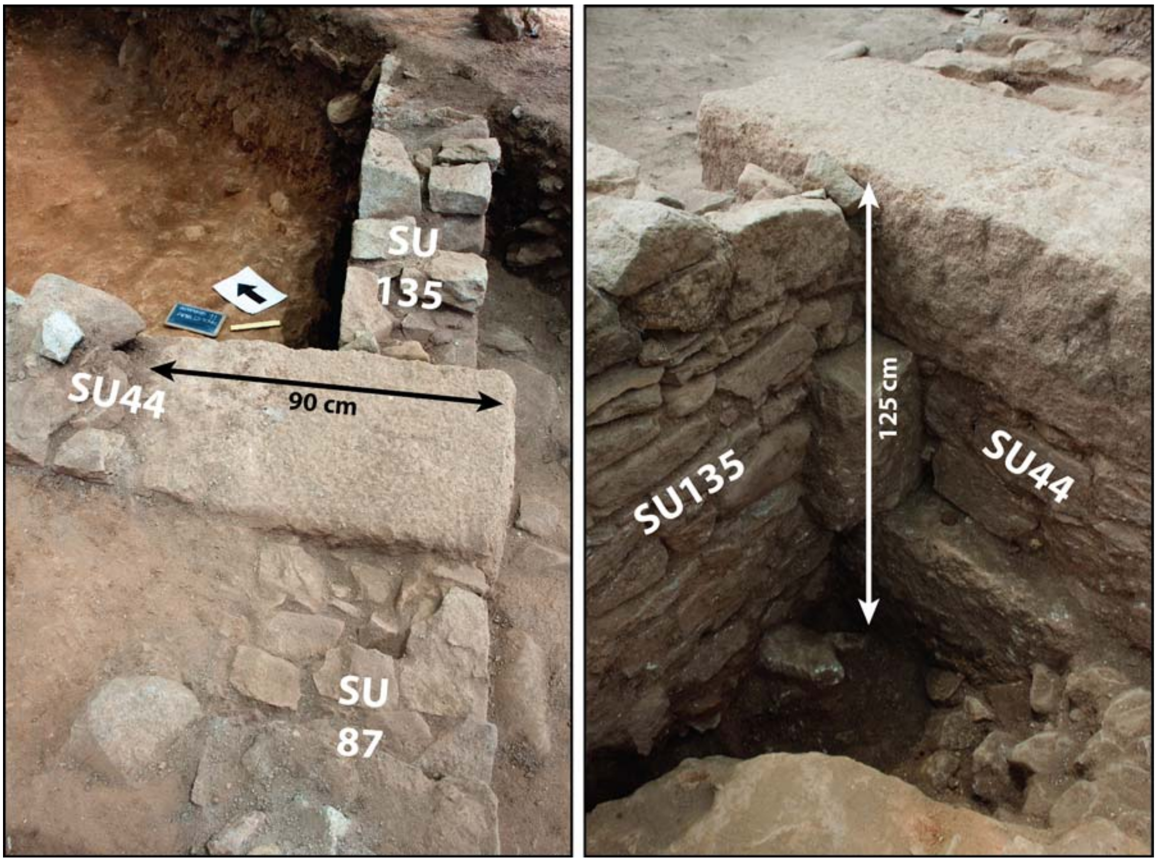

Figure 4.20 Protected and reinforced corner of the main supporting wall of the bath complex.

For the southeastern perimeter wall of the baths (SU87–88), a robber trench filled with stone rubble and negative traces of ashlars suggest that the wall was reinforced with large ashlars positioned in alternating horizontal and vertical position, in a manner similar to the *opus africanum* building technique (Figure 4.21). As only a small portion of the wall has been exposed, the spacing between the ashlar piers cannot be determined yet. In correspondence with the situation in other excavated sectors of the town, it can reasonably be assumed that the ashlars were made of granite. The rubblework between the piers consists of irregular, but roughly dressed granite facing stones with few pieces of sandstone and shale. One piece of a marble revetment panel is also detected. The purpose for this more robust construction technique is without a doubt related to the original slope of the terrain and the retaining function of the wall for the entire building.

Figure 4.21 Broken out and spoliated ashlar pier of the *opus africanum* building technique in the southeastern outer wall (SU87–88) of the bath building. Wall courses are indicated by a white dashed line (scale: 20 cm).

The *opus africanum* building technique probably has its roots in the Phoenician and Punic architecture. Its main distribution area was North Africa, hence its name, but it has also been detected in Sicily and in cities around the Vesuvius in Italy (Adam, 2005; Daniels-Dwyer, 2000). On the Iberian Peninsula, it was probably introduced by Phoenician settlers during the Iron Age. A local Iberian variation of the technique was mainly popular during the Flavian period, i.e. the period in which the forum bath complex of *Ammaia* was constructed. The use of this building technique has been detected, for example, at *Carmo* (Carmona, Spain), *Baelo Claudia* (Bolonia, Spain) and *Munigua* (Castillo de Mulva, Spain), all located in the *Baetica* province (Mierse, 1999#). Closer to *Ammaia*, *opus africanum* was used in the Augustan period for the construction of the retaining wall of the Guadiana River in *Emerita Augusta* (Pizzo, 2010b).

The walls of the forum bathhouse are generally between 57 cm and 60 cm wide, but some variations may occur. For example, the walls of the *natatio* are slightly wider

(68 cm), whereas the outer wall of the *palaestra* (SU135), and the possible portico wall of the *palaestra* (SU173) measure only 47 cm and 54 cm. The reduced width of SU135 confirms that it had no proper structural purpose and that the area to the northwest was an open space. Interesting is also that the possible portico wall of the *palaestra* is constructed without a proper foundation, also confirming that it had no supporting task.

The preserved height of the walls is between 30 cm and 80 cm above foundations for the internal walls and between 125 cm and 145 cm for the main supporting walls. Wall GPR30 in the field west of the EN359 road is significantly better preserved to a height of c. 3.9 m above the present-day walking surface. Courses could be observed only in walls SU87–88 and SU44 – these are the only walls that have a sufficient height – and have a vertical spacing of 40 cm and 30 cm (Figure 4.21). No courses could be detected in GPR30, because of its bad state of conservation. Putlog holes for scaffolding have not been observed, most likely because walls have not survived high enough. Another explanation is that the building was designed with only one story and maximally around 3 m high, so that builders could work from freestanding trestles without needing to construct a proper scaffolding system (Adam, 2005).

As excavations are still on-going, foundations have only been reached for the wall between the *palaestra* and the bath building and for the southeastern outer wall. Moreover, excavations generally stopped when the upper levels of the foundations were reached resulting in a lack of information on the depth of the foundations. Foundations are in *opus caementicium* with unworked, naturally rounded gravelstones with some pieces of sandstone and granite. The stones are predominantly between 5 cm and 20 cm diameter; some rare larger blocks attain more than 30 cm. Foundations are trench-built with foundation trenches having vertical edges. Foundations of the internal dividing wall and of the southeastern outer wall are between 70 cm and 80 cm wider than the superstructures. For SU15, foundations are only 15 cm wider.

A very distinct structural feature in the forum bath complex is the corridor surrounding the *natatio*. The core of the corridor is composed of rounded to subrounded sandstone and quartzite gravelstones with some granite and sandstone blocks. The stones are generally between 10 cm and 20 cm across, but some larger ones up to 45 cm occur (Figure 4.22). On top of this core, a 45 cm thick layer of smaller rounded stones embedded in whitish fine mortar forms the basis of an *opus signinum* floor of 25 cm to 30 cm thick (Figure 4.15-B and Figure 4.22).

Figure 4.22 Floor preparation layer of the corridor around the *natatio*, consisting of rounded to subrounded sandstone and quartzite gravelstones with some granite and sandstone blocks. The *natatio* perimeter wall (SU60–71) is on the right.

The facing of the *opus caementicium* core of the corridor is composed of large, upright inserted granite ashlars; ten of which have been (partially) unearthed (Figure 4.15-A). The blocks are securely dressed and smoothed on all sides, except for the backside that was left rough to improve the cohesion with the *caementicium* core of the corridor. For connecting the ashlars to the mortared core of the corridor, a mixture of a whitish mortar with small marble flakes, fragments of stucco and pieces of brick is used. The ashlars are 83–132 cm in length, 50 cm in height and 27–36 cm in width. Using an average mass density for granite of 2640 kg/m^3 (Hunt et al., 1995), the weight of the blocks is calculated between 296 kg and 627 kg.

At several places on the blocks, shallow, elongated holes measuring between 6 cm and 9 cm long and 1.5 cm to 2 cm wide were carved in the ashlars. Some were located only 7 cm apart. As most holes are found on the sides of the blocks, outside the centre of gravity, they are likely to be crowbar or spike holes for manoeuvring the blocks into their final position (Adam, 2005; Rockwell, 1993).

The drain channels are constructed using a mixture of small granite stones (max. 15 cm across) and vertically placed ceramic tiles. The channels are covered with grey shale slabs of 40 cm to 90 cm in length. In the part of drain 1 immediately next to the basin of *ambiente A*, no bottom is found. A lead tube or *fistula*, mortared into the wall with the basin and connected to an opening in the marble slabs of the basin's wall revetment, suggests that the first part of the water channel consisted of a lead tube. In *ambiente D*, the bottom is made of a mortar layer on a foundation of small pebbles. The large drain (drain 2) uses the foundation of the *natatio* wall on one side, while the other side is built with several reused elements such as broken pieces of brick and tile, small column drums, shale and marble slabs (Figure 4.13-A). On the inside, the channel is partially covered with mortar. The channel bottom consists of large *tegulae* near the corner of the *natatio* where the drain turns 90°, and mortar.

Apart from the forum complex, the excavations of the forum baths have yielded the largest volume of ornamental stone unearthed at *Ammaia* thus far (555 fragments or 113 kg). Judging from their small size, most collected marble pieces are waste material from the intensive stripping and salvaging in later times. All marble were used as floor or wall veneer. Apart from 9 large fragments in the pool of *ambiente A* (Figure 4.23), no pieces have preserved in situ. Already in the Flavian period, the reuse of marble is attested. Several pieces of marble veneer were recuperated for the construction of the drain channel along the *natatio* (Figure 4.13-A). Reuse is also identified for the construction of wall SU88. Apart from the fragment of a veneer panel that is used in the wall proper, a large amount of marble flakes was used to fill the foundation trench. A final example of marble recuperation from the earlier building is observed in the mortar layer used to attach the granite ashlars of the *natatio* with the corridor's *caementicium* core.

The fragments are almost exclusively white marble or white marble with few coloured streaks. Of the 555 fragments, only five grey–white marble fragments (102 g) have been identified. Considering the small size of these five pieces, they might also belong to a white, veined marble block with locally a higher density of grey veins.

Figure 4.23 Veneer panels in white marble for the wall and floor decoration of the pool in *ambiente A*.

Proposing a hypothesis for the decoration of the forum baths is problematic as only few elements have been preserved in situ. The entire floor and at least the lowest part of the wall surfaces of the basin of the *frigidarium* were decorated with white marble veneer. While most panels appear to be around 55–58 cm in length, the width is never fully preserved and measures 53 cm maximally. Judging from these dimensions, a square shape for the panels is likely. Some panels are, however, remarkably longer and measure up to 108 cm. The thickness of the slabs varies between 3 and 5 cm. Based on the dimensions of the pool and an average thickness of 4 cm for the slabs, the approximate volume of white marble needed for the surface decoration of the entire floor area of the *piscina* was about 0.824 m^3 or about 2274 kg, as calculated using an average mass density for marble of 2760 kg/m^3 (Hunt et al., 1995). The decoration or finish of the higher areas of the walls remains unclear at the moment. The large number of small marble fragments unearthed during the excavations of the basin, probably the result of the later looting of the slabs, suggests that the marble veneer decoration continued in the upper surfaces of the walls. After the reduction in size of the basin and the construction of a new staircase, the earlier marble veneer was stripped and possibly reused for the decoration of the renovated *piscina*. Considering that several other rooms in the building such as the *tepidarium*, *caldarium* and perhaps even the *natatio* might have been decorated with a similar marble veneer, the costs of embellishing the bath complex must have been enormous.

4.3 The South Gate or *porta sul*

Without doubt the best-preserved Roman remains of *Ammaia* are the buildings of the so-called *porta sul* or South Gate (Figure 4.1 – n°3). Archaeological remains include part of the town wall, a gate building with two round towers, a monumental paved square and residential and commercial buildings. Excavations were carried out non-continuously between 1994 and 2002, with a major restoration campaign in 1997 (Barata and Mantas, 2004; Oliveira et al., 1997; Pereira, 2009). Apart from the works in the *porta sul* area, the aboveground remains to the west of the excavated area were cleaned from vegetation and studied preliminary. No excavations were carried out. Because of the limited archaeological information for this building, it will be discussed only briefly.

4.3.1 Building configuration

The monumental gate complex with its two towers and paved square was constructed on top of earlier housing structures dated to the Claudian period (Quaresma, 2010-2011). As a result of the monumentalisation of the area at the end of the 1st and the beginning of the 2nd century CE, very little is known of the earliest phase except for a few structures preserved underneath the western half of the paved square (Pereira, 2005) (Figure 4.24). Among the main features of this first phase is the town's main northwest–southeastern street or *cardo maximus*. The absence of a street paving indicates a dirt street or a street made of beaten earth mixed with small pebbles. An original entrance to the town must also have existed, but was completely dismantled during the rebuilding of the sector in the Flavian–Trajan period.

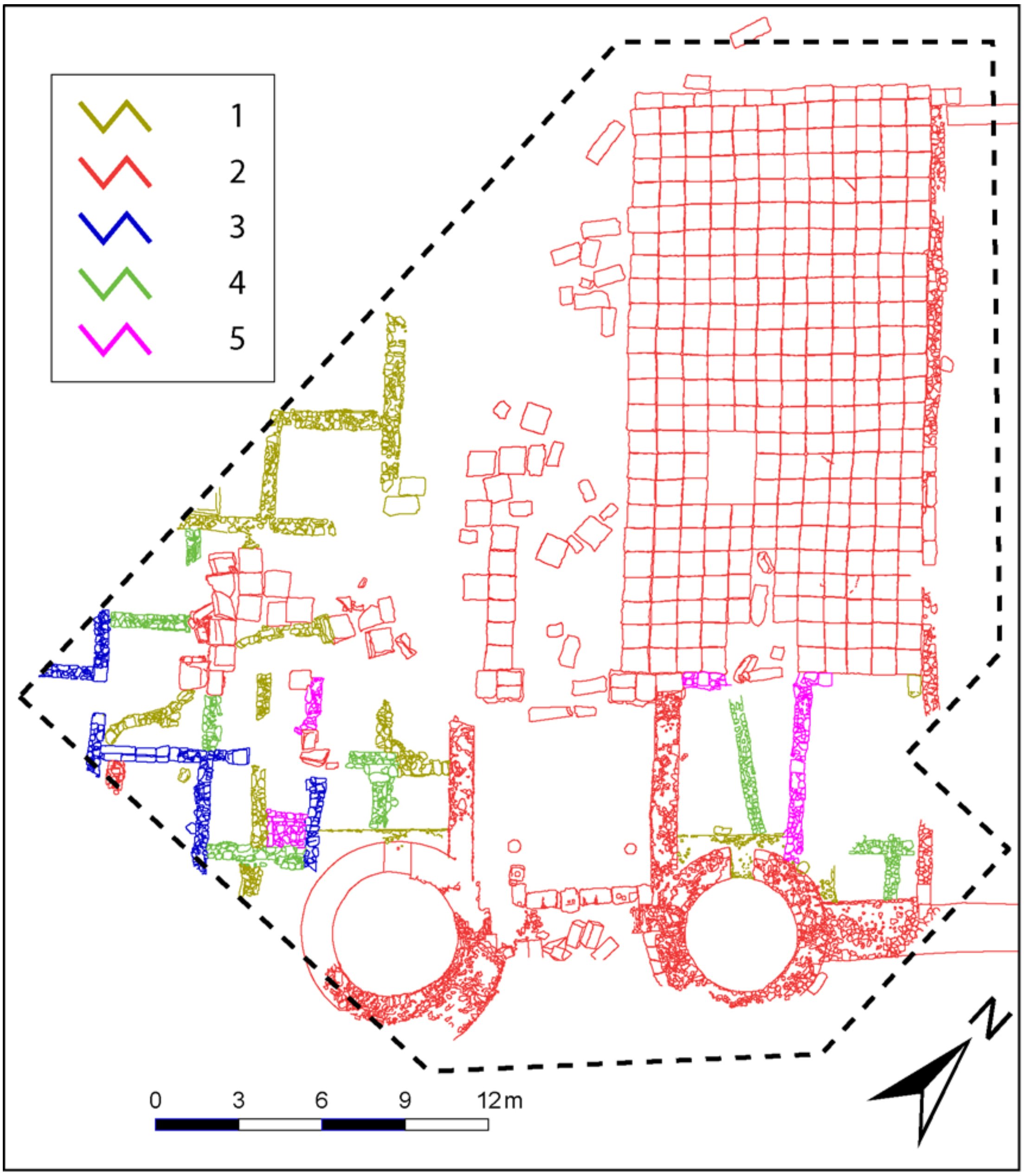

Figure 4.24 Phase plan of the porta sul excavations (after Pereira, 2009). Phase 1 = middle 1st century CE; Phase 2 = end of the 1st – beginning 2nd century CE; Phase 3–4–5 = 2nd half 2nd to late 4th – early 5th century CE.

At the end of the 1st century CE and in the beginning of the 2nd century CE, the whole area was monumentalised (Pereira, 2002; 2009; Quaresma, 2010-2011). Earlier buildings were demolished and a monumental complex was erected on the site. The new architecture was dominated by an arched gate building flanked by two circular towers and a monumental square (Figure 4.26). To support the massive towers and the archway, the part of the town wall immediately adjacent to the towers was widened. The towers have external diameters of 6.3 m and are separated by an open space for a gateway of 6.4 m wide. Two rectangular holes for lock-pins in the central block of the threshold and four circular and rectangular holes for hinges show that the gate consisted of two elements measuring each 1.75 m wide and turning inwards (Figure 4.25-A). The actual passage was 3.15 m, just wide enough for one cart. Interesting are the well-developed cart ruts in the granite blocks of the gate threshold. These cart ruts (c. 16 cm deep) prove that the South Gate was one of the town's main entrances through which heavily loaded carts entered the town. Measured from the centre of the ruts, a gauge of 1.33 m for the Roman carts in *Ammaia* can be estimated (Figure 4.25-B).

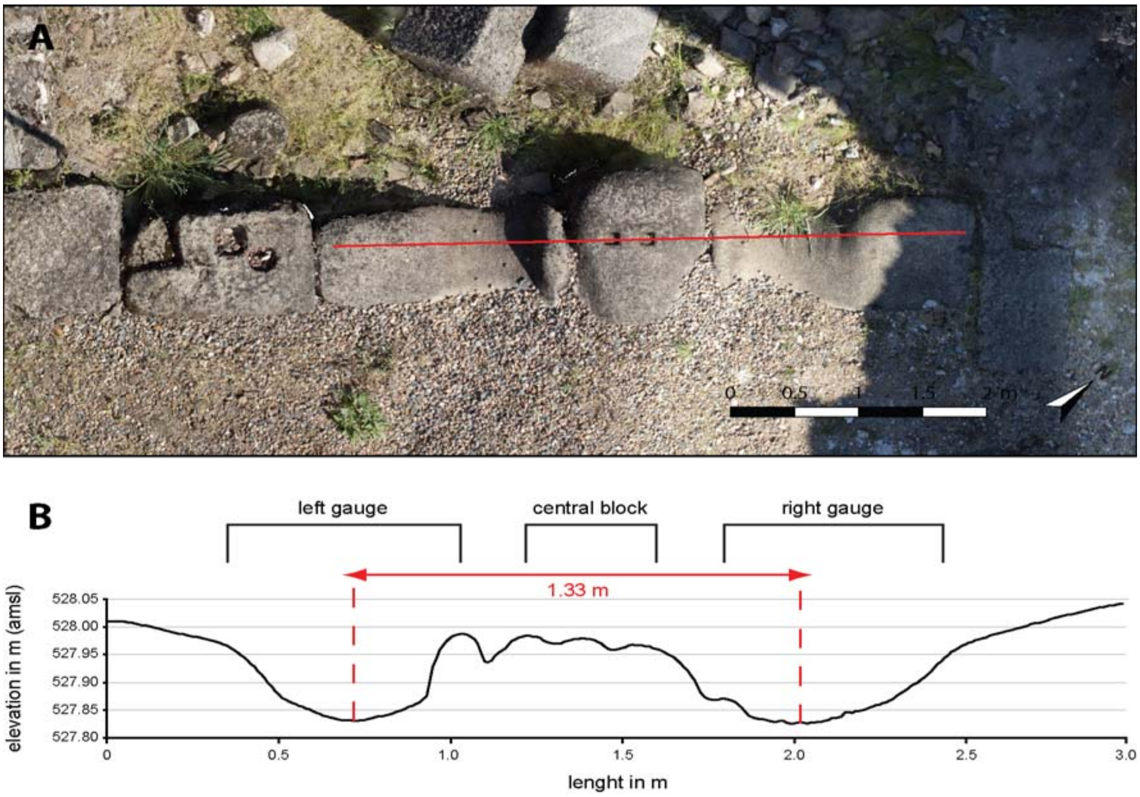

Figure 4.25 (A) Orthoimage of the gate threshold. (B) Profile of the the threshold. The distance between the centre of the gauges is 1.33 m.

Except for the arch abutments that have survived to a height of 3.30 m, nothing remains in place of the original archway. Nevertheless, some ideas on the original arched entrance can be proposed on the basis of a photograph taken in 1890 of the *Arco da Aramenha*. In 1924, Laranja Coelho mentions the transfer of the South Gate, the so-called *Arco da Aramenha*, in 1710 to Castelo de Vide, where it stayed in use until 1891 (Coelho, 1988; Mantas, 2010; Stylow, 2009) (see Chapter 3 and Figure 3.1-A). Using a commemorative plaque on the 1890 photograph, of which the dimensions are known, V. Mantas (2010) calculated a 3.30 m span for the *Arco de Aramenha*, after which he argues that the *Arco de Aramenha* is not the original gateway from Roman *Ammaia* as the spanned area between the remains of the two towers equals 6.50 m. However, 6.50 m does not correspond to the width of the gateway, but to the width of the courtyard behind the gateway. Considering the actual distance of the spanned area in *Ammaia* (see the 3.15 m long gate threshold), a span of 3.30 m for the *Ammaia* archway is perfectly plausible. Moreover, a distance of 4.70 m between the preserved parts of the arch abutments leaves sufficient space for the ashlar blocks of the facing of the abutments. Based on the 1890 photograph, the height of the arch is estimated at 4.90 m, plus an extra 1.25 m for the cornice, totalling around 6.15 m.

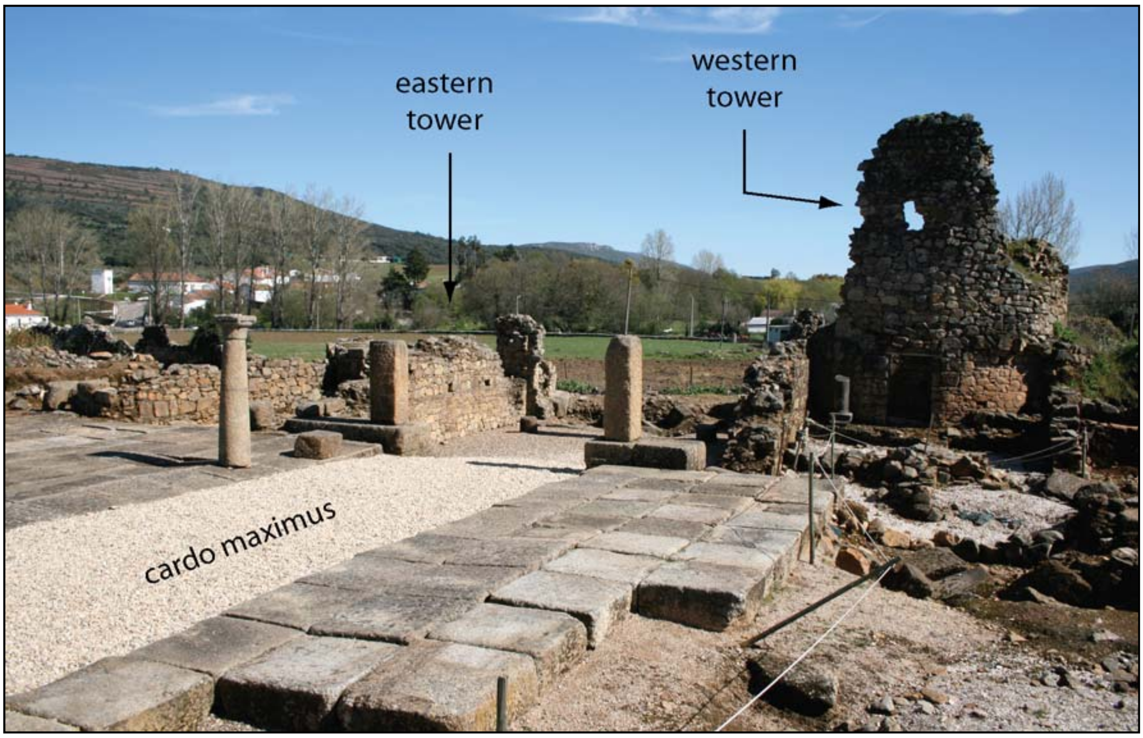

Figure 4.26 View of the two towers, the gateway and the *cardo maximus* at the South Gate.

Two parallel walls define an internal courtyard. At the end of the two walls, two foreparts slightly reduce the width of the street and mark the entrance to the monumental paved square. The assumption of a second archway at this location, as proposed by S. Pereira (Pereira, 2009), is unlikely considering the absence of proper abutments and a completely different construction technique for the two foreparts of the courtyard in comparison to the gateway near the towers.

The gate building opens onto a large rectangular square of 20.95 m by 24.30 m, symmetrically arranged on either side of the 4 m wide *cardo maximus*. While the western half of the square is heavily destroyed, the eastern part is almost perfectly preserved. The side of the square facing the town was open. On the northeastern edge, the square was defined by the perimeter wall of a neighbouring building. No similar structure was detected on the southwestern edge. Given the location along one of the town's main streets and entrances, a commercial function for the rooms between the towers, the town wall and the square is likely. More or less in the middle of both sides of the square, a small podium for a statue base was created (Pereira, 2005) (Figure 4.27). In the northeastern corner of the square, two holes of 10 cm by 10 cm probably contained vertical dowels for an upstanding structure. Several openings of c. 7 cm in the joint of the pavement blocks occurring at 2.6 m from the northeastern edge of the square were used for placing wooden or iron posts. These posts could have been used for attaching a canvas to provide the necessary shade during the hot summers (Klein, 2009) (Figure 4.28-B). Three monolithic columns found during the excavation of the street area give an impression of the architectural decoration of the square. How this decoraration was exactly conceived is uncertain.

Figure 4.27 Podium in *opus caementicium* for a monument base in the eastern part of the square. The square paving blocks measure 88–90 cm (scale: 1 m). Author photo: unknown.

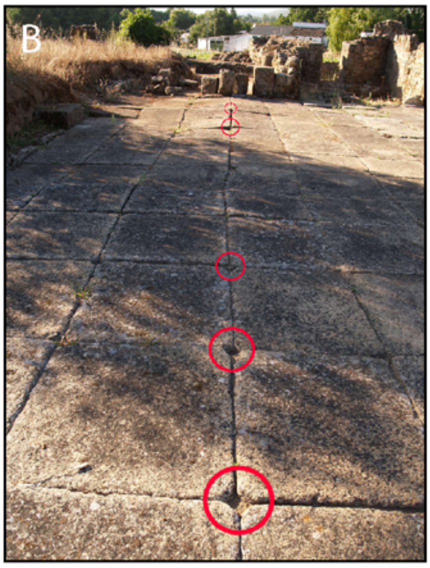

Figure 4.28 (A) Holes for vertical dowels in the northern part of the eastern part of the square; (B) Holes for wooden or iron posts. The square paving blocks measure 88–90 cm. Photo-B by M. Klein.

In the middle of the eastern half of the square, a passageway opens onto a large rectangular area of c. 975 m^2. The results of the magnetometer survey revealed a large courtyard occupying most of the building east of the *porta sul*. Judging from the orientation and location, it is possible that some of the features detected in the geomagnetic data belong to an early phase, immediately after the foundation of the town and prior to construction of the *macellum*. Towards the end of the courtyard, three rooms and a small peristyle were partly exposed during a cleaning and restoration campaign. The structural stratigraphy of the exposed remains indicates several successive building phases. Some structures might even be related to the 18th century CE farmhouse of the *Quinta do Deão*. Originally, two series of five rectangular rooms of c. 4 m by 4 m occupied most of the eastern end of the building and opened onto the central courtyard. The nature of these rooms suggests shops or *tabernae*. Even though very little is known of its layout of the building, the building can be interpreted as a *macellum* or food market, (Mantas, 2000). Most elements that typically occur in *macella*, especially in the North African examples, are present in the building in *Ammaia*. The building is fully enclosed by a perimeter wall, a courtyard surrounded by a peristyle forms the main part of the building, and shops are located at least along one side of the complex (Young, 1993). Other typical elements such as hydraulic features and multiple entrances have not been identified yet.

Sometime in the second half of the 2nd century CE, a large fire destroyed parts of the monumental building, after which architectural modifications were plentiful (Oliveira et al., 1999; Pereira, 2002; 2005; 2009). Despite these modifications, the general view and layout of the town entrance with its gate building, towers and monumental square remained the same. Architectural changes are most notable in the areas between the towers, the town wall and the square where the existing rooms were subdivided into smaller units. On the eastern side, the large room was subdivided into two more or less equal rooms. The paving of the new rooms was made of shale slabs. On the western side, the new rooms served as *tabernae* or shops. These shops are identified essentially by their characteristic method of closing with a detachable wooden shutter that was placed into a grooved door threshold (Adam, 2005) (Figure 4.29). The presence of two *dolia* in one of the rooms confirms its commercial function (Pereira, 2009). The succession of fireplaces in the other shop perhaps illustrates that hot drinks or food was served (Adam, 2005).

Figure 4.29 Threshold of the entrance to one of the shops along the western half of the *porta sul* square. The groove for the wooden shutter is visible in the centre of the image. On the right, a cut-away and a hole for the hinge indicate the location of the door opening.

Proposing an exact chronology for these modifications is difficult as a result of the little stratigraphic information available. The few archaeological material from the 3rd and early 4th century CE might indicate that the area was intensively occupied in and that waste material, such as pottery, was properly deposed outside of the inhabited area. This intensive occupation is confirmed by successive floor levels in most shops (Pereira, 2009). The pottery record illustrates an occupation into the late 4th century CE and perhaps even the beginning of the 5th century CE (Quaresma, 2010-2011). A Visigoth and Moorish occupation, as suggested by Pereira (Pereira, 2009), is improbable as virtually no material dating later than the 5th century CE has been found (Quaresma, 2010-2011). Nevertheless, substantial restorations of the towers appear to have been carried out in later times.

4.3.2 Construction technique and stone use

As mentioned above, only few remains of the earliest buildings have survived. The walls are between 46 cm and 51 cm wide and consist almost exclusively of granite facing stones with a core of gravelstones and some quartz and shale. The bonding material is earth. The size of the facing stones is around 20 cm across, with some larger stones reaching up to 35 cm. For the construction of the drain channel, rounded gravelstones, granite and roof tiles are used. The cover plates are shale.

Together with the monumentalisation of the area, some new elements regarding the construction technique were introduced. These included foremost the use of mortar and of granite ashlars.

Unlike the few remains of the archway, the two walls defining the small courtyard behind the archway are well preserved. Remains of the two structures stand to a height of 2.7 m and 2.3 m, for the western and the eastern wall respectively. The width of the walls is 87 cm. Both walls are constructed with an *opus caementicium* core of quartzite sandstone gravelstones and some fragments of ceramic tile. The mortar is a light-coloured to yellowish lime mortar (sn, 2010). Towards the main square, the walls end in two foreparts formed by rusticated granite ashlars. The wall facings consist of rubblework alternated at regular distances by brick courses (Figure 4.30). The vertical spacing of the brick courses is 94 cm for the western wall and 90 cm for the eastern wall. The bricks are not limited to the wall facings, but connect both faces of the walls. The facing stones are granite and some shale. The size of the granite facing stones is around 30 cm across. In addition to the brick courses, level surfaces were created in the rubblework masonry with smaller granite stones and shale slabs. Vertical spacing of these horizontal courses is 52 cm, 48 cm and 47 cm. In the eastern wall, brick courses occur on top of every two horizontal courses. In the western wall, the bricks are laid slightly above the horizontal courses. This type of masonry that combines brick courses with rubble architecture was, for example, also observed in the so-called *Temple of Diana* on the colonial forum (dated in the Augustan period) and in the *Portico del Foro* (dated in the first half of the 1st century CE), both in *Emerita Augusta* (Pizzo, 2010b).

One series of putlog holes for scaffolding aligns to the brick courses. A total of three putlog holes were needed to span the length of the small courtyard (Figure 4.30). Putlog holes have a horizontal spacing of 1.92 m and 1.71 m. As the putlog holes extend through the entire width of the walls, it is clear that a cantilever scaffolding system with transverse putlogs supporting a scaffold on both sides of the wall was used (Adam, 2005).

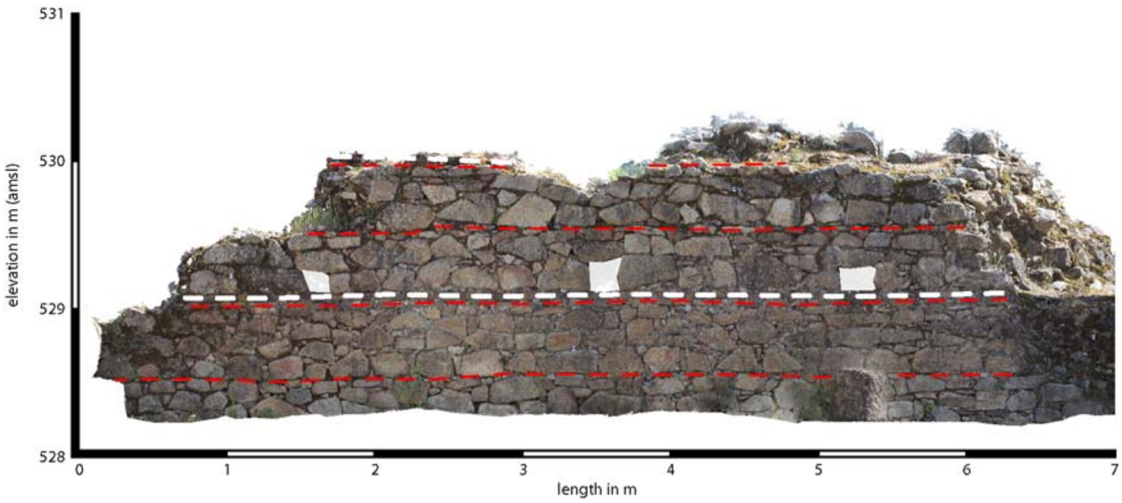

Figure 4.30 Orthorectified image of the eastern courtyard wall of the gate building. Levelling courses are indicated with a red dashed line, brick courses are indicated with a white dashed line.

The two towers, that were constructed together with the the archway and the inner courtyard, still stand to a height of c. 1.85 m for the eastern tower and c. 5 m for the western tower. The upper part of the western tower is a recent restoration, dated in modern times according to S. Pereira (2009). The width of the tower walls is 180 cm for the lower courses of the western tower and 150 cm for the eastern wall. These lower courses consist of carefully cut granite ashlars of roughly 55 cm x 60 cm x 40 cm set into an *opus caementicium* core. The width of the upper parts is between 105 cm and 110 cm for both towers. The construction method used for the upper parts was *opus caementicium* with an *opus mixtum* facing, similar to that of the two courtyard walls. The mortar used is light-coloured to yellowish and composed of a lime binder with crushed tiles and bricks and grains of shale (sn, 2010). The brick courses occur on top of every two horizontal courses in the rubblework architecture. Putlog holes are associated with the brick courses. In the eastern tower, the putlog holes were found on one level only. In the western tower, they are observed on three different levels with a vertical spacing of 90–95 cm. A similar cantilever scaffolding system like that of the courtyard walls was used.

The paved square is composed of square granite blocks with an average size of 88–90 cm. A row of smaller, rectangular granite ashlars defines the edge of the square facing the town. Their size ranges from 45 cm by 63 cm to 55 cm by 120 cm (Figure 4.31). The thickness of the blocks varies from 26 cm to 35 cm, with an average thickness of 33 cm. To pave the entire 509 m^2, a total of 540 blocks are needed. With a mass density for granite of 2640 kg/m^3 (Hunt et al., 1995), the average weight of the blocks is 693 kg. A similar paving technique with large rectangular to square granite blocks was used in *Emerita Augusta* in the colonial forum (Nogales Basarrate, 2008). On several blocks, shallow, elongated holes (6–10 cm) can be interpreted as crowbar holes to lever blocks in place. Some deeper square homes (10 cm) were probably intended to hold vertical dowels for upstanding structures, perhaps related to a canvas roofing (Figure 4.28).

Figure 4.31 Overview of the eastern half of the paved square. The square granite paving blocks measure 88–90 cm (scale: 1 m). Photos by J. Carvalho.

The perimeter wall of the square on the eastern edge measures 47 cm in width and was made up exclusively of irregular granite stones in *opus incertum*. The size of the stones varies between 20 cm and 30 cm. The use of earth as bonding material imposes the idea that the wall did not serve any structural purpose, but merely separated the monumental square from the neighbouring *macellum.* The connection with the town wall is reinforced with ashlar blocks measuring 120 cm (L) x 50 cm (W) x 43 cm (H). In addition, the threshold of the doorway to the *macellum* and the doorposts are also made of granite ashlar blocks.

In comparison with the Flavian–Trajan phase, the later phases are characterised by a coarser building technique. Stonecutting is less careful, stones tend to be slightly larger and less care is given while laying the stones. There is also clear evidence of stone recuperation from earlier buildings (Figure 4.32). Even though granite remains the prime stone, the use of gravelstones and sandstone is more marked. The width of the walls remains roughly the same (45–52 cm). Walls are constructed with an *opus incertum* facing and the bonding material is earth. Like in the Flavian–Trajan phase, granite ashlars were used at wall corners and intersections, doorways, but also for the *taberna* thresholds (Figure 4.29). Walls are not preserved high enough for remains of a scaffolding system.

Figure 4.32 Late Roman wall of the South Gate complex characterised by a coarser construction technique and the reuse of granite ashlars from an earlier phase.

In total, 230 fragments or some 90 kg of ornamental stone come from the *porta sul* excavations. Hundred and twenty-four pieces or 53 % of the total volume originate from the boxes corresponding to the western tower. The remaining fragments were found in the area of the eastern tower and in the commercial areas between the square, the town wall and the towers. Finally, a column base with pedestal in white marble that is currently exposed in front of the western tower comes from the *porta sul* excavations, but its exact provenance is unknown (Figure 4.33).

Figure 4.33 Column and pedestal in white marble (scale: 50 cm).

Among the ornamental stones, two different types can be identified: (1) a white marble, sometimes with few grey veins; and (2) a pink limestone. With 65 % of the total volume, the white or white, veined marble forms the largest category. In addition, pink limestone (35 %) was also important for the embellishment of this monumental complex (Figure 4.34-A).

Typologically, most pieces are part of wall and floor revetment. Veneer panels occur more or less equally in white or white, veined marble and pink limestone, respectively 54 % and 46 % of the total volume, whereas five of the six mouldings are in white marble. The fragments of moulding were found in the area of the eastern tower (4 pieces) and in the area between the eastern tower and the eastern half of the square

(2 pieces). The fragments of pink limestone come almost exclusively (84 % of the total volume) from the interior of the western tower. One fragment of an inscription bearing the letter *O* was found in the eastern tower (Figure 4.34-B). Two small column bases were found in the eastern half of the paved square; one near the monument base and one halfway along the eastern edge of the square. Finally, a large fragment of a white marble veneer panel (40 cm x 20 cm x 5 cm) was reused for the construction of the eastern wall of the gateway.

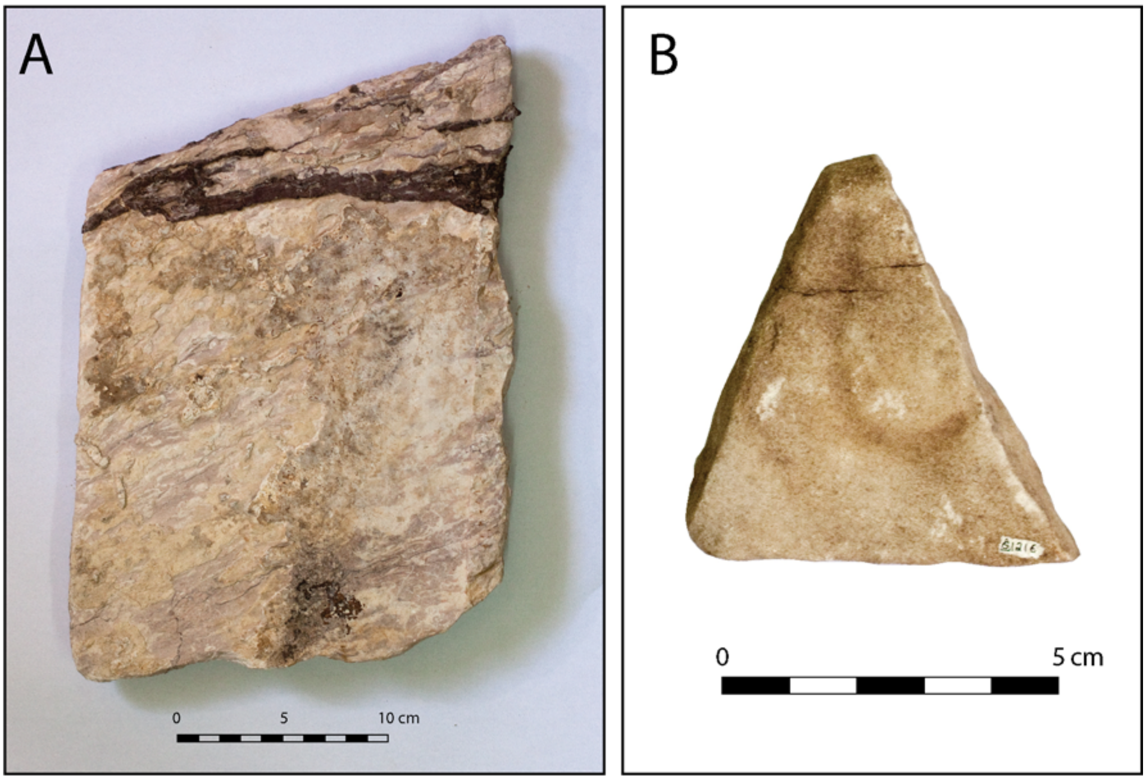

Figure 4.34 Ornamental stone from the *porta sul* area: (A) Fragment of a pink limestone veneer panel found inside the western tower; (B) Fragment of an inscription in white marble bearing the letter 'O', found in the eastern tower.

4.4 The residential area of *insula 38*

As virtually none of the remains are still exposed today, the information presented in this section derives from the available excavation reports and preliminary publications.

The results of the magnetometry survey of the remaining part of *insula 38* are mentioned only briefly. The main reason for this is the complex evolution of the occupation in the area. The excavations of *insula 38* have clearly illustrated that the layout of the original building was modified several times. Because geomagnetic survey has the effect of 'flattening' this complex evolution of successive building phases (Corsi et al., in press), a correct interpretation of the survey results for *insula 38* is extremely difficult and in some cases even impossible. A full discussion of the magnetometry results would therefore be simplistic in comparison with the complex history presented by the excavation data.
Chronological information is based on numismatic evidence and on studies of the fine-ware pottery. Preliminary chronological conclusions presented by S. Pereira (2009) were refined by recent studies of J.-C. Quaresma (2011) and V. Pereira (2006).

4.4.1 Occupation history

Insula 38 is located in the southeastern corner of the town (Figure 4.1 – n°4). The main structural feature of Roman date is without a doubt the town wall that forms the perimeter wall for most buildings in the area. In its initial design, the *insula* measured c. 65 m by 37 m (Corsi et al., in press; Johnson, 2010), but several secondary streets divided the area into smaller building units (Pereira, 2009). Throughout time, these secondary streets and the main street were gradually being incorporated into the housing structures that occupied the *insula* (Figure 4.35). A similar situation was encountered at various places in the town, for example, in the forum bathhouse.

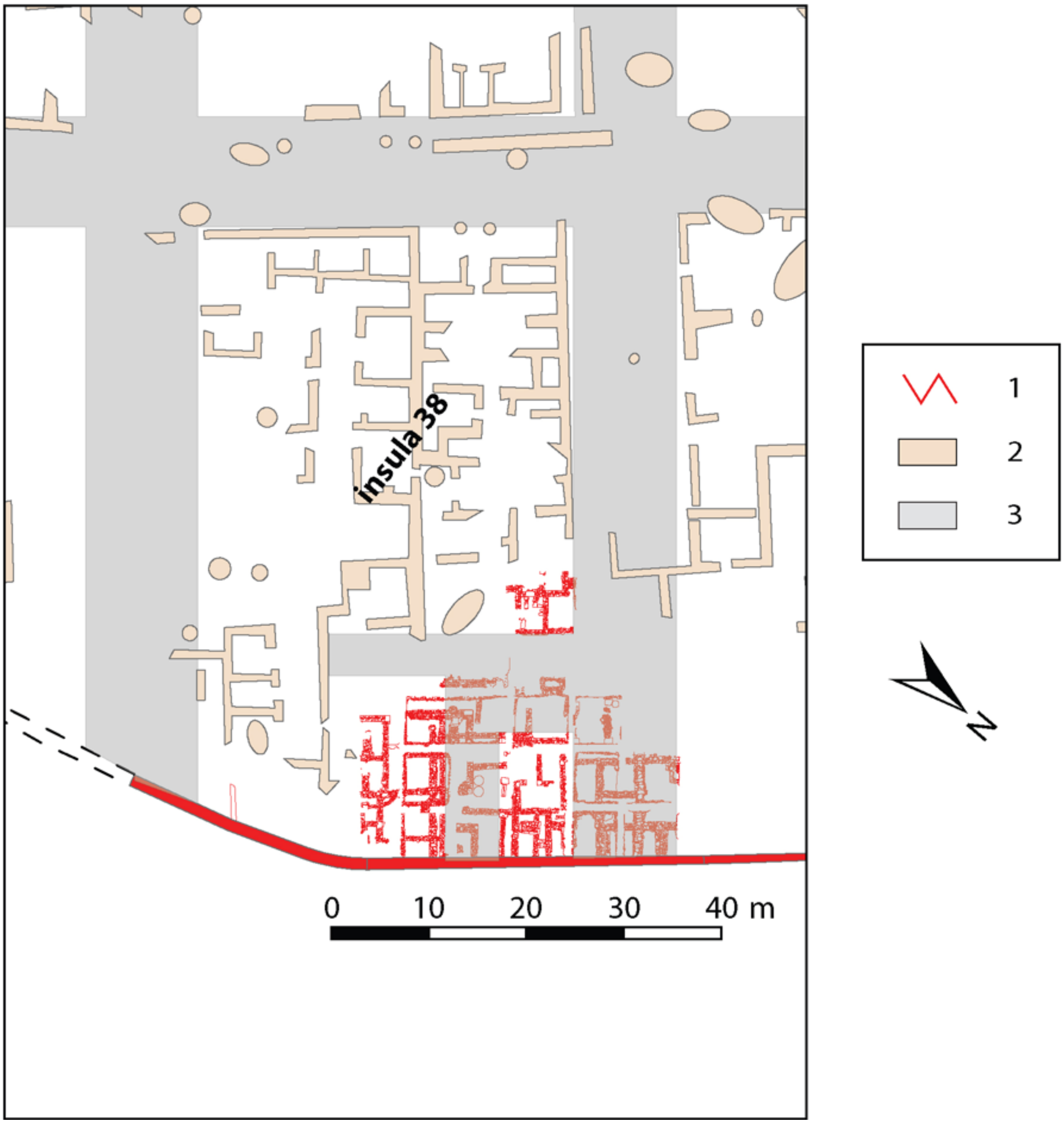

Figure 4.35 Plan of *insula 38* with the excavated structures (1), the interpretation of the geomagnetic results (2) and the Roman urban street network (3).

Excavations have illustrated that *insula 38* was occupied from the middle of the 1st century CE onwards, soon after the foundation of the town. The main features of this first phase are a large sewer connected to an outlet in the town. The magnetometry data has illustrated that the sewer was located underneath one of the main *decumani* of the town. No remains of street paving were detected. In addition to the *decumanus* and the sewer, one of the units of *insula 38* was excavated. The building, measuring roughly 7.5 by 13 m, was defined on one side by the town wall. The *decumanus* to the northwest and two secondary streets formed the other limits. The building was composed of four rectangular rooms organised along a central corridor that was entered from one of the secondary streets in the southeast through a grooved threshold for a detachable wooden shutter, similar to the ones found at the *porta sul*. This typical doorway points towards a commercial function for the building, probably with shops (Pereira, 2009). A possible entrance from the main *decumanus* to the northwest could not be verified due to a superimposed modern wall of the farmhouse. Southeast of the shop building, remains of a second building were detected. As only few remains of this second building have been preserved, it was not possible to define its function (Pereira, 2009). Between these two buildings, the ritual deposition with the Rhodian wine amphora and the two oil lamps described in one of the previous sections was found (Pereira, 2009).

Figure 4.36 Phase plan of the excavated remains of *insula 38* (Pereira, 2009). Phase 1 = middle 1st century CE; Phase 2, 3a and 3b = 1st–4th century CE; Phase 4a and 4b = 4th century CE, Phase 5 = modern.

Between the middle of the 1st century CE and the 4th century CE, the plan of the existing buildings was modified several times. As a result of these modifications, parts of the streets were incorporated into the new building and the streets were gradually reduced to alleys (Pereira, 2009).

In the 4th century CE, all existing buildings were demolished and a set of new building were erected on the site (Pereira, 2009). The northeastern end of the *decumanus* that defines the *insula* in the north was completely incorporated into one of the new buildings. Similarly the secondary street parallel to the *decumanus* became part of the same building. The presence of several fireplaces and kitchens points towards lower-class housing where several families lived together (Pereira, 2009).

A new building was also erected to the northwest, on the opposite side of the street. Even though most of the building is located outside the excavated area, a furnace or *praefurnium* for a hypocaust system indicates the presence of private baths and therefore of a rich *domus* (Pereira, 2009) (Figure 4.37).

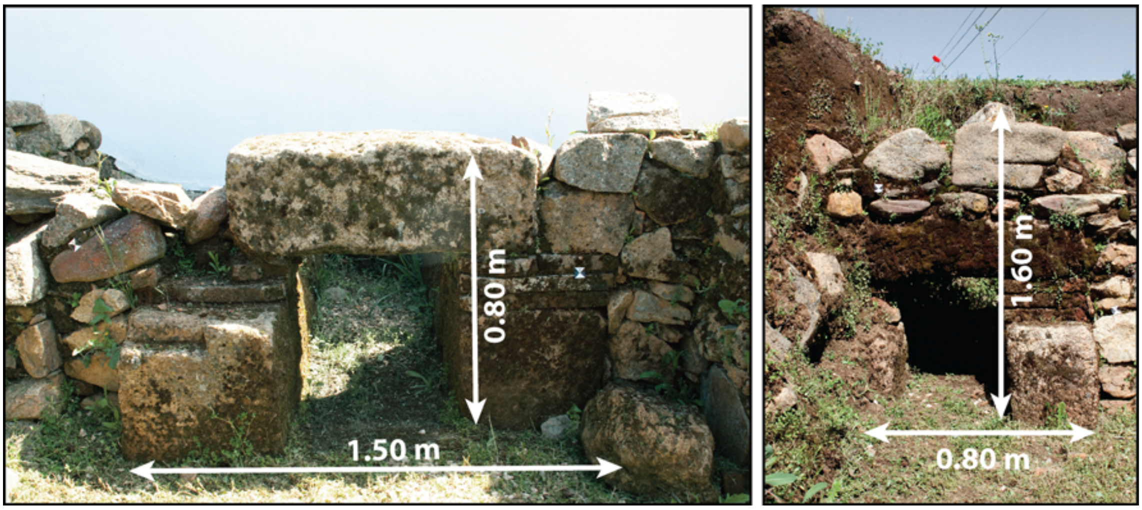

Figure 4.37 Underground conduits of a hypocaust system in *insula 38*.

Around the middle of the 5th century CE, a fire probably destroyed part of the building after which it was permanently abandoned (Pereira, 2009). A Visigoth and Moorish occupation, as suggested by S. Pereira (2009), has recently been disproven. Most ceramic material that S. Pereira places in the Visigoth and Moorish period can actually be dated to the 4th century CE or the first half of the 5th century CE (Quaresma, 2011). Numismatic evidence proves this chronology.

4.4.2 Construction technique and stone use

The 1st century CE buildings are characterised by walls that are generally between 45 cm and 49 cm wide. Walls are constructed in *opus incertum* and earth is used as bonding material. Granite and shale were the main stones (Pereira, 2009).

The houses that were constructed between the middle of the 3rd and the late 4th century CE are marked by a construction technique with many reused elements. The width of the walls is more varied and ranges from 52 cm to 64 cm. Walls are built in *opus incertum* and use earth as bonding material. In comparison with the structures from the earlier phases, the construction technique is coarser and less care is given while laying the stones. The building material includes foremost granite, shale and gravelstones. Brick is used in a few cases. Typical for the later structures is the use of granite ashlars to protect the rubblework architecture. Some of these ashlars are clearly reused (Pereira, 2009) (Figure 4.38).

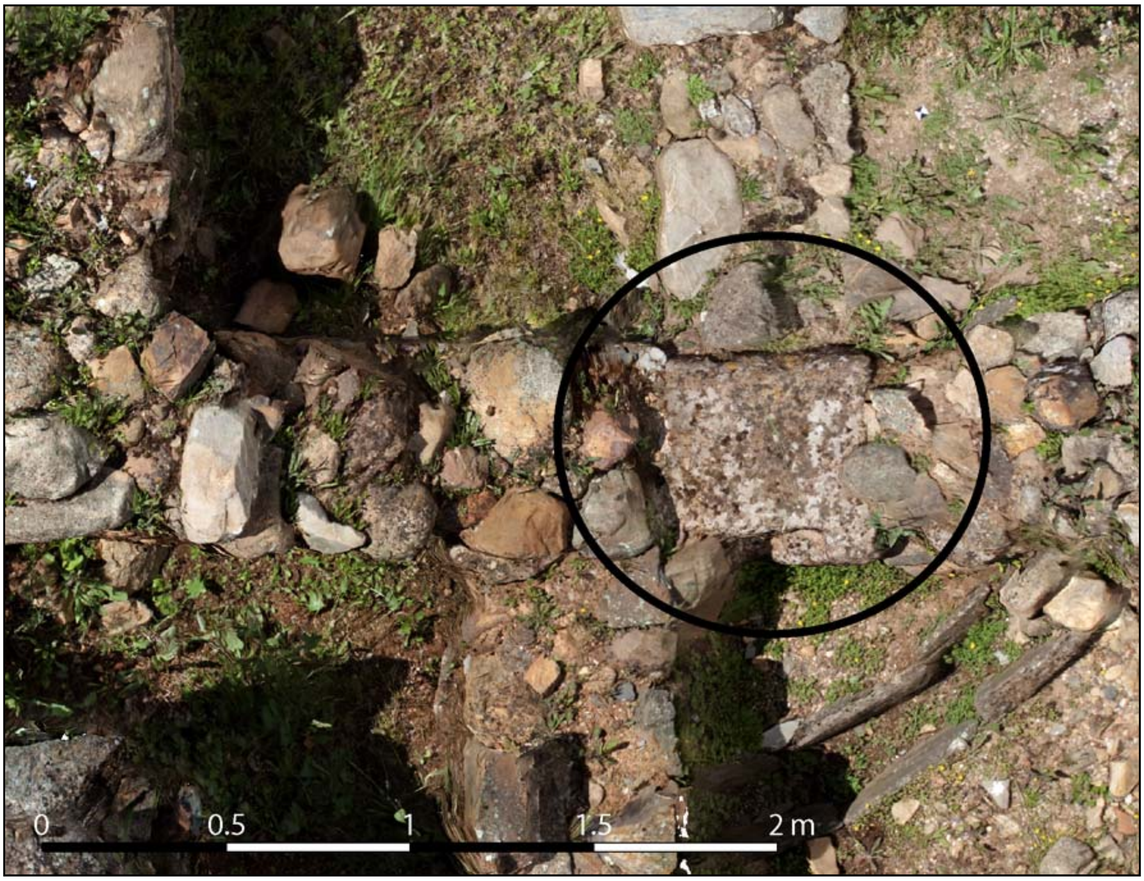

Figure 4.38 Reused granite ashlar for reinforcing wall intersections in *insula 38*.

For *insula 38*, only 147 fragments or some 18 kg of ornamental stone was recovered. Among the ornamental stones, three different types can be identified: (1) a pure white or white, veined marble; (2) a grey–white marble; and (3) a pink limestone. The latter two are only marginally represented, respectively 2 % and less than 1 % of the total volume. All objects are fragments of veneer panels.
Where stratigraphic information is available, the finds usually date to the second half of the 4th century CE or beginning of the 5th century CE, i.e. the last phase of the occupation. The predominance of material from the last occupation phase is not surprising considering that the reuse of these highly valued stones in a residential context was undoubtedly very large.
Most ornamental stone, about 38 % of the total volume, comes from the area of the presumed private baths. The remaining fragments are found essentially in the area of the building with the shops and the building that replaced the building with the shops.

4.5 The town wall

4.5.1 Trace of the urban enclosure

Approximately 135 m of the town enclosure has been excavated or is preserved aboveground. Parts of the town wall can be observed near the South Gate and along the eastern side of the town, where the wall was reused as the foundation for a terrace wall and for the façade of the 18th–19th century CE farm that now houses the on-site museum (Figure 4.39). The remaining trace was revealed through geophysical surveys (Corsi et al., in press; Johnson, 2010) and detailed topographic and geomorphological observations (Vermeulen et al., 2005). Overall, the urban area had a trapezoidal shape. The total length of the wall is estimated at some 1750 m, enclosing an area of 19.8 ha.

Figure 4.39 Town wall and part of its foundation reused as the foundation for the façade of the *Quinta do Deão* farmhouse.

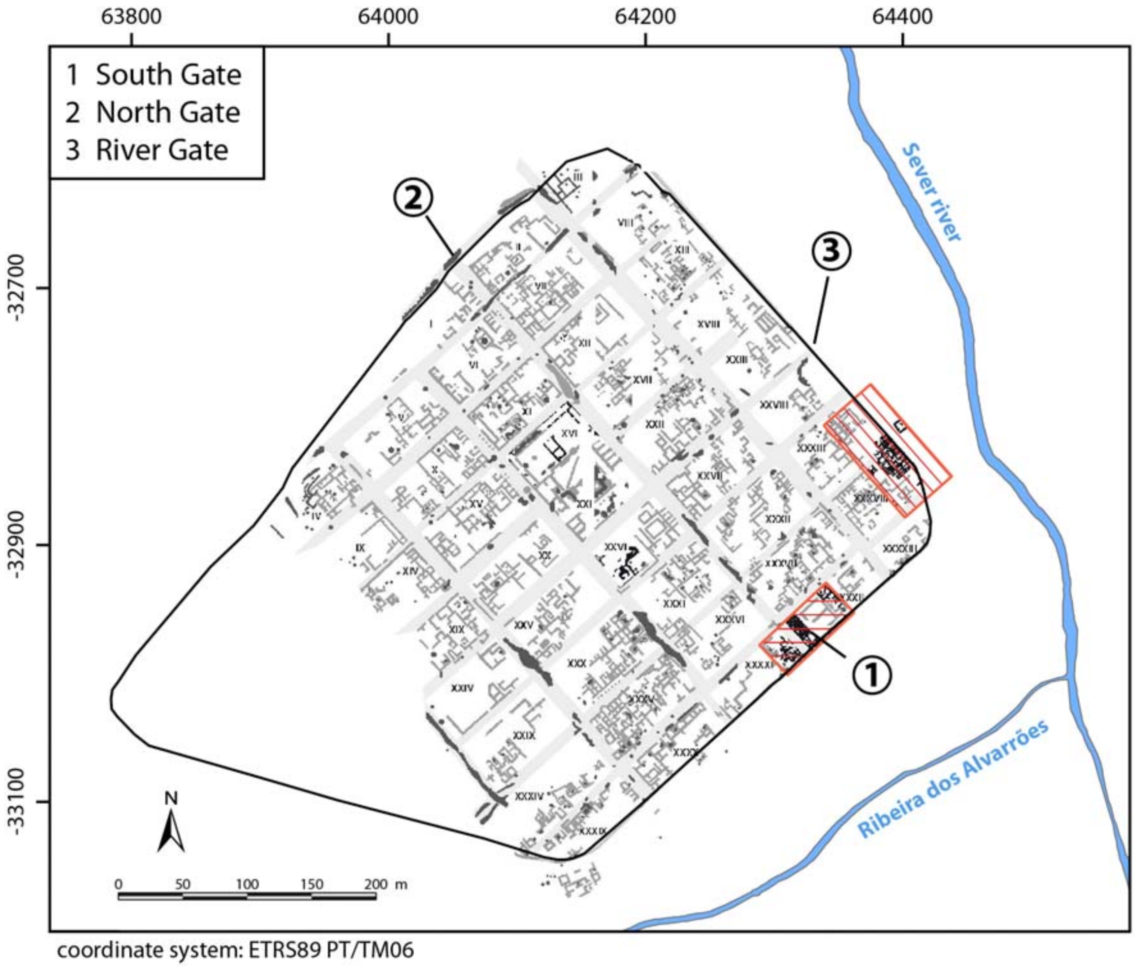

Figure 4.40 Plan of the urban area (full black line: observed town wall, dashed black line: hypothetical trace, red: excavated structures, grey: magnetometer interpretation). The locations of gates are indicated with numbers; the locations of excavated parts of the town wall are indicated in blue (a: *insula 38*, b: South Gate).

On the eastern side, the enclosure followed the course of the Sever River, while the northern and southern traces were defined by two narrow paleovalleys. The western trace remains uncertain as to whether the urban area incorporated the hilltop extension of the Malhadais Hill or not (Vermeulen et al., 2005). At least three gates must have been located along the circuit wall, at: the South Gate, the River Gate leading towards the Sever River, and the North Gate (Figure 4.40).

Excavations of *insula* 38 and of the suburban area between the town and the Sever River have shown that the enclosing wall was built early in the history of the town, around the middle of the 1st century CE, together with the construction of the residential areas of *insula* 38 (Pereira, 2009). Near the South Gate, there is evidence of rebuilding of parts of the town wall in the Flavian–Trajan period, related to the reorganisation and monumentalisation of the gate complex (see above) (Oliveira et al., 1999; Pereira, 2005). Chronological evidence for the remaining trace of the circuit wall is inexistent, but it is likely that the entire enclosure was built at the same time with some minor later modifications, for example near the South Gate.
Along the eastern side of the town, two openings in the exposed part of the wall served as outlets for the underground sewer system of the town (Figure 4.41-A). Just outside the town, a large V-shaped ditch running more or less parallel to the town wall, collected the waste water and served as the main drainage channel for the town (Figure 4.41-B). The ditch has a width between 70 cm and 140 cm. The average depth is 130 cm; at some places, however, the depth was limited to only 60 cm (Pereira, 2009). A perpendicular drain for discharge towards the Sever River was also identified. Preliminary studies of the material found in the extramural drain showed that the channel was dug around the middle of the 1st century CE and stayed in use at least until the end of the 4th century CE. At the end of the 4th century CE or in the beginning of the 5th century CE, maintenance stopped and the ditch lost its function, perhaps as a result of the disintegration of the town's central administration. Gradually, large soil accumulations filled in the ditch (Barata and Mantas, 2003).

Figure 4.41 (A) Sewer opening in the town wall in the area of *insula 38* (scale: 50 cm); (B) V-shaped ditch serving as the main drainage channel for the town. Photo-A by J. Carvalho, photo-B by S. Deprez.

During the excavations of *insula 38*, underneath the present archaeological museum, a ritual deposition in a small pit defined by four shale slabs was found. The deposition consisted of a perfectly preserved Rhodian or Rhodian-type amphora (Peacock 9: 1st century BCE – early of the 2nd century CE) flanked near the mouth by two oil lamps. The two volute lamps depict the goddess Victory wearing a crown. On one lamp, the goddess holds a palm branch. Both lamps are dated around the middle of the 1st century CE. The location of the deposition at c. 50 cm from the town wall and underneath a secondary street of *insula 38* suggests a foundation offer for the construction of the town's enclosure and the definition of the town boundary (Oliveira et al., 2001; Pereira, 2009).

4.5.2 Construction technique and stone use

The average width of the excavated parts of the town wall is 1.2–1.3 m near the *Quinta do Deão* and around 1.8 m near the South Gate. On either side of the South Gate, the segments of the wall are slightly widened (to 2.1 m) to support the two circular towers. Judging from the nature of the wall, especially its reduced width, it is clear that it did not have a defensive role, but that it essentially served a symbolic purpose to express the status and wealth of the town and to indicate the boundary between the urban and suburban area.

Near *insula 38,* the wall stands to a height of 1.65 m above foundations. Near the South Gate, the wall is preserved to a maximum height of 2.4 m above the modern surface (Figure 4.42). Compared with the level of the threshold of the nearby gate entrance, the total preserved height is calculated as 3.25 m. Based on the presumed heights of the towers and the arched entrance (see above), a height between 5 m and 6 m for the town wall can be proposed.

The parts of the town wall that are best preserved show a maximum of four horizontal courses with a vertical spacing between 38 cm and 54 cm (Figure 4.42). The courses are determined by larger stones at the bottom and smaller elongated stones at the top to obtain a more or less levelled surface. In comparison with other buildings in the town, the courses in the town wall are more pronounced, indicating the great care given while selecting and laying the stones. Putlog holes for scaffolding are detected on two levels (Figure 4.42). The lowest series occurs c. 90 cm higher than the gate threshold of the South Gate, indicating that this was the first scaffolding level. The vertical spacing between the first and second level of putlog holes is again 90 cm. Putlog holes are placed on top of every two courses. Horizontal spacing between the holes is inconsistent and varies between 2.4 m and 3.9 m for the observed putlog holes. As the putlog holes extend through the entire width of the walls, it is clear that a cantilever scaffolding system with transverse putlogs supporting a scaffold on both sides of the wall was used (Adam, 2005).

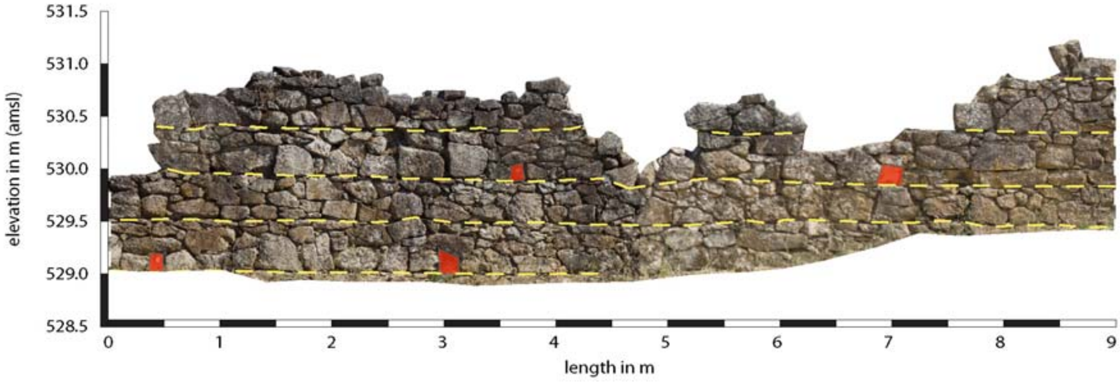

Figure 4.42 Orthorectified image of the northern face of part of the town wall near the South Gate. Courses are indicated by a yellow dashed line; putlog holes for scaffolding are indicated in red.

The exposed parts of the town wall consist of well-dressed, irregular facing stones (*opus incertum*) set into a mortared core of unworked stones (*opus caementicium*). Apart from a few quartzite gravelstones, granite is used almost exclusively for the facing. Shale slabs are sometimes applied for creating level surfaces. The blocks are generally between 25 cm and 35 cm across. Some larger ones can attain up to 60 cm. Granite ashlars of 56 cm by 120 cm by 50 cm were used at the intersection of the town wall with the buildings along the paved square of the *porta sul*.

In *insula 38*, where foundation levels have been reached, the town wall was erected on top of a trench-built foundation dug directly into the shale bedrock. The width of the foundations is about 15–20 cm wider than the upper wall structures. The foundations were made of *opus caementicium* with gravelstones and few granite blocks. The stones are 20 cm across on average (Figure 4.39).

4.6 The eastern suburban area

Archaeological research in the area between the town wall and the Sever River revealed traces of suburban activity and occupation (Figure 4.1 – n°5). Besides a large excavation of c. 1700 m^2 underneath the museum parking (Pereira, 2009), two artefact surveys (2010 and 2011) (Mlekuz and Taelman, in press) and a magnetic survey (2010)

(Eastern atlas, 2010) were organised in the agricultural field next to the river. Finally, a series of geomorphological core drillings was carried out in 2011 to assess to near-surface geology and the stratigraphic built-up of the area (De Dapper, 2011).

4.6.1 Occupation history and organisation

The local geology of the area consists of shale bedrock forming a kind of platform underlying the valley bottom of the Sever River. A shallow layer of maximum 30 cm of fluvial sediments, deposited by the river after periods of heavy rainfall, covers the bedrock. Providing that necessary measures were taken against occasional inundations, the area was perfectly suited for occupation (De Dapper, 2011).

In addition to the drainage ditch discussed above (Figure 4.41), several buildings were erected between the town wall and the Sever River, some of which were partly uncovered during the excavations of the museum parking (Barata and Mantas, 2003; Pereira, 2009); most were, however, revealed by the geomagnetic survey. An 8 m to 9 m wide extramural road, the continuation of the *decumanus maximus*, was detected leaving the town towards the river. On either side of the road, a large building complex was located. In addition, a smaller construction was detected in the southernmost corner of the surveyed field (Eastern atlas, 2010) (Figure 4.43). The material recovered during the artefact surveys consists essentially of ceramic building material, artefacts related to industrial/economic activities (*amphorae*, *dolia*, metal slag and loom weights) and some material from domestic contexts (tableware and glass). The chronology of the material ranges broadly from the 1st century CE to the 4th century CE. The low quantity of material, especially roof tiles, in the central part of the field suggests possible open areas (Mlekuz and Taelman, in press).

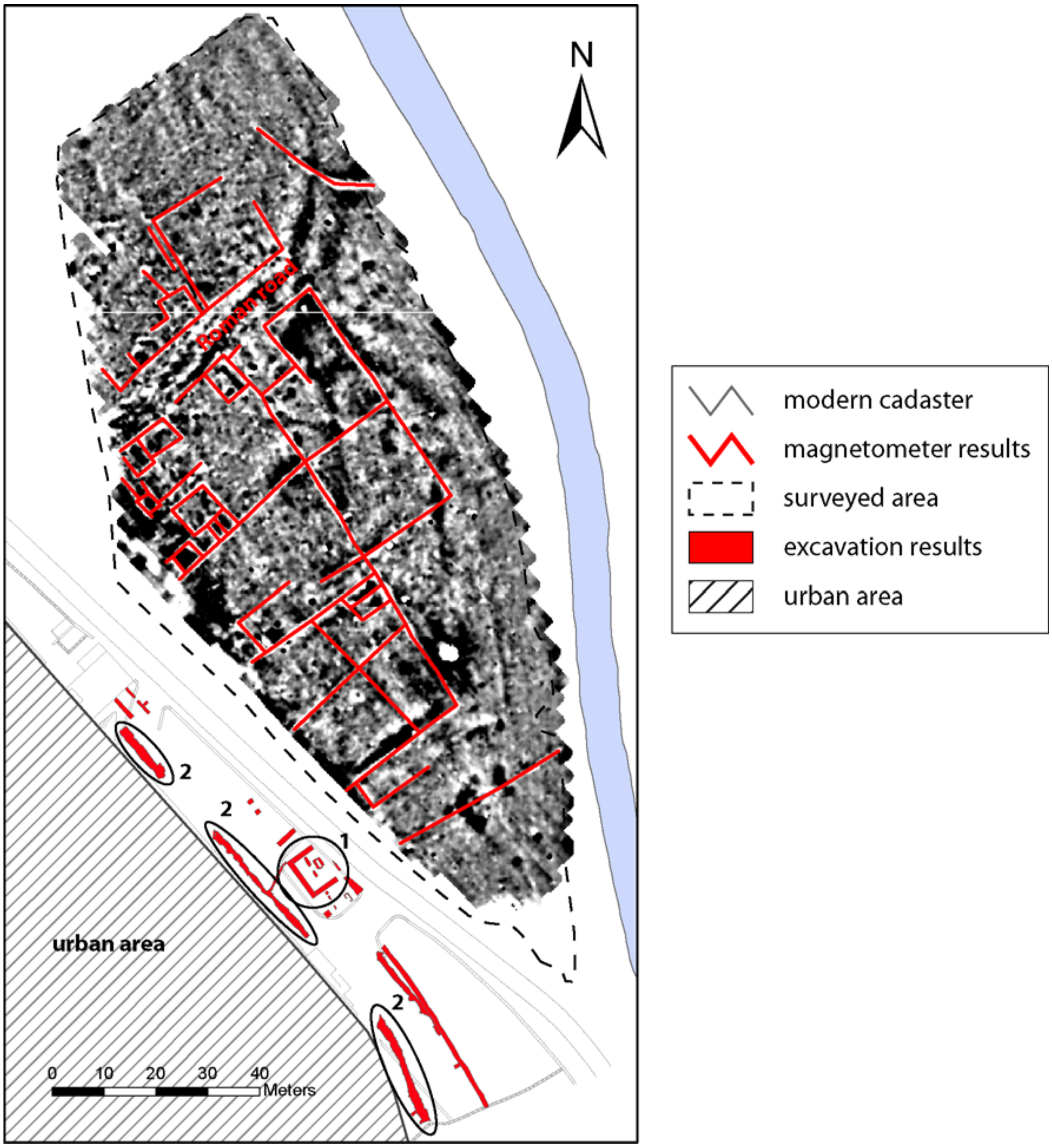

Figure 4.43 Plan of the results of the excavations and the geophysical survey in the suburban area between the town and the Sever River: (1) mausoleum, (2) drainage ditch.

In the Flavian–Trajan period, some of the early buildings appear to have been abandoned and the area was partly transformed into one of the town's necropolis (Pereira, 2009). Noteworthy are the remains of an imposing mausoleum (8.5 m by 8 m) constructed in *opus quadratum* (Figure 4.44). The initial interpretation as a *castellum aqua* or water distribution centre can be discarded because of the absence of any hydraulic mortar in the construction. Judging from the plan and dimensions, the monument was likely to be an altar mausoleum. A granite cornice and column shaft found nearby indicates the nature of the architectural decoration of the monument

(Pereira, 2009). A *pulvinus* of unknown archaeological provenance that is now displayed in the *Ammaia* archaeological museum might have been part of the top decoration of the burial monument (see Chapter 5 and Figure 5.13). Similar monuments have been found in *Emerita Augusta* and near the *Quinta da Fórnea* in Belmonte, about 100 km north of *Ammaia* (Carvalho dos Santos and Carvalho, 2008). This type of funerary monuments with this particular decoration was developed on the Italic Peninsula around the end of the 2nd century BCE and was introduced in *Lusitania* in the Julio–Claudian period by Roman colonists (Beltrán Fortes, 2004; Carvalho dos Santos and Carvalho, 2008; Gros, 2001). As these typically Roman funerary monuments required substantial investment to erect, especially the large examples such as the one in *Ammaia*, they clearly indicate a wish of local elite families to portray themselves as proper Romans in order to promote their social status.

Besides the necropole, there are also indications of a possible workshop towards the southern end of the studied suburban area. A large amount of bronze dump material and moulds for ceramic production, together with material dated to the 2nd and 3rd century CE (Pereira, 2009), was probably refuse from a nearby workshop, perhaps the structures detected by the geomagnetic survey in the extramural fields to south of the town.

At the latest in the 8th–9th century CE, the Roman buildings were demolished and the main drain channel was filled. A 5–6 m wide road, partly covering the large sewer, was constructed parallel to the Roman town wall (Pereira, 2009). The road was essentially composed of a mixture of earth, small stones (granite, river pebbles, quartz, quartzite, shale) and ceramic building material. In some areas, the road paving consisted of levelled shale bedrock (Pereira, 2009). The road probably served to connect Marvão and Portagem with Porto da Espada after the abandonment of the town (Oliveira et al., 2002).

Finally, in the 18th century CE, the Medieval road was moved to the location of the current *Estrada da Calçadinha* and the area was transformed into agriculture terrain associated with the *Quinta do Deão* farmhouse (Pereira, 2009).

4.6.2 Construction technique and stone use

This section focuses on the altar mausoleum. Information for the other Roman structures is derived from the available excavation reports and is discussed only briefly. Finally, some general hypotheses are advanced about the nature of the subsurface structures detected in the geomagnetic survey.

The mausoleum monument is constructed in *opus quadratum* with well-cut and smoothed granite ashlars. In general, the carving quality of the blocks is high and horizontal and vertical joints between blocks fit well. No mortar is used. Blocks are laid with headers exposed. Presently, three rows of blocks of the western wall, two rows of blocks of the northern wall and one row of blocks of the southern wall are preserved (Figure 4.44-A). The eastern wall of the structure was destroyed during the construction of the *Estrada da Calçadinha*. Dimensions of the ashlars are relatively consistent with an average width between between 59 cm and 63 cm. Some smaller blocks are used to fill gaps at the end of walls. The length of the ashlars is 95 cm for the lower two rows and 90 cm for the upper row. The height differs between 33 cm for the lowest course (i.e. the foundations), 45 cm for the middle course and 47 cm for the upper preserved course. The approximate average weight of the blocks is between 488 kg and 711 kg (calculated using an average mass density for granite of 2640 kg/m^3 (Hunt et al., 1995)). As for foundation type, the mausoleum was constructed in a different manner than the intramural buildings. Whereas foundations were generally trench-built, the mausoleum walls were constructed on top of a free-standing foundation deposited in U-shaped trenches dug directly into the shale bedrock. The foundation used the same types of ashlars as the upper structure of the monument, but blocks were slightly longer (Figure 4.44-B). The width of the foundation trench goes from 130 cm at the top to about 170 cm at the bottom. The depth varies between 52 cm and 146 cm, depending on the terrain topography (Pereira, 2009). This different construction method for the foundation is without a doubt related to the fact that foundations were built directly into the bedrock and because of the *opus quadratum* building method.

Figure 4.44 (A) Well-cut and smoothed granite ashlars used for the construction of the mausoleum (scale: 50 cm); (B) Free-standing foundation build into a U-shaped trench dug into the shale bedrock.

The remaining Roman structures are built in *opus incertum* with an *opus caementicium* core, similar to the buildings inside the perimeter of the town. Stone types used were primarily granite, rounded to subrounded gravelstones and some shale. The width of the walls varies between 46–52 cm and 60–62 cm; one wall is slightly wider (74 cm). For the buildings detected in the geophysical results, no direct information is available concerning their construction technique and stone types used. However, the presence of several granite stones in the surveyed field shows that granite was certainly used. Given the shallow depth of the bedrock, foundations must have been dug directly into the bedrock, in a similar method as that for the mausoleum.

Only few fragments of ornamental stone were recovered during the excavations of the parking area: 79 fragments (c. 4–5 % of the total) or some 10 kg (less than 1 % of the total). All fragments are pure white marble or white marble with few coloured streaks. Fragments are generally very small and probably represent parts of veneer panels.

Almost all marble was found either in the area of the mausoleum or in the infill of the waste ditch, respectively 32 % and 65 % of the total volume.

The presence of ornamental stone in the mausoleum area suggests that the funerary monument might have been decorated with white marble veneer. Later stripping of the monument undoubtedly involved the removal of substantial quantities of marble. This is confirmed by the fragmentary state and small size of the preserved fragments.

The marble found in the infill of the waste ditch is probably debris from the intramural areas of the town or from the funerary monument.

Chapter 5
The *Ammaia* lapidary collection

The *Ammaia* lapidary collection consists of worked granite and marble objects. Many of which were reused during the construction of the 18th–19th century CE *Quinta do Deão* farmhouse that now houses the site archaeological museum. In addition to building blocks of various sizes, a large amount of column elements, millstones, epigraphic monuments, one piece of statuary and various architectonical elements have been found on the site.

5.1 Building stones

Most objects in the *Ammaia* lapidary collection are building stones (49 items). Their dimensions range from 60 cm by 42 cm by 20 cm for the smallest blocks to 128 cm by 66 cm by 51 cm for the largest ones. Using an average mass density for granite of 2640 kg/m^3 (Hunt et al., 1995), the average weight of the blocks is calculated as 354 kg, with a minimum and maximum weight of 133 kg and 1137 kg respectively. Ten blocks have a rusticated front face (Figure 5.1). Crowbar holes and a various types of sockets for sealing clamps and vertical dowels can be seen on some blocks.

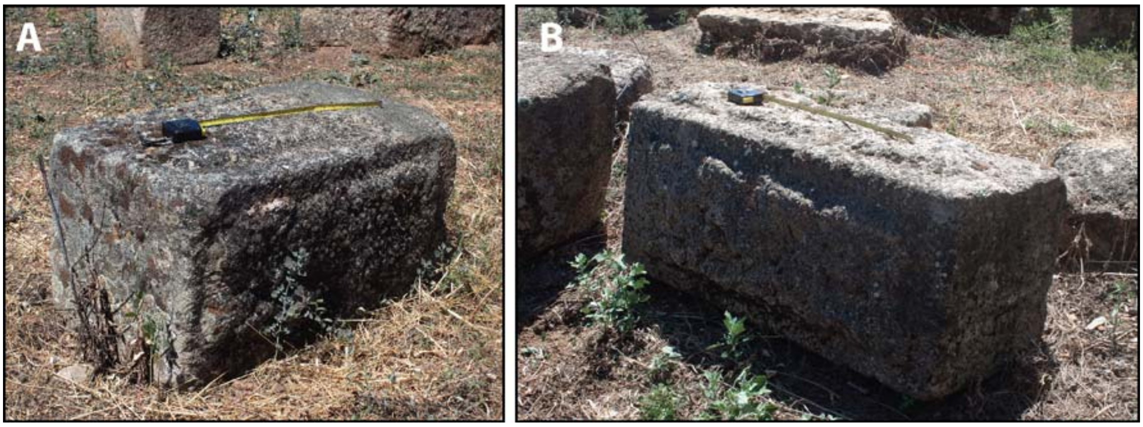

Figure 5.1 Ashlars with rusticated front face: (A) Lap_164 (scale 50 cm); (B) Lap_159 (scale: 50 cm).

Sixteen square granite blocks with average dimensions of 88 cm and a thickness of 33 cm are pavement blocks from the *porta sul* square. Like on some blocks of the preserved eastern half of the square, small and elongated crowbar holes can be discerned. One block, measuring 62 cm by 53 cm by 30 cm, belongs to the row of blocks defining the square along the northwestern side.

Finally, two granite blocks are part of a threshold. One item (lap_102) is a typical threshold for shops or *tabernae* with a central groove for placing a detachable wooden shutter (Adam, 2005). The dimensions of the block are 120 cm, 36 m and 23 cm (Figure 5.2-A). Similar thresholds have been found along the western half of the square of the *porta sul* and in *insula 38*. The second block (lap_144) is part of a gate threshold and displays a well-developed cart rut resulting from the wearing by heavily loaded carts. The dimensions of the block are 89 cm, 34 cm and 23 cm (Figure 5.2-B).

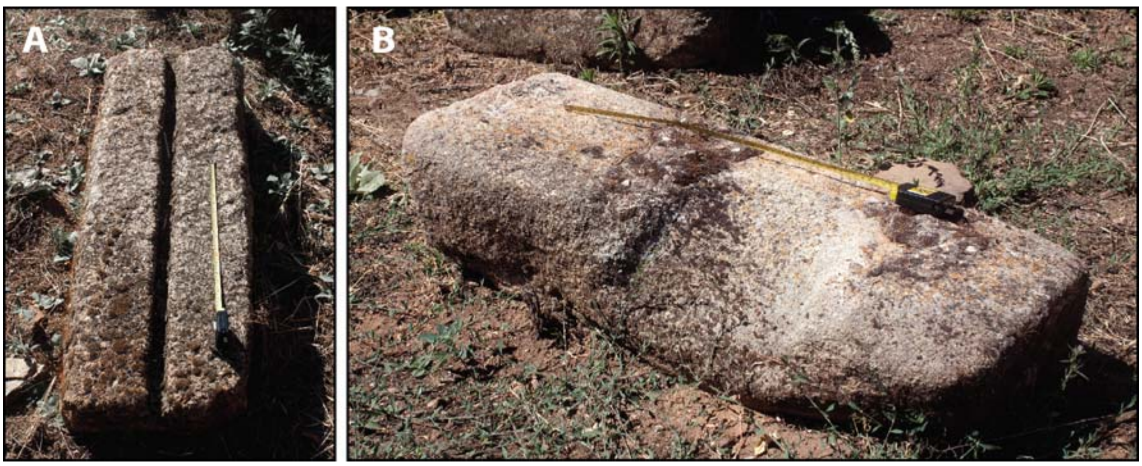

Figure 5.2 (A) Grooved threshold for holding a wooden shutter (lap_102) (scale 50 cm); (B) Gate treshold with worn-out cart rut (lap_144) (scale: 50 cm).

5.2 Columns

Many column elements such as capitals, bases, shaft elements and column pedestals have been found at *Ammaia* so far. Most elements are in granite, with only a few in white or white, veined marble

The main characteristic of the columnar architecture is its plain and sober execution. Capitals and bases consist only of the essential components. Ornamental elements like astragals, refined volutes, and egg and dart motives are never worked out. Similarly, column shafts are not fluted. This is related to the working properties of the raw material (granite) from which most columns were carved. Although granite presents excellent structural properties and is extremely suitable for use as building stone, the material does not allow easy carving. As a result, simpler forms of the decoration were used and the decorative elements were executed only roughly.

5.2.1 Capitals

The capitals from *Ammaia* belong to either the Tuscan order or the plain Ionic order with Tuscan influence (Fernandes, 2001). The main characteristic of both types is the plain and sober execution, making it sometimes hard to distinguish between capitals and bases (Fernandes, 2001). Typically, the capitals are made up of only the basic elements, being the *abacus*, the *echinus*, the neck and the start of the column shaft. For the plain Ionic capitals with Tuscan influence, the *echinus* is decorated with two lateral *pulvini* (Fernandes, 2008) (Figure 5.3). Elements like astragals, refined volutes, and egg and dart motives are never worked. The plain Ionic capitals with Tuscan influence can be considered a more elaborated type of the regular Tuscan capital (Fernandes, 2008). No proper Ionic, Corinthian or Composite capitals have been found in *Ammaia* so far.

Thirty capitals have been discovered so far. Most have already been studied in detail by L. Fernandes (2001; 1997). This study not only includes the capitals found on the site, but also some spoliated examples from nearby houses and villages. Apart from the capitals studied by Fernandes, one recently discovered capital is included in this overview.

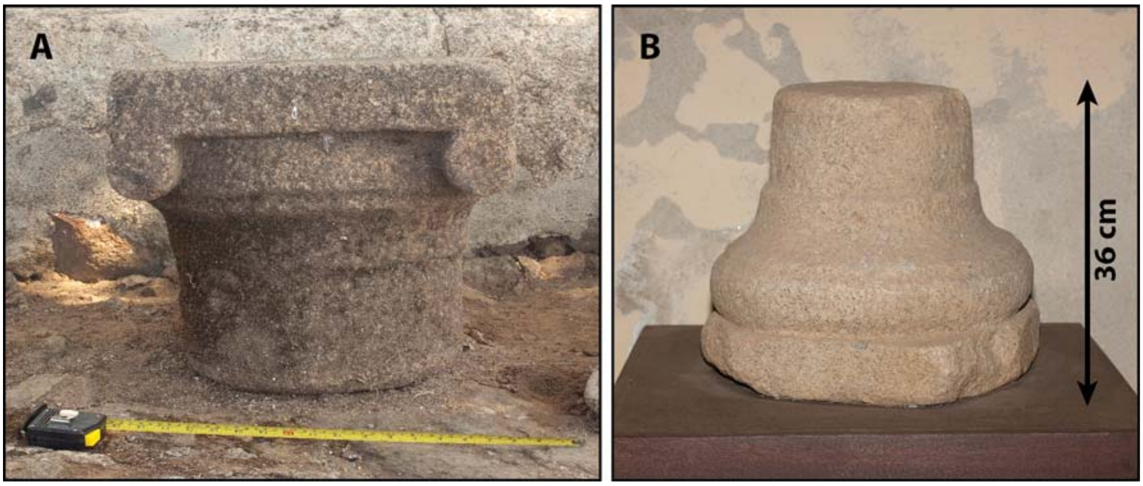

Figure 5.3 (A) Plain ionic capital with Tuscan influence of type 1 (lap_041); (B) Tuscan capital of type 2 (fer_007).

A typology is proposed based on order, constituting elements, shaft diameter and dimensions of the individual elements. Small differences in dimensions were considered with care as these often result from the stonecutting. Certain types of stone (e.g. fine-grained marble) allow a finer carving and a higher degree of precision and consistency (Wilson Jones, 2009). Moreover, metrical correctness was not a primary concern for Roman architects and builders, as long as columns of the same colonnade appeared identical. Small differences in dimensions of the capitals often result from correcting small errors in the height of the shafts. For example, in many buildings, the *abaci* of the columns have slightly varying heights in order to compensate for small differences in the lengths of the shafts (Wilson Jones, 2009).

Typical for the Tuscan capitals from *Ammaia* is the gradual transition from *abacus* to *echinus*. The diagonal of the *abacus* and the diameter of the *echinus* have similar dimensions (Fernandes, 2001). Except for the height of the neck that varies between 8 cm and 25 cm, the height of the other components is similar for most capitals. Based on the dimensions and proportions of the constituting elements, four types of Tuscan capitals can be distinguished (Table 5.1). One capital (fer_011) could not be assigned to any of these types because of its bad state of conservation.

Type 1 includes six capitals and is characterised by the absence of a listel or moulding to mark the transition between the different components (Fernandes, 2001). On the basis of column diameter and dimensions of the individual components, type 1 is subdivided into subcategories, perhaps representing designs for different colonnades or buildings. With a shaft diameter of 29 cm, capital fer_004 certainly belongs to a different subcategory than fer_005 and fer_006 that have a diameter of 43 cm and 41 cm. The other three capitals have a diameter between 35 cm and 39 cm, but the short neck separates fer_002 from fer_001 and fer_003 that further present similar dimensions.

The three capitals of **type 2** differ from type 1 by the presence of a simple lintel between the *echinus* and the neck. Within type 2, a distinction can be made between capitals with a sharp curve between the *echinus* and the neck (fer_007), and capitals with a more gradual curve (fer_008 and fer_009) (Fernandes, 2001). The latter two have similar dimensions, suggesting that they originally belonged to the same colonnade.

Type 3 is represented by only one capital (fer_010). This type is more elaborated and has simple mouldings and grooves to mark the transition between the different elements. The *echinus* is slightly *torus*-shaped (Fernandes, 2001).

Type 4 is similar to type 2 (fer_012 and fer_013), but the constituting elements of the capital are separated by a small *torus* instead of a listel. Moreover, the *echinus* is *torus*-shaped and separated from the neck by a small convex moulding (Fernandes, 2001). Except for the height of the shaft, the dimensions of the individual elements of the two type 4–capitals are very similar, suggesting that they were designed for the same colonnade.

Table 5.1. Dimensions (in cm) and types of the Tuscan capitals from Roman *Ammaia*.

ID	Order	Height	Diameter	*Abacus*	*Echinus*-Neck-Shaft	Type
fer_001	Tuscan	52	35	52x52x9	8-11-24	T.1
fer_002	Tuscan	33	39	?x?x?	10-5-17	T.1
fer_003	Tuscan	?	36?	?x?x10	10-12-?	T.1
fer_004	Tuscan	36	?	39x39x6	8-8-14	T.1
fer_005	Tuscan	36	28	39x39x6?	8-0-14	T.1
fer_006	Tuscan	30	41	50x46x?	8?-7-10	T.1

ID	Order	Height	Diameter	*Abacus*	*Echinus*-Neck-Shaft	Type
fer_007	Tuscan	36	21	41x41x8	6-9 -13	T.2
fer_008	Tuscan	31	21	35x35x7	7-7-10	T.2
fer_009	Tuscan	30	22	37x37x7	7-7-9	T.2
fer_010	Tuscan	40	29	45x45x8	8-15-9	T.3
fer_011	Tuscan	43	22	?x?x7?	?-?-22	T.?
fer_012	Tuscan	49	49	60x60x12	10-13-14	T.4
fer_013	Tuscan	40	49	58x58x11	10-11-8	T.4

Within the group of the plain Ionic capitals with Tuscan influence, four types can be distinguished (Table 5.2).

Type 1 is characterised by a well-defined *abacus*, *echinus*, neck and start of the shaft. The transition between the *abacus* and *echinus* is marked by a small groove, the transition between *echinus* and neck is formed by a moulding. Where the neck goes over into the shaft, a small kink can be observed. The *echinus* is *torus*-shaped or has the shape of a quarter circle. The neck starts with a smooth curve and is almost vertical (Fernandes, 2001). One capital with a short shaft that Fernandes (2001) defines as a subtype is part of this group as well. Two capitals with a slightly larger neck (12 cm and 14 cm, respectively for fer_014 and fer_021) probably belong to a different colonnade than the type 1 capitals with neck between 7 cm and 10 cm.

Three capitals make up **type 2** (fer_024, fer_025 and fer_026). The main difference with type 1 is the small diameter of the shaft compared with the diagonal of the *abacus*. Type 2 is further characterised by a pronounced separation between the *abacus* and *echinus* on the one hand and the neck and shaft on the other hand. The neck starts with a sharp curve after which it continues virtually straight (Fernandes, 2001).

Type 3 is made up of one capital (fer_027) that is similar to type 1, except that the height of the *echinus* exceeds the diameter of the *pulvini*.

The remaining two capitals (fer_028 and fer_029) are **type 4**. These capitals lack a neck and the *echinus* continues straight into the shaft.

Table 5.2 Dimensions (in cm) and types of the plain Ionic capitals with Tuscan influence from Roman *Ammaia*.

ID	Order	Height	Diameter	*Abacus*	*Echinus*-Neck-Shaft	Type
fer_014	plain Ionic	39	32	50x50x8	7-12-12	I.1
fer_015	plain Ionic	38	25	41x?x7	6-8-13	I.1
fer_016	plain Ionic	38	37	52x52x8	8-8-14	I.1
fer_017	plain Ionic	50	34	45x45x8	7-10-25	I.1
fer_018	plain Ionic	36	28	44x44x8	8-10-10	I.1
fer_019	plain Ionic	37	28	45x45x9	8-9-11	I.1
fer_020	plain Ionic	37	35	55x53x8	8-10-11	I.1
fer_021	plain Ionic	46	37	?x?x8	10-14-14	I.1
fer_022	plain Ionic	41	38	50x?x8	8-8-17	I.1
fer_023	plain Ionic	31	32	?x?x11	9-7-4	I.1
fer_024	plain Ionic	32	24	40x40x8	8-8-8	I.2
fer_025	plain Ionic	30	?	42x?x7	7-6-?	I.2
fer_026	plain Ionic	40	?	?x?x9	7-5-19	I.2
fer_027	plain Ionic	27	40	50x44x8	10-?-?	I.3
fer_028	plain Ionic	28	25	35x?x9	6-6-7	I.4
fer_029	plain Ionic	43	32	?x?x8	8-10-17	I.4
lap_041	plain Ionic	39	36?	45x45x8	10-7-14	I.1

Based on the diameter of the start of the shaft and using the ratios for the Tuscan order mentioned by Vitruvius (*De Architectura IV, 7, 2–3*), the original height of the columns (including base and capital) was estimated (Table 5.3). No distinction was made between the Tuscan and plain Ionic capitals with Tuscan influence, as the latter can be considered a more elaborated type of the former. Vitruvius states that the top diameter of a Tuscan column equals 3/4 of the bottom diameter and that the bottom diameter of the shaft equals 1/7 of the height of the total column. Regardless of the difficulties involved in using Vitruvius as source (cf. Wilson Jones, 2009) and the variations that undoubtedly existed to these ratios, these height reconstructions allows for a good indication of the columnar architecture in *Ammaia*.

The average height of the columns would have been 302 cm, with a minimum of 196 cm and a maximum of 457 cm (Table 5.3).

Table 5.3 Estimated theoretical heigth (in cm) of the columns from *Ammaia* based on the dimensions of the capitals.

ID	Order	Diameter-Top	Diameter-Bottom	Heigth
fer_001	Tuscan	35	47	327
fer_002	Tuscan	39	52	364
fer_003	Tuscan	36?	48	336
fer_004	Tuscan	?	?	?
fer_005	Tuscan	28	37	261
fer_006	Tuscan	41	55	383
fer_007	Tuscan	21	28	196
fer_008	Tuscan	21	28	196
fer_009	Tuscan	22	29	205
fer_010	Tuscan	29	39	271
fer_011	Tuscan	22	29	205
fer_012	Tuscan	49	65	457
fer_013	Tuscan	49	65	457
fer_014	plain Ionic	32	43	299
fer_015	plain Ionic	25	33	233
fer_016	plain Ionic	37	49	345
fer_017	plain Ionic	34	45	317
fer_018	plain Ionic	28	37	261
fer_019	plain Ionic	28	37	261
fer_020	plain Ionic	35	47	327
fer_021	plain Ionic	37	49	345
fer_022	plain Ionic	38	51	355
fer_023	plain Ionic	32	43	299
fer_024	plain Ionic	24	32	224
fer_025	plain Ionic	?	?	?
fer_026	plain Ionic	?	?	?
fer_027	plain Ionic	40	53	373
fer_028	plain Ionic	25	33	233
fer_029	plain Ionic	32	43	299
lap_041	plain Ionic	36?	48	336

Summarising, the columnar architecture in *Ammaia* was dominated by the Tuscan order and the plain Ionic order with Tuscan influence. The sober and plain execution of the capitals in *Ammaia* is undoubtedly related to the working properties of the raw material (granite) from which the capitals were produced.

It was long-time believed that the Corinthian order dominated the architecture of the Iberian Peninsula, see for example *Ebora* and *Conimbriga* in *Lusitania*. Recent studies, however, illustrated the importance of the Tuscan order and the plain Ionic order with Tuscan influence in the Early Imperial period, especially in the centre and the north of *Lusitania* (Fernandes, 2008). Like in *Ammaia*, Tuscan capitals and plain Ionic capitals with Tuscan influence are the only type of capitals that have been found at Roman Bobadela (Portugal) and *Civitas Igaeditanorum* so far (Fernandes, 2008). Also in *Emerita Augusta*, these types of capitals are frequent. In all cases, the capitals were carved from local granite stone. The best parallels for the capitals from *Ammaia* come from the so-called *Casa do Anfiteatro* and the *postcaenium* of the theatre in *Emerita Augusta*. Originally, these examples were dated in the 3rd and 4th century CE, but recent studies propose an Early Imperial chronology. These capitals were introduced in *Emerita Augusta* shortly after the foundation of the town and subsequently served as a model for towns in the northern and the central part of *Lusitania*. Small differences in morphology point to local workshops producing from a local market, for example also in *Ammaia* (Fernandes, 2001; 2008).

5.2.2 Bases

Like the capitals, the granite bases are rather plain and sober, making it sometimes difficult to distinguish between capitals and bases. Four bases consist of an *abacus*, an *echinus* (in the shape of a *torus*) and the start of the shaft. In one case, the *echinus* is not elaborated (lap_112). The diameter of the column shafts ranges from 37 cm to 42 cm. Two small bases in white marble (dep_0287 and dep_0295) originate from the eastern half of the paved square of the *porta sul*. Both consist of an *abacus*, followed by a simple *echinus* and the start of the shaft. The latter is only 5 cm high. The diameter of both bases is 16 cm.

By applying the same ratios as described above for the Tuscan order, an average full height for the granite columns of 271 cm is estimated. With these dimensions, the columns associated with the granite column bases are slightly smaller than the average estimated height of the columns associated with the capitals. The marble columns are estimated at only 112 cm, indicating that these columns were only decorative architectural elements.

Table 5.4 Dimensions (in cm) of the column bases from Roman *Ammaia*.

ID	Material	Height	Diameter	*Abacus*	*Echinus*	Shaft
lap_112	granite	51	38	44x44x12	/	39
lap_113	granite	49	38	52x52x16	7	26
lap_115	granite	52	37	53x49x12	11	29
lap_121	granite	30	?	?x?x7	7	16
lap_172	granite	60	42	63x60x13	14	33
dep_0287	marble	12.5	16	21x21x5	2.5	5
dep_0295	marble	?	16	?	?	5

5.2.3 Shafts

The column shafts from *Ammaia* are all plain (unfluted). Sockets for dowelling have not been observed. Three monolithic shafts were found in the excavations of the South Gate, one drum comes from the northwestern portico wing of the forum. The archaeological provenance of the remaining shafts is not known. In the area of the forum portico, remains of brick columns were also found. Column shafts in white marble that were reused in the nearby town of Marvão are not incorporated in this overview.

Four **monolithic shafts** in white marble have a diameter 13 cm (2) and 29–30 cm (2). The two shafts with the smaller diameter have a height of 93 cm and 98 cm and were used as decorative architectonical elements. The two shafts with a diameter of 29–30 cm are preserved to a height of 34 cm and 77 cm. The marble shafts in Marvão belong to the same type as the latter. Seventeen granite monolithic shafts range in height from 40 cm to 195 cm, with half of the shafts measuring between 80 cm and 103 cm.

The average length is 101 cm. The diameter is between 23 cm and 51 cm, with an average of 38 cm (Figure 5.4-A).

Six granite **column drums**, with a height smaller than or equal to the shaft diameter, have a height ranging from 25 cm to 45 cm. Their average diameter is 45 cm (range: 38 cm to 63 cm). The drum with a diameter of 63 cm and a height of 45 cm comes from the northwestern portico wing of the forum and probably served to support the portico colonnade (Figure 5.4-B).

Finally, the lapidary collection contains two **drums of engaged columns**, measuring 30 cm diameter and 28 cm high, and 44 cm diameter and 45 cm high.

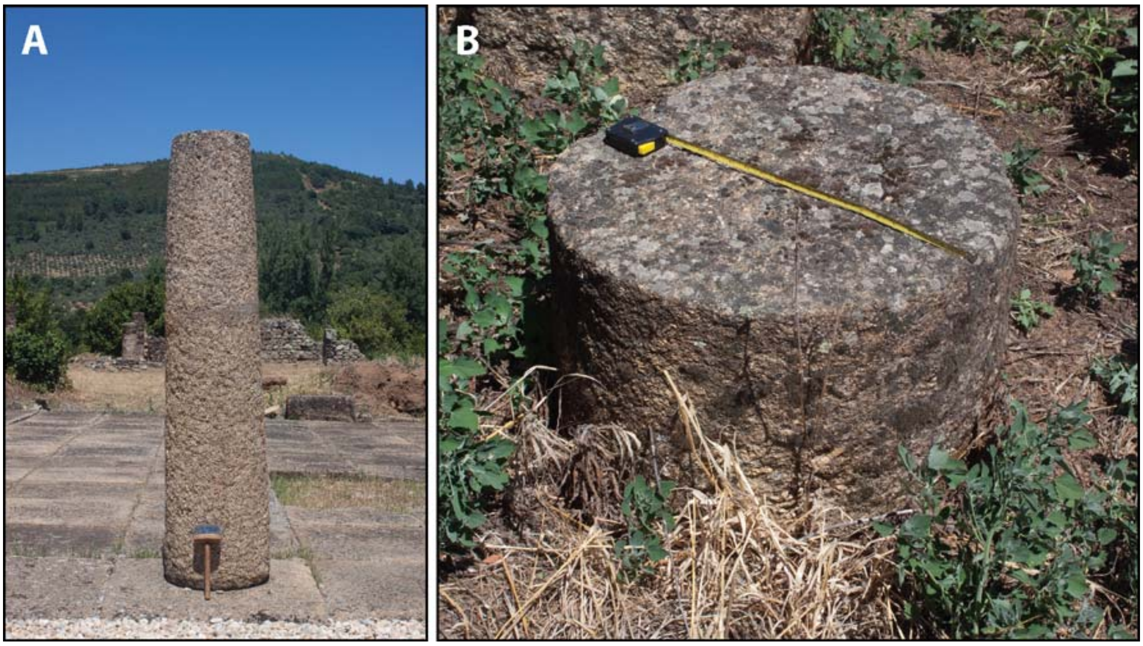

Figure 5.4 (A) Monolithic column shaft in granite from the South Gate (length brush: 30 cm); (B) Granite column drum from the northwestern portico wing of the forum (scale: 50 cm).

In general, the column diameter of the granite columns ranges from 23 cm to 63 cm with an average of 40 cm. Half of the columns have a diameter between 36 cm and 45 cm. With these dimensions, the columns from *Ammaia* are within the typical range of the granite columns from Roman Hispania (c. 40 cm diameter). Only rarely, the Hispanic granite columns reach over 60 cm in diameter. In other regions of the Mediterranean area, the columns tend to be slightly larger (50 cm to 60 cm diameter), for example in Cyprus and Israel. In Leptis Magna, the columns have an average diameter between 60 cm and 90 cm, while in Rome and Tuscany they easily reach up to 100 cm and even more (Williams-Thorpe, 2008; Williams-Thorpe and Potts, 2002; Williams-Thorpe and Rigby, 2006).

By applying the same ratios as described above for the Tuscan order, a full height of the granite columns between 252 cm and 315 cm, on average, can be estimated. The largest column is estimated at 441 cm. These heights are in the same line as the ones estimated on the basis of the capitals and bases.

5.2.4 Pedestals

A granite pedestal (lap_145) has a plain and sober execution, similar to that of the granite capitals and bases. The block is square (61 cm by 61 cm) and measures 49 cm in height. Two pedestals in white marble are more elaborated. The first marble pedestal measures 48 cm by 48 cm and is 35 cm high (lap_123). The second marble pedestal with associated marble column (lap_093) was found during the excavations of the South Gate and measures 47 cm by 45 cm by 24 cm (Figure 4.33).

5.3 Millstones

Eleven millstone elements have been documented in the lapidary collection (Table 5.5). Nine are part of circular rotary querns (five upper stones or *catilli* and four lower stones or *metae*). The two remaining stones are part of an hourglass-shaped or Pompeian style mill. The millstones are carved from a similar pale brown granite that is very suitable for grinding because of its hard and rough surface resulting from the abundant quartz grains present in the rock. No lava querns were imported from the main production centres in the Mediterranean area (cf. Antonelli and Lazzarini, 2010; Antonelli and Lazzarini, 2012; Peacock, 1980; Williams-Thorpe, 1988; Williams-Thorpe and Thorpe, 1989; 1991; Williams and Peacock, 2006; 2011).

Table 5.5 List of the millstones found in Roman *Ammaia*.

ID	Type	Millstone element	Weight (kg)[1]
lap_188	rotary quern	upper stone	59
lap_189	rotary quern	upper stone	/
lap_190	rotary quern	upper stone	87
lap_191	rotary quern	upper stone	123
lap_192	rotary quern	lower stone	83
lap_193	rotary quern	lower stone	48
lap_194	rotary quern	lower stone	35
lap_195	Pompeian style mill	lower stone	199
lap_196	Pompeian style mill	upper stone	334
lap_197	rotary quern	lower stone	44
lap_198	rotary quern	upper stone	51

[1] Weight of the millstones was estimated using the average mass density for granite of 2640 kg/m^3 (Hunt et al., 1995).

The rotary querns have a diameter between 38 cm and 50 cm, with an average of 45 cm (Figure 5.5). The examples from *Ammaia* are slightly larger than the most popular size for Roman rotary querns (33 cm to 36 cm). Larger rotary querns were generally used in Sardinia and on the Iberian Peninsula (Williams-Thorpe, 1988).

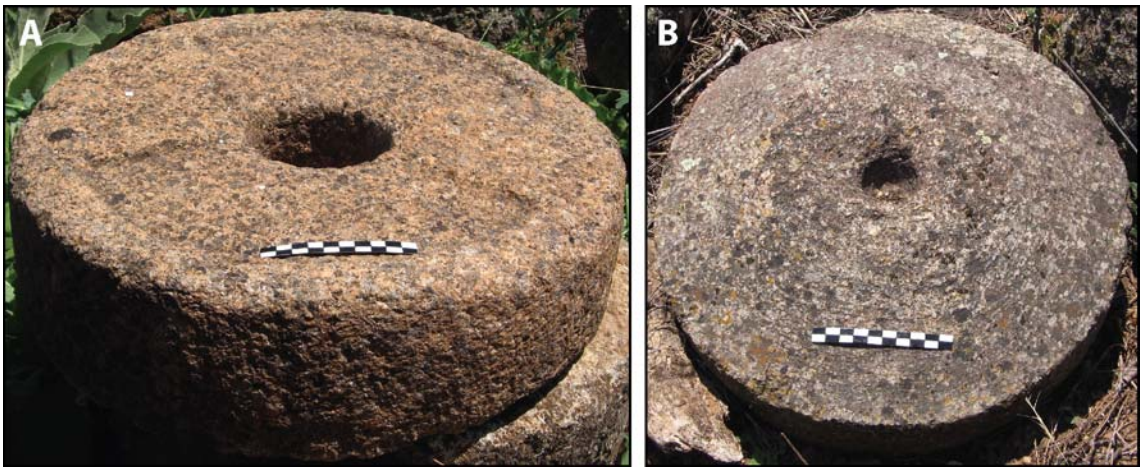

Figure 5.5 Rotary querns from *Ammaia*: (A) Upper stone (scale: 10 cm); (B) Lower stone (scale: 10 cm).

The Pompeain style or hourglass-shaped mill consists of a large conical *meta* of 44.5 cm high with a vertical base of 5.5 cm high. The diameter is 90 cm. The *catillus* consists of a single ring with handle slots on either side of the upper part. The stone reaches about the same height as the *meta* (Figure 5.6).

The millstone belongs to the group of ring-*catillus* mills, a variety of the Pompeian style mills that occurs especially in Morocco, Portugal and Sicily (Williams-Thorpe, 1988). These large millstones were not only used for cereal grinding, but also for olive crushing. Judging from the weight of the moving element (334 kg), it was surely pushed by at least two men or by animals. The ring–*catillus* mill suggests milling on industrial scale and was probably used in a large bakery or olive oil production centre.

Figure 5.6 Ring-*catillus* mill from *Ammaia*.

5.4 Epigraphic monuments

In pre-Roman times, no proper epigraphic tradition existed in *Lusitania*. Following the arrival of the Romans, epigraphy arose as a new phenomenon and marked a Roman(ised) lifestyle (Edmondson, 2002). It is essential to realise that not all people in the Roman society had the habit or the necessary means for erecting epigraphic monuments. For example, monuments for members of the local elite are attested more frequently, as these people used epigraphy to display their Roman nature and to establish their rank in society (Edmondson, 2004).

The epigraphic collection of *Ammaia* contains 25 monuments (Table 5.6). Twenty-nine are in the *Ammaia* archaeological museum; three are in the *Museu Nacional de Arqueologia* in Lisbon and another three inscriptions are lost but were documented in the past. The monuments can be classified in three distinct categories: tombstones

(13), dedicatory inscriptions to deities (8), and commemorative inscriptions of emperors (2). Two fragments could not be assigned to any of these categories, because of their small preserved size. Regarding stone type, a pale brown granite and a white marble were used, represented by 14 and 11 examples respectively (Table 5.6). Generally, good effort was spent in manufacturing the monuments. The marble monuments are always smoothed and polished. The carving was well executed and the lettering was adapted to the available space. In a few cases, however, the wrong splitting of ending words (e.g. lap_014: *liben-s*, lap_016: *Meduge-ni*), words crossing the raised border of the epigraphic field (e.g. lap_029: *STTL*), or a reduced letter size at the end of the lines (e.g. lap_016), reflect the work of an inexperienced sculptor or a sculptor unfamiliar with the Latin language.

Only two monuments are dated exactly thanks to the imperial titulature in the inscribed text. The remaining monuments are only roughly dated using palaeographic evidence together with some indications from the inscription. For example, the tombstone of C. Iulius Vegetus (CIL II 160, IRCP 617), a provincial flamen of the imperial cult, can be dated in the post-Vespasian period because of the typical formulation of *flamini provinciae Lusitaniae* (Delgado Delgado, 1999). Similarly, the tombstone of P. Cornelius Macer (CIL II 159, IRCP 618) is dated in the post-Claudian period, as the inscription refers to *Divus Claudius* (i.e. later than 54 CE).

The monuments are mainly dated in the second half of the 1st century CE and the first half of the 2nd century CE, with a concentration in the Flavian and early Antonine period. The earliest marble monument with a certain chronology dates to 44–45 CE, thus providing a *terminus ante quem* for the introduction of white marble in *Ammaia*.

Table 5.6 List of the epigraphic monuments from *Ammaia* with indication of the inscription type, stone type and chronology of the monument.

ID	Type	Stone	Chronology
dep_0306	?	marble	?
dep_0346	?	marble	?
lap_016	funerary	granite	1st century CE
lap_021	funerary	granite	mid 1st century CE
lap_022	funerary	granite	second half 1st century CE – early 2nd century CE
lap_025	funerary	granite	?

ID	Type	Stone	Chronology
lap_029	funerary	granite	late 1st century CE
lap_031	funerary	granite	second half of 1st century CE
lap_019	funerary	marble	2nd half 1st century CE
lap_024	funerary	marble	post-Vespasian – early 2nd century CE
lap_033	funerary	marble	second half 1st century CE
lisbon_06	funerary	marble	1st century CE
unknown_03	funerary	marble	flavian – early 2nd century CE
unknown_05	funerary	marble	?
unknown_06	funerary	marble?	?
lap_020	honorific	marble	166 CE
lisbon_01	honorific	marble	44–45 CE
lap_014	religious	granite	?
lap_018	religious	granite	?
lap_023	religious	granite	mid 1st century CE
lap_026	religious	granite	early 2nd century CE
lap_027	religious	granite	2nd century CE
lap_028	religious	granite	early 2nd century CE
lap_030	religious	granite	?
lisbon_03	religious	granite	?

A first group of **funerary inscriptions** are the simple, elongated granite *stelae* with rounded tops or triangular pediments. This group is represented by six pieces. None are complete; the top part is always missing (Figure 5.7-A). Eighteenth-century CE drawings show that at least three of these *stelae* ended in a rounded top. Four of the six granite tombstones were also decorated in the upper part with a bas-relief rosette (Abascal and Cebrián, 2009). In general, the epigraphic field is enclosed by a raised border. The width of the *stelae* measures between 42 cm and 50 cm, while the thickness is between 14 cm and 24 cm. The height could not be determined because of the fragmentary state of the stones. These funerary monuments have many parallels in Roman *Hispania* and in Late Republican and Early Imperial Rome (Edmondson, 2001; 2002; 2007). The *stelae* with rounded tops and a rosette decoration are typically found in indigenous contexts in *Emerita Augusta* and north of the Tagus River in central *Lusitania* (Edmondson, 2002; 2007; Márquez Pérez et al., 2008).

A second group of inscribed tombstones are carved in pure white or white, veined marble. The marble funerary monuments are more elaborated and display a larger typological diversity than their granite equivalents. Three of the seven marble funerary monuments have unfortunately disappeared. For two monuments (unknown_005 and unknown_006), only the inscribed text has been documented. The third monument (unknown_003) is better known thanks to a 19th century CE description. It concerns an altar-type monument of approximately 2 m to 2.5 m high. The central part of the block contained the inscription. The square base and capital were separated from the central shaft by a moulded decoration (Stylow, 2009).

Three funerary inscriptions (lisbon_06, lap_019 and lap_024) are carved on thin marble panels designed for insertion into the façade of a larger funerary monument. The thickness of the panels is 8.5 cm, 14.5 cm and 20.5 cm. On lap_019, insertion elements are visible at the top and base of the panel.

A large marble stele (185 cm high) (lap_033) was decorated with five rosettes and a leaf-like frieze on the top, followed by the framed epigraphic field. The bottom decoration resembles a pilaster and consists of nine elongated grooves (Archivo Epigráfico de Hispania, 2007; Mantas, 2000) (Figure 5.7-B).

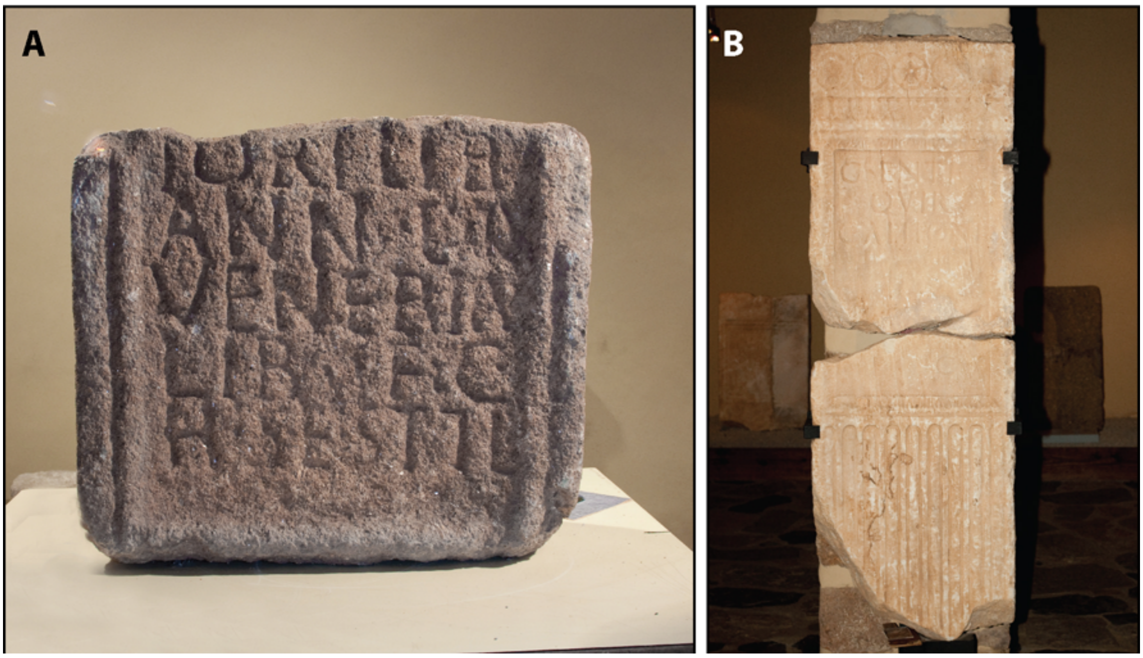

Figure 5.7 Funerary epigraphic monuments: (A) Part of a granite stele (lap_029) (height: 36 cm); (B) Decorated white marble stele (lap_033) (height: 185 cm).

The **religious, dedicatory inscriptions on altars** are all carved in granite. Typologically, all monuments are similar and resemble rectangular miniature pillars with a clearly marked moulded base and capital, a common shape for private altars (Keppie, 1991). Two cylindrical *pulvini* with a circular front decorate both sides of the capital. In half of the pieces, a central *foculus* was carved to contain the offers. The text is inscribed on the shaft. Based on the size of the monuments, two groups can be distinguished: the large altars with heights between 81.5 cm and 96 cm (three monuments) and the small altars with heights between 41 cm and 53 cm (five monuments) (Figure 5.8). The smaller altars were probably used in household shrines, while the larger monuments could have been placed inside a temple.

Figure 5.8 (A) Large altar dedicated to *Jupiter Optimus Maximus* (height: 96 cm) (IRCP 606); (B) Small altar dedicated to *Jupiter Optimus Maximus* (height: 31 cm) (IRCP 608).

Four altars are dedicated to *Jupiter*. In three cases, the god is given the epithet of *Optimus Maximus*, 'Best and Greatest'. This again indicates the importance of the

Jupiter cult in *Lusitania*, especially in its interior part (Beltrán Lloris, 2002; Mantas, 2000). On two altars, the text refers to the *genius* of the town (*Genius Ammaiensis* and *Genius oppidum constitutum*). One altar refers to the indigenous cult of *Ocrimira*, a local goddess probably related to water (Mantas, 2000). On one altar, the name of the god or goddess could not be determined.

Among the religious, dedicatory inscriptions, two uninscribed altars in granite need to be mentioned. The first monument was decorated with a central rosette and a moulded base and capital. On the capital, a central *foculus* was carved for holding the offers (Figure 5.9-A). The second altar was not fully finished and illustrates that *Ammaia* had its own workshop(s) for epigraphic monuments in granite (Figure 5.9-B). While the general shape and layout of the altar are already marked, the fine carving of the moulded base and top and the inscribed text still have to executed.

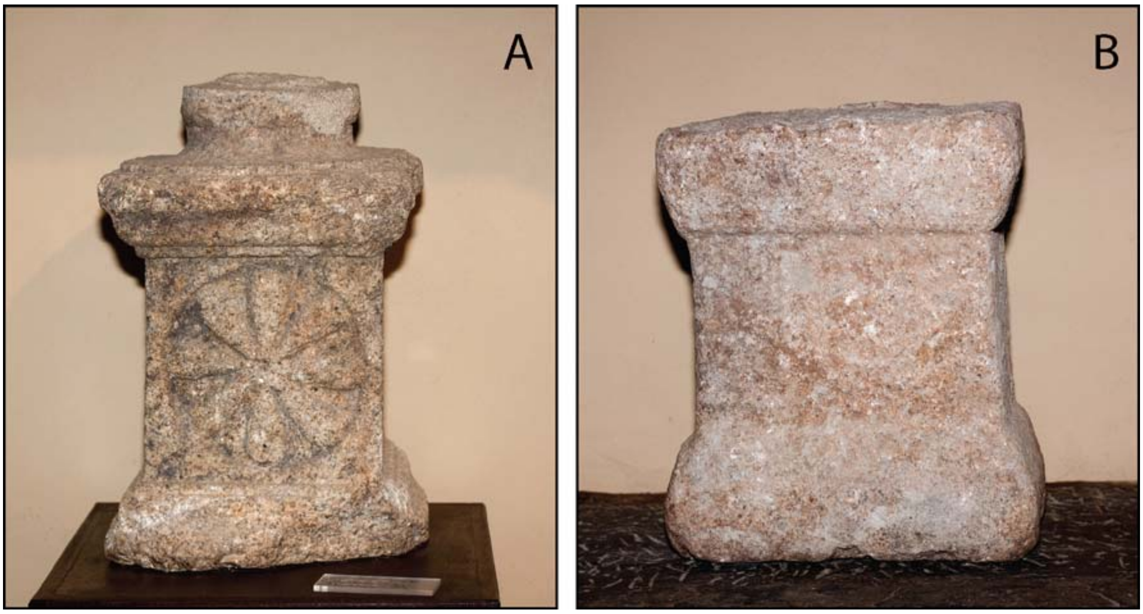

Figure 5.9 Two uninscribed altars from the *Ammaia* lapidary collection: (A) rosette decorated altar (lap_006) (height: 36 cm); (B) semi-finished altar (lap_013) (height: 35 cm).

Finally, two **commemorative inscriptions or monuments** from *Ammaia* are carved in white marble. The first monument, now stored in the *Museu Nacional de Arqueologia* in Lisbon (MNAE E 7267), contains an annual vow of two local magistrates to the Emperor Claudius (Figure 3.1-B). The commemoration is inscribed on a marble slab of 18 cm thick and is smoothed on three sides. The top and bottom part were originally decorated with a moulding (Encarnação, 1984). The stone was probably designed for insertion into the base of a monument. According to J.M. Højte (2003) the block is too small for a statue base and could perhaps have held a portrait buste. The second commemorative inscription honours the Emperor Lucius Verus and was dedicated by the town of *Ammaia* and its inhabitants. The inscription is inscribed on a polished small pedestal with a moulded base and capital. On top of the capital, the presence of a hole with remains of an iron dowel suggests that a portrait bust originally topped the monument.

It is interesting to note that there is a link between the monument type and the stone type from which the monument is carved. For the two commemorative inscriptions honouring the emperor only a high-quality ornamental stone was used. Likewise, all religious inscriptions are in granite. The inscribed funerary monuments are in both marble and granite. The names of the deceased on the marble funerary monuments suggest that marble was used by members of the higher classes of the *Ammaia* society, for example local magistrates. Six of the seven marble funerary inscriptions are dedicated to inhabitants holding the Roman citizenship. The granite monuments usually refer to freedmen or -women and slaves. It needs to be stressed, however, that also the granite inscribed funerary monuments represent a monumental way of honouring the deceased (Edmondson, 2004; Keppie, 1991).

5.5 Statuary

A life-size togate statue in white marble, now displayed in the *Ammaia* archaeological museum, is the only piece of sculpture known from *Ammaia*. It was discovered as part of a 19th–20th century CE fountain in the nearby village of Escusa. In addition to this piece, many other statues certainly embellished Roman *Ammaia*. The Spanish historian J. De Viu (1852), for example, mentions the shipping of 'more than 20 beautiful statues' to England.

The togate statue of *Ammaia* represents a young boy dressed in a *toga praetexta* and wearing a *bulla*, an amulet worn by male children until they received the *toga virilis* and were considered mature. The statue is missing the head, the right forearm and the left hand. A large circular hole also cuts through the lower half of the torso. The right arm is raised and bends at the elbow, the sleeves of the *toga* reach the elbow. The left hand is next to the body and the *toga* is thrown over the arm. The *toga* extends in a U-shaped *umbo* and the *sinus* extends below the right knee. The figure places its weight on the left foot, while the right leg is slightly bent at the knee (Figure 5.10-A).

Figure 5.10 (A) Togate statue of *Ammaia*, probably representing the 13-year-old Nero (50 CE) (*Ammaia* archaeological museum, São Salvador da Aramenha) (height: 91 cm); (B) Togate statue of young Nero from the basilica in *Veleia* (MA 1210 – inv.mr 337, N1580, Louvre, Paris) (Giroire and Roger, 2007).

The maximum preserved dimensions are 91 cm (H), 60 cm (W) and 32 cm (T). Comparison with parallels (cf. below) suggests that the statue had an original height of about 150 cm. The head, the right arm and the left hand were carved from separate pieces of stone. The latter two were attached to the torso by iron dowels, of which the remains can still be seen in the torso block (Figure 5.11-A); the head was inserted into a socket (Figure 5.11-B). The back of the statue is not elaborated. The reduced thickness of the piece and the unelaborated back suggest that the figure was designed to be placed in a niche or against a wall from where the backside was not visible.

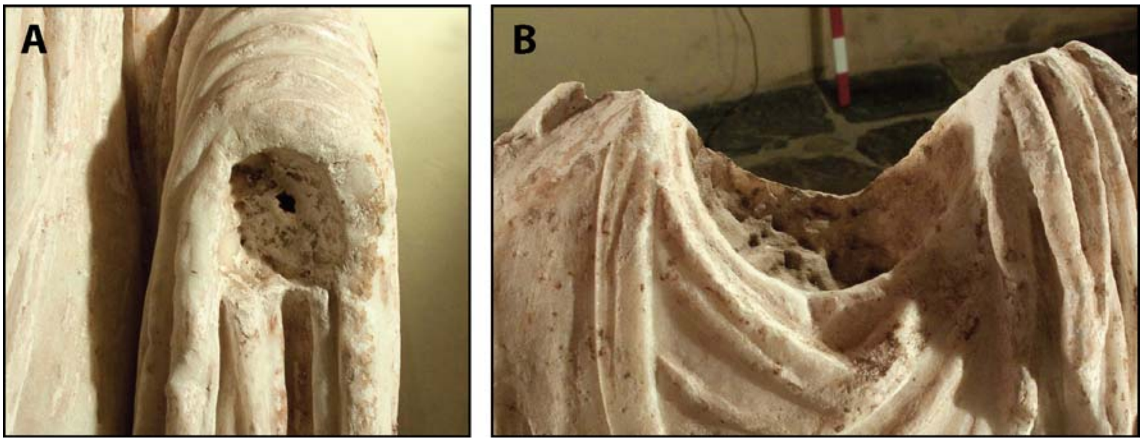

Figure 5.11 Detailed photographs of the togate statue from *Ammaia*: (A) Remains of an iron dowel for attaching the left hand to the torso block; (B) Socket for inserting the head of the statue. Cutting marks of a point chisel can be seen.

Even though the head of the togate statue is not preserved, a comparison with similar pieces and the high-quality carving suggests a Julio–Claudian chronology. The link between *Ammaia* and the Claudian family has already been attested by two honorific inscriptions: (1) an annual vow of the town's inhabitants dedicated to the Emperor Claudius in 44–45 CE (IRCP 615) (Encarnação, 1984; Vasconcelos, 1935); and (2) a funerary inscription of P. Cornelius Macer (CIL II 159, IRCP 618), a member of the local *Ammaia* magistracy, who was given the Roman citizenship by Claudius, probably as one of the first people in the town (Edmondson, 2006; Encarnação, 1984; Stylow, 2009). Based on this chronology, the figure can be identified as the young prince Nero or his stepbrother Britannicus. Comparison with other togate statues with a *bulla* from Julio–Claudian groups, such as the one from *Veleia* (Lugagnano Val d'Arda, Italy) or *Rusellae* (Roselle, Italy) (Hiesinger, 1975; Kleiner, 1992; Nogales Basarrate, 2008; Poulsen, 1928; Poulsen, 1951) suggests the young prince Nero (Figure 5.10-B). The argument of *damnatio memoria* by J. Oliveira (1991) to identify the figure with Britannicus needs to be treated with caution. The author states that the description of in J. Viu (1852) mentions that the statue still had a head when it was discovered in Escusa, making it impossible that the figure represents Nero because all imagery of the Emperor was destroyed after his death and *damnatio memoria* in 68 CE. However, the imagery of condemned emperors was not always destroyed. In many cases, portraits were recarved or just removed from public display (Kleiner and Matheson, 1996; Varner, 2004). Also, in the context of dynastic groups, the presentation of the genealogy of the imperial family was considered more important than the *damnatio*, especially if the person was not yet emperor at the time of depiction (Varner, 2004). This is for example illustrated by the Julio–Claudian dynastic groups of *Veleia* and *Rusellae*, where the statues of the young Nero were never removed (Varner, 2004; Wood, 2000).

If the figure represents Nero, it needs to be dated before 51 CE, when the prince was granted the *toga virilis*. The statue from *Ammaia* therefore belongs to the earlier portrait types of the later emperor, that were erected to celebrate the adoption of Nero by Claudius and his designation as official heir to the throne in 50 CE (Hiesinger, 1975; Højte, 2003). In its ancient setting, the figure from *Ammaia* must have belonged to a statuary group dedicated to the *Gens Augusta*. These statuary groups were a popular iconographic programme in the western Iberian in the Claudian period (Gonçalves, 2007). Some of the sculptures referred to by J. De Viu might have been part of this group.

In the western Roman world, dynastic groups were generally displayed in the main public buildings of the town. Fora and adjacent buildings (such as the basilica) were the most popular locations, but statues were also displayed in theatres, public baths and temples or sanctuaries (Edmondson, 2006; Højte, 2005).

5.6 Various architectonical elements

The final objects in the lapidary collection from *Ammaia* include four granite cornice blocks, a monumental granite *pulvinus* with a lateral extension (probably used for the decoration of the upper part of a Roman altar mausoleum), a rectangular panel of a coffered ceiling with a central rosette in high-relief surrounded by dentils, two marble plaques with moulded edges (probably part of a socle or pedestal and later reused for pressing mechanism of an olive press), a large veneer panel in white marble (probably used for a door threshold), and a door lintel in white marble decorated with circular motifs (Figure 5.12).

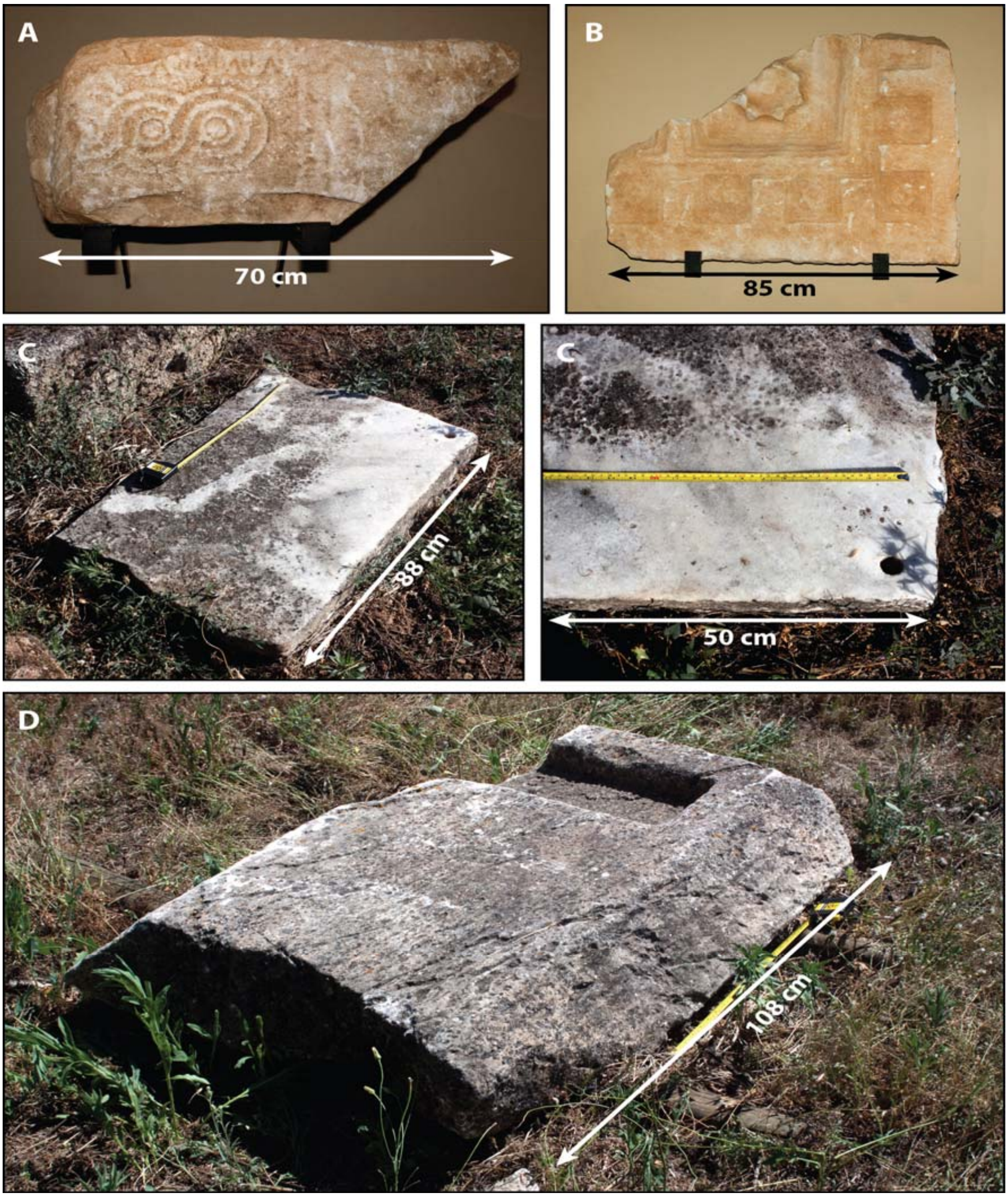

Figure 5.12 Various architectonical elements in the lapidary collection of *Ammaia*: (A) Decorated door lintel with circular motifs (lap_008); (B) Panel for coffered ceiling (lap_007); (C) Veneer panel with hole for the door hinge (lap_181); Moulded marble plaques with sockets for reuse in an olive press (lap_043).

The granite *pulvinus*, measuring 80 cm by 40 cm by 33 cm, is decorated on one side with a bas-relief hexapetal rosette (Figure 5.13). As for dimensions and decoration, the *pulvinus* from *Ammaia* is comparable to one found in Salgueira (Fundão, Portugal), about 100 km north of *Ammaia*, as part of an altar-type funerary monument (Carvalho and Encarnação, 2008). *Pulvini* were used almost exclusively for the decoration of square or squarish *mausolea* constructed in *opus quadratum* (Carvalho and Encarnação, 2008). Judging from the monumental size and the construction method of the funerary monument found in the suburban zone east of *Ammaia*, it is possible that the *pulvinus* from *Ammaia* originally belonged to this building.

Besides some isolated examples such as the *pulvinus* from *Ammaia*, two main collections are known from *Lusitania*: one from *Emerita Augusta* and one from *Civitas Igaeditanorum* (Beltrán Fortes, 2004; Carvalho dos Santos and Carvalho, 2008). All *pulvini* found in *Lusitania* belong to the same type, suggesting that they developed from the same model. According to Beltrán Fortes (2004), the *pulvinus* as decorative architectonical element for *mausolea* was introduced in *Lusitania* by Roman colonists from the Italic Peninsula that settled in *Emerita Augusta*. In general, the Hispanic *pulvini* are introduced at the earliest in the Augustan period and had their largest distribution during the 1st century CE. From the 2nd century CE onwards, their use starts to decline (Beltrán Fortes, 2004).

Figure 5.13 *Pulvinus* from *Ammaia*.

Chapter 6
Construction technique and stone use

Based on the results of the excavations and surveys carried out in *Ammaia* (see Chapter 4 and Chapter 5), an overview was made of the construction techniques and the stones used for constructing and embellishing Roman *Ammaia*. Given the small excavated area of the town (c. 2–3 %), the presented overview is far from complete and still subject to change as archaeological research continues. Moreover, it must be realised that stone material was often recovered for reuse in later buildings. This not only applies for building stones, it is equally valid for ornamental stones. The rare and special ornamental stones were among the first to be removed because of their intrinsic high value. In addition, marble and limestone were frequently reused as raw material for lime production. Nevertheless, as the studied remains include buildings and objects from different categories or functions (e.g. public and private buildings) and chronological contexts (from the 1st century CE to the early 5th century CE), the presented data provide a good overview of the construction techniques and types of stone used in *Ammaia*.

In addition to a general characterisation of the construction techniques, the different types of stone used for the architecture and embellishment of *Ammaia* are characterised in view of their structure, colour, basic mineralogy and texture. In many cases, a simple visual inspection of the discriminating rock features sufficed to distinguish and determine the provenance of the stones. Where necessary, thin section petrography and geochemical methods were carried out to obtain a detailed mineralogical–petrographic description of the rocks. The results of these thin section observations and geochemical studies are presented in the respective chapters.

6.1 Construction technique and the use of building stones

The *ex novo* foundation of *Ammaia* in the late Julio–Claudian period resulted implied intensive construction works during the first years of the town's existence. Typically Roman buildings such as a forum, bathhouses and funerary monuments were erected using newly introduced techniques such as worked stone, mortar and stucco. Soon after the foundation, a fully functioning supply system for building material had been established that supplied the necessary building stones for the architecture of the town. A second period of intensive building corresponds to the Flavian–Trajan period. Several existing buildings were dismantled and replaced by monumental, public complexes. The construction of a new bathhouse just south of the forum and a monumental gate building at the South Gate undoubtedly implied major architectural investments. Architectural modifications, dated between the middle of 2nd century CE and the beginning of the 5th century CE when the town was abandoned, have been observed in most excavated buildings.

Robbing, spoliating and recycling of building stones was not an uncommon feature in *Ammaia*. Especially since the 16th century CE, many building elements were taken from *Ammaia* and used to construct new buildings in nearby places like Portalegre, Marvão, Castelo de Vide, Escusa, Porto da Espada, Portagem and São Salvador da Aramenha (Oliveira et al., 1999). In addition to the recycling of building stones in post-Roman times, there is abundant evidence for the recycling of building material already in Roman times. *Spolia* have been observed in the buildings of *insula 38*, in the southeastern perimeter wall of the forum bathhouse and in the drain channel alongside the *natatio* of the forum bathhouse. Moreover, archaeological evidence in the Flavian bathhouse indicates the systematic recycling of stones from the Claudian–Neronian *domus* that previously occupied the site. Small heaps of stone debris underneath the levelling deposits of the bath complex illustrate that reusable stones were separated from unusable stones during the demolition of the earlier building. The recycling of building material was thus not a typical late Roman or post-Roman phenomenon related to a declining economy, but occurred already in the town's heydays. A recent study by S. Barker (2010) has illustrated that Roman builders could recycle up to 90 % of the stone material from an *opus incertum* wall. As a result the need of quarrying and transporting new stones to the construction site was to a large extent eliminated. Recycling therefore formed an easy and cheap way of obtaining 'new' building material (Barker, 2010).

From the town's early years onwards, granite was the most widely used stone. This is not remarkable given the particular physical properties of the stone. As a result of the hard minerals (such as quartz and feldspar) that make up this rock, granites are massive, mechanically tough and durable, making it an excellent stone for building purposes. A systematic study of the Roman architecture at *Ammaia* illustrated that all granite displays similar macroscopic properties. The granite in *Ammaia* is a two-mica granite with muscovite and brown to reddish brown biotite. The rock is medium-grained and has a porphyritic texture with feldspar phenocrysts reaching up to 5–7 mm in length. Granite was used for wall facings, ashlars, columnar architecture, but also to produce millstones and epigraphic monuments. The granite capitals and epigraphic monuments are characterised by a plain and sober execution, resulting from the specific working properties of the stone. Although granite presents excellent structural properties and is extremely suitable as building stone, the material does not allow easy carving. As a result, simpler forms of the decoration were used and the decorative elements were only executed roughly.

Apart from granite, gravelstones were the most common type of building stone. Gravelstones were used mainly for wall cores and foundations. In private buildings, gravelstones were also used as facing stones. All gravelstones are naturally rounded, implying a fluviatile origin. The gravelstones documented in *Ammaia* are predominantly quartzite with some sandstone examples. The colour ranges from yellow–beige to brown–red. In accordance with their specific function, the average size of the stones varies from large pebbles or small cobbles (10–15 cm across) for wall foundations to large cobbles and small boulders (25–40 cm across) for wall cores and the walls of houses.

Two colour varieties of shales were used: a brown–yellow and a grey–black. No fossils were observed. Because of the laminated structure of the rock, shale is ideal for producing thin slabs. These were used essentially for creating horizontal courses in the rubblework masonry and as cover stones for drain channels. It was sometimes also used in wall foundations and in the *opus caementicium* core of the rubblework masonry. It needs to be noted that the rock described here is a proper shale, i.e. an indurated and laminated fine-grained sedimentary rock composed of silt- or clay-size particles (Neuendorf et al., 2005). This is not to be confused with slate or schist that are metamorphic rocks. Confusion between these three different rock types occurs often as a result of incorrect translation from the Portuguese language. The Portuguese *xisto* means both schist and slate, while *xisto argilloso* means shale.

The final type of building stone is a uniform, fine-grained and well-cemented sandstone with no indication of lamination or bedding planes. The rock is well sorted and contains little or no matrix material. It has an overall red–brown colour due to a high concentration of iron oxides, with some yellowish spots. The rock contains no fossils or micas. Calcite veins occur frequently. Sandstone blocks were used mainly for wall cores and wall foundations. In some cases, sandstone blocks were used as facing stones.

The standing and excavated architectural remains show a reduced range of building techniques, dominated by rubblework masonry with a facing of irregular and roughly dressed facing stones (*opus incertum*) set into a core of mortared rubble (*opus caementicium*). Mortar, generally a pale brown to whitish lime mortar (Cardoso, 2011; sn, 2010; 2011), was applied when required to ensure structural stability. The size of the stones is 20–35 cm on average, but larger stones can attain up to maximum 60 cm. The stones were generally small enough to be handled by one or two persons without needing sophisticated lifting devices on the construction site. Ashlars were used essentially for quoining to ensure the structural stability at wall corners, wall intersections and doorways.

Great care was given while selecting and laying the rubble stones. The stones fit carefully and horizontal courses can generally be observed. The courses are defined by larger stones at the bottom and smaller stones and shale slabs at the top to obtain a more or less level surface. The vertical spacing between the courses differs considerably throughout the different buildings and, sometimes, even within the same building. On average, courses are separated 40–45 cm, but in some cases vertical distances of 30 cm and 50 cm can be observed. These differences in vertical spacing indicate the work of separate teams of builders. In some later constructions, for example in the forum portico and the South Gate complex, courses are less clear or even absent as a result of a coarser building technique. The stonecutting is less careful, the stones tend to be slightly larger and less care was given while laying the stones.

For the monumental buildings, such as the forum temple and the towers of the South Gate, the *opus incertum* facing was (partly) replaced by a facing of regular granite ashlars. The lowest courses of the temple podium were originally faced with rusticated granite ashlars. Likewise, the lowest courses of the two towers flanking the South Gate were faced with carefully cut granite ashlars. A similar construction technique has been observed, for example, for the Augustan–Tiberian temple of the provincial forum in *Emerita Augusta* (Pizzo, 2010b).

Putlog holes for scaffolding have been observed only in the forum portico, the South Gate and the town wall. Other buildings have not survived to a sufficient height. Generally, putlog holes are associated with horizontal courses, occurring just above them. In the *opus mixtum* walls of the South Gate, putlog holes are aligned to the brick courses. As the holes extend through the entire width of the walls, it is clear that a cantilever scaffolding system was used with transverse putlogs supporting a scaffold on both sides of the wall. The height above foundations is 140–150 cm for the forum portico, 90–95 cm for the South Gate walls and 90 cm for the town wall.

Two variations of the rubble work masonry have been observed. The first is in the forum bathhouse where the southeastern perimeter wall of the complex was built in a manner similar to the *opus africanum* technique, with rubblework supported by piers of horizontal and vertical ashlars. The purpose for this more robust construction is without a doubt related to the original slope of the terrain and the retaining function that the perimeter wall performs for the entire upslope-lying building. On the Iberian Peninsula, *opus africanum* constructions have been observed mainly in the Flavian period, i.e. the period in which the forum bath complex of *Ammaia* was constructed. The use of this building technique has been detected, for example, at *Carmo*, *Baelo Claudia* and *Munigua* (Mierse, 1999). Closer to *Ammaia*, in *Emerita Augusta*, *opus africanum* was used in the Augustan period for the construction of the retaining wall of the Guadiana River (Pizzo, 2010b).

A second variation is seen in the towers and the walls of the courtyard of the gate building of the South Gate. Here, the wall facings consist of rubblework alternated at regular distances by brick courses (*opus mixtum*). This type of masonry that mixes brick courses with rubble architecture was also observed in the so-called *Temple of Diana* on the colonial forum (dated in the Augustan period) and in the *Portico del Foro* of the municipal forum (dated in the first half of the 1st century CE), both in *Emerita Augusta* (Pizzo, 2010b).

Ashlar masonry was only detected in the suburban area towards the Sever River for the altar mausoleum. In addition, granite ashlars were used for the paving of the monumental square of the South Gate. The presence of numerous granite ashlars in the lapidary collection suggests that the use of ashlars might have been more widespread than suggested by the standing and excavated remains.

The foundations of the walls are normally dug in natural soil and are trench-built with foundation trenches with vertical edges. The width of the foundations is slightly wider than the upper structure. The foundations are normally mortared. In the lower parts of the town, the foundation trenches are dug directly into the shale bedrock. For the *opus quadratum* funerary monument in the suburban area, the walls are on top of a freestanding foundation deposited in a U-shaped trench dug directly into the shale bedrock. The foundation uses the same type of ashlars as the upper structure of the monument.

6.2 The use of ornamental stones

During 18 years of systematic archaeological research, 1739 fragments or 3682 kg of ornamental stone have been recovered in *Ammaia*. Most finds originate from archaeological excavations, but some were also found as reused items in nearby houses and villages.

Ornamental stone was used mainly for wall and floor decoration, i.e. veneer panels and mouldings. Architectural elements such as columns and column elements, but also epigraphic monuments and statuary occur only in marginal quantities. A last category concerns pieces that are difficult to classify because of weathering or small size. These tiny fragments are in most cases part of broken out or looted veneer panels. The popularity of veneer can be explained by the technological and practical difficulties involved in transporting fragile and bulky goods such as columns and statuary, whereas veneer panels could be brought to the town as standardised blocks that were sawn up on the construction site (Dodge, 1991; Ward-Perkins, 1951). Moreover, veneer does a great job of economically embellishing a building with 'noble' material, certainly in comparison with, for example, statuary. Non-standard blocks, such as columns, capitals, altars and statuary were less common and present a more prestigious form of ornamental stone import.

Four different types can be identified among the ornamental stones from *Ammaia*: (1) a white or white, veined marble (further referred to as white marble), (2) a pink limestone, (3) a grey–white marble and (4) a marble breccia. In this reduced range, the white marble clearly forms the principal type. Besides its general predominance, it outranks by far the other ornamental stones in all object categories and in all excavated sectors. Pink limestone objects also occur in considerable quantities. Grey–white marble and marble breccia were attested only rarely (Figure 6.1).

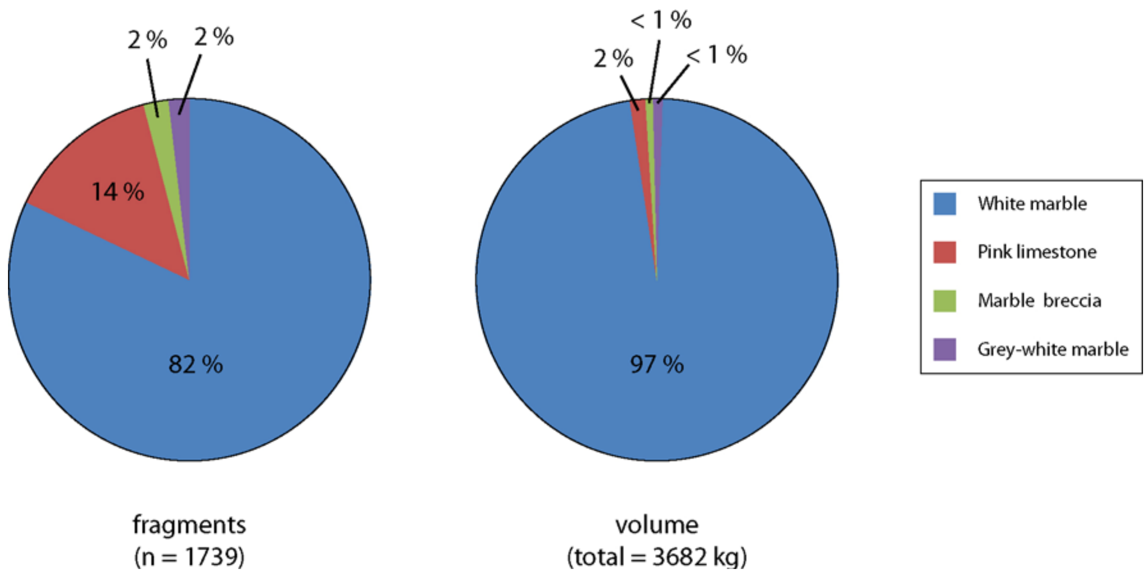

Figure 6.1 Pie chart showing the distribution of the different types of ornamental stone used in Roman *Ammaia*.

The white marble has a sugarish texture and is fine- to medium-grained, making it ideal for high-quality carving. The colour is either pure white or white with occasional coloured veins and streaks (red, green, brown and grey). Some pieces show a light pink shine. Tests using dilute 10 % hydrochloric acid indicate calcite as the dominant carbonate mineral. White marble was used for wall and floor revetment, epigraphic monuments and statuary. In some cases, columns and other architectural elements such as door lintels, panels for a coffered ceiling were also carved in white marble.

The pink limestone is a fine-grained limestone with a dominant pink colour and some white streaks. Dark-coloured stylolites occur frequently. Macroscopically, no fossils or bioclasts can be observed. Tests using dilute 10 % hydrochloric acid reveal calcite as the dominant carbonate mineral. Pink limestone was used exclusively for wall and floor revetment.

The grey–white marble has a similar sugarish texture as the white marble. The marble is medium-grained. The rock is further characterised by abundant (dark) grey veins alternating with white-coloured zones, giving the stone a distinctive colour palette. Tests with dilute 10 % hydrochloric acid reveal calcite as the dominant carbonate mineral. The white and grey–white marble differ mainly in the overall grey aspect of the rock resulting from the dense grey veining pattern. Grey–white marble was attested in *Ammaia* only as fragments of veneer panels.

The final ornamental stone is a monomict, matrix-supported breccia with poorly sorted clasts of white marble, sometimes with a light pink–red shine. The clasts have a maximum size between 0.4 cm and 8 cm and have sharp and clear boundaries. The matrix is compact, fine-grained and dark brown to grey. Just as the grey–white marble it was used exclusively as veneer.

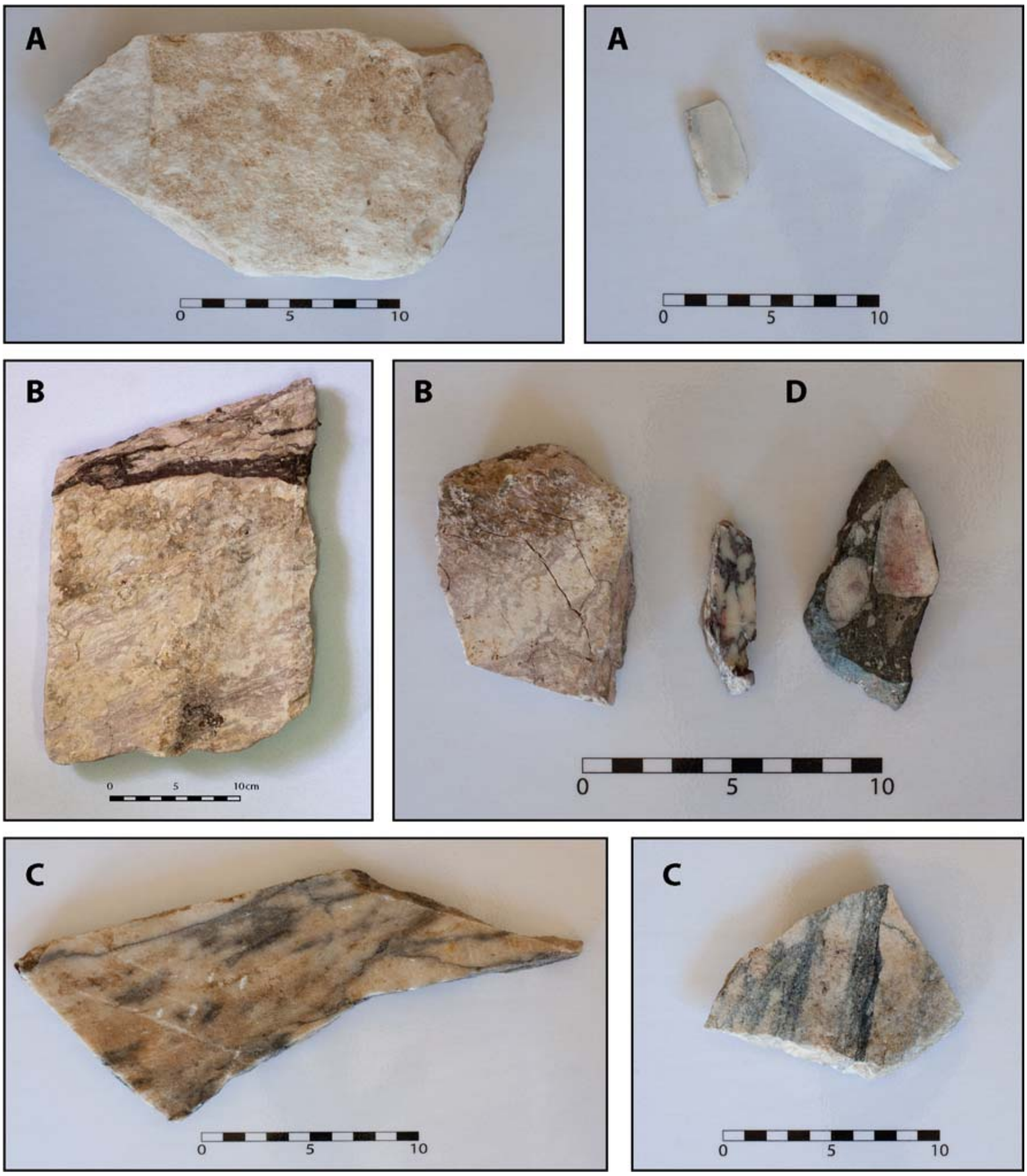

Figure 6.2 Overview of the different varieties of ornamental stones used in *Ammaia*: (A) White marble; (B) Pink limestone; (C) Grey–white marble; and (D) Marble breccia.

In essence, the decorative programme at *Ammaia* was rather sober, with generally only one type of ornamental stone – white marble – being used (Figure 6.1 and Figure 6.3). The forum complex is without a doubt the most sumptuous of the excavated buildings in terms of quantity and quality of ornamental stones. A prestigious decorative programme combined all four types of ornamentals stone. The forum complex is also the area where the highest volume of ornamental stone was recovered so far (34 % of the fragments). White marble is clearly dominant. In addition, a considerable amount of pink limestone can be found; the rest is grey–white marble and marble breccia. Similar polychromatic effects can be found in the *frons scaenae* of the *Emerita Augusta* theatre where white marble sculpture and capitals were combined with columns of grey marble and a podium floor of pink limestone panels (Fusco and Manãs Romero, 2006; Nogales Basarrate et al., 2009). Apart from the forum area, the forum bathhouse yielded a considerable amount of ornamentals stone (32 % of the fragments). Except for five small fragments of grey–white marble, only white marble was found here, including nine in situ preserved wall and floor veneer panels of one of the baths' pools. The excavated area of *insula 38*, the suburban area east of the town and the South Gate yielded, respectively, 5 %, 8 % and 13 % of the total amount of ornamental stone finds. The remaining 8 % of the finds are objects of which the exact archaeological provenance is unknown. Even though white marble is again dominant in the South Gate area, the high volume of pink limestone is remarkable here.

So far, little chronological information is available for the introduction and the use of ornamental stone in *Ammaia*, mainly because of limited stratigraphic recording of the earlier excavations. While some well-dated objects such as epigraphic monuments and statuary give a rough indication, the situation for the most ornamental stone finds (mainly veneer decoration) is less clear. Wall and floor veneer was generally the last element to be added to a building. In some cases, it was even applied or replaced in significantly later times. As a result, the actual construction of a building and the application of veneer could have taken place as part of two chronologically distinct events. Moreover, veneer is easily removed and therefore frequently spoliated and looted to provide decoration for later buildings.

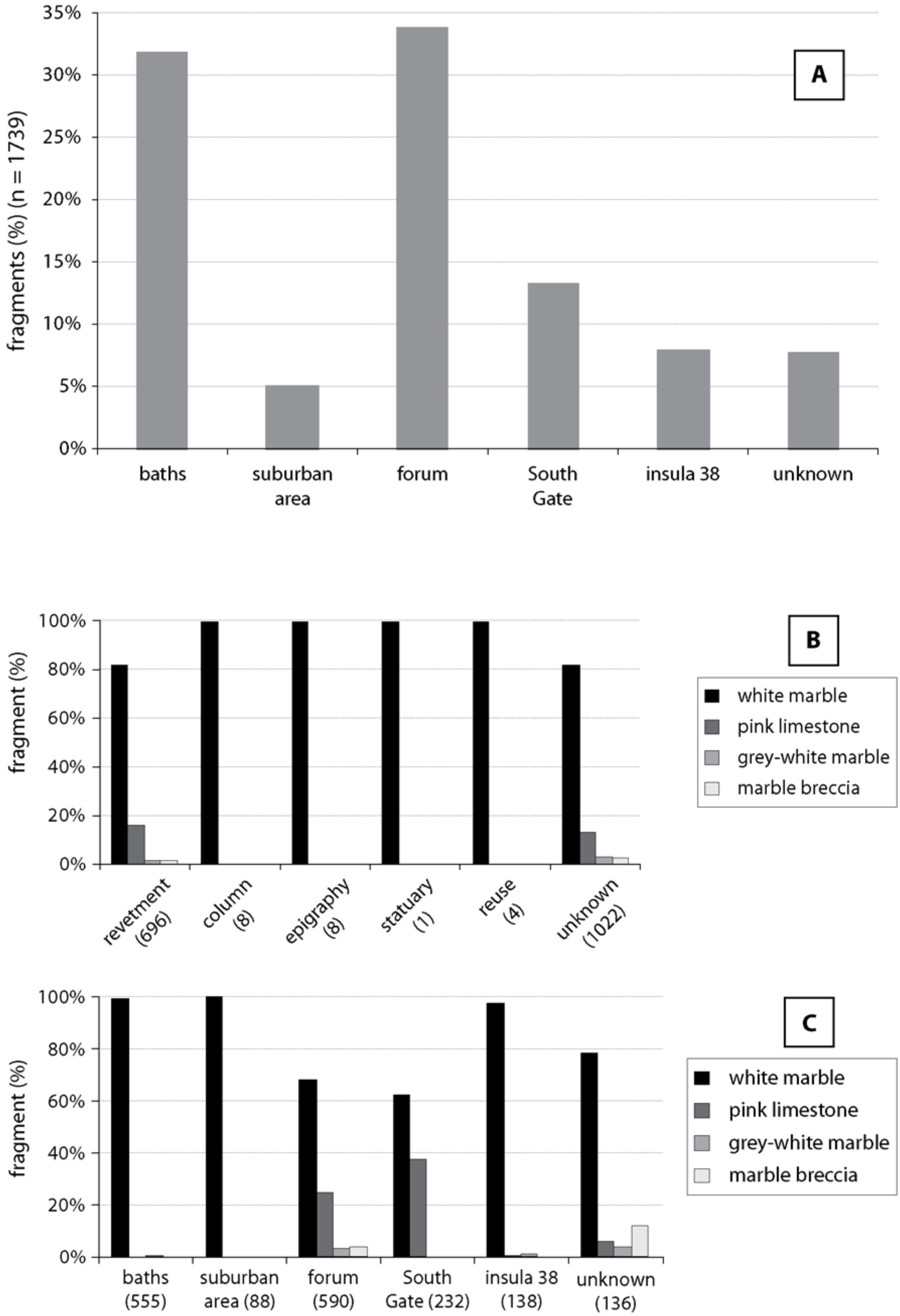

Figure 6.3 Bar graphs showing the use of ornamental stone at *Ammaia*: (A) distribution per excavated sector; (B) proportions of ornamental stone type per object category (*n*-value is indicated in brackets); (C) proportions of ornamental stone type per excavated sector (*n*-value is indicated in brackets).

The marble epigraphy and the statuary illustrate that ornamental stone, in particular white marble, was introduced in *Ammaia* at the latest in the Claudian period, not long after the foundation of the town. The earliest evidence of white marble is the commemorative inscription dedicated to the Emperor Claudius (44–45 CE) and the togate statue of young Nero or Britannicus (c. 50 CE). Other evidence for the early use of marble can be seen in *insula 26*, where several pieces of white marble veneer panels were recuperated for the construction of the Flavian bath complex (see Chapter 4). The presence of these reused elements illustrates that white marble was already present in considerable quantities in the pre-Flavian period.

The import of ornamental stone was attested particularly in the Flavian and early Antonine period, indicating a prosperous period for *Ammaia*. In this period, the construction of the forum bath complex and the monumentalisation of the South Gate required large volumes of ornamental stone. The peak of import in the Flavian and early Antonine period is also illustrated by the epigraphic monuments. Most marble inscriptions are dated in between the second half of the 1st century CE and the first half of the 2nd century CE.

Finally, the ornamental stone finds from the excavations of the residential area of *insula 38* indicate that ornamental stone, particularly white marble, was used well into the 4th and even the beginning of the 5th century CE. It needs to be noted that many finds of the last occupation phase might have been spoliated from earlier or abandoned buildings.

Summarising, the situation regarding the import and use of ornamental stone in *Ammaia* is to a certain extent comparable to that of most towns in the western part of the Iberian Peninsula. The architectural decoration of towns that were founded in Early Imperial times consisted initially of local stones that were stuccoed and painted to imitate marble or coloured ornamental stone (Fusco and Manãs Romero, 2006; Nogales Basarrate, 2002). The use of stone for embellishing architecture became common in the late Julio–Claudian period and especially from the Flavian period onwards when many new monumental buildings were erected and existing buildings were lavishly redecorated using abundant ornamental stone (Mierse, 1999). Notable examples are the municipal forum and theatre in *Emerita Augusta*, the Flavian forum in *Conimbriga*, and the theatre in *Olisipo* (Alarcão and Etienne, 1977; Ayerbe Vélez et al., 2009; De la Barrera, 2000; Fusco and Manãs Romero, 2006; Nogales Basarrate, 2002; Nogales Basarrate et al., 2009).

Chapter 7
Building stones: provenance and supply

Chapter 7 discusses the provenance of the building stones used for the architecture of Roman *Ammaia*. The study partly builds upon the PhD research of S. Deprez (2009) that, amongst other topics, investigated the provenance of the granite building material. In this thesis, the focus is set on the archaeological aspects of the research, and also the source tracing of the other types of building stone used in *Ammaia* is discussed.

The burst of building activity during the first years of the town's existence (see Chapter 4) implied that the urban area must have looked like a huge construction site. Inevitably, this involved an enormous demand for building stone. In a region without a proper pre-Roman architecture, this required the development of a well-organised stone supply system. Not only physical properties and quality were key factors in the choice for building stone sources, the importance of the material for the urban development of *Ammaia*, and of any other town, suggests that the exploitation happened in an economically efficient manner. It was noted by J. Fitchen (1986) that sources should be easily accessible (distance, methods and routes of transportation), the material of sufficient quality, the supply reliable and the costs and feasibility of obtaining the material should be proportionate. Considering the difficult, time-consuming and expensive transport of bulk building stones, nearby availability was extremely important (Adam, 2005; Fant, 1988). In general, building stone quarries were situated relatively close to towns, sometimes even inside the town. As suggested by P. Goodman (2007), quarries for building stones are generally part of the periurban landscape of a Roman town. As the value of the stone increased and when other factors such as aesthetical properties, prestige, fashion and ideology were involved, for example for ornamental stones, accessibility and ease of obtaining became less important and more distant sources could be exploited (see for example Chapter 9, Chapter 9 and Chapter 10).

7.1 Provenance tracing of the building stones

Based on the detailed architectural survey, an overview was made of the major rock types used in the buildings of *Ammaia*. As no ancient references or clear indications of the source of the building stones of *Ammaia* have survived, the sourcing of the building stones of *Ammaia* and the study of the quarry landscapes required an interdisciplinary, geoarchaeological and archaeometric approach.

In a first steps, samples from all rock types were taken for careful macroscopic and – where necessary – thin section petrographic observation. The data obtained was compared with data gathered from a detailed review of the available archaeological, geomorphological and geological literature of the study area, and with data gathered during an extensive archaeological and geological survey of the area. All field data collected using handheld GPS were incorporated in a geographical information system (GIS), in which other data sources (mainly topographic maps, geological maps and vertical aerial photographs) were integrated.

Based on the results of the above analyses, potential source areas for the building stones were determined. Within a 10-km radius from *Ammaia*, several surveys were organised aimed at locating ancient quarry sites. In case no quarry sites or potential source areas were detected in the 10-km radius area, the survey zone was to be enlarged. It needs to be noted that ancient quarries, more than other archaeological sites, are threatened by destruction as a result of modern quarrying. High-quality stone material quarried in ancient times was often also the target for later people requiring high-quality building material. Traces of ancient exploitation have therefore often not survived and in some cases it is only possible to define the geological, and not the archaeological source or quarry.

After identifying potential ancient extraction sites, the appropriateness for supplying *Ammaia* with raw construction material was considered based on an archaeological, geomorphological and geological assessment of each site. Aspects like the extraction method, quarry size, spatial and temporal organisation, debris management, transport from the quarries to town, and the proximity to Roman settlements and to the Roman road network were investigated to comprehend the scale and organisation of the quarrying activities. If necessary for the provenance determination, thin section petrography was carried out to obtain a detailed mineralogical–petrographic description of the rocks.

7.2 Local geology

It was already noted in Chapter 1 that the area of *Ammaia* is located on the boundary between the CIZ and the OMZ, two zones of Iberian Massif. The town itself lies in the core of the *La Codosera Syncline* (LCS), an Ordovician to Devonian sedimentary sequence that overlies the late Proterozoic rocks of the Schist–Greywacke Complex (SGC) of the CIZ and stands from it as the small mountain range of the *Serra de São Mamede* (Sanderson et al., 1991) (see Chapter 1 and Figure 7.1). The syncline is about 90 km long and maximally 10 km wide, and extends between Castelo de Vide (Portugal), where it is cut by the Nisa–Alburquerque Batholith (NAB), a large granite pluton (see below), and Cordobilla de Lácara (Spain), where Tertiary deposits of the Guadiana Depression cover the Paleozoic rocks of the syncline. The Messejana Fault cuts the syncline in two parts and causes a displacement of some 3 km in northern direction of the eastern half of the LCS. The general orientation is northwest–southeast for the western half and west–east for the eastern half (Menéndez et al., 2011; Ramirez and Menéndez, 1999; Solá et al., 2009; Soldevila Bartolí, 1992).

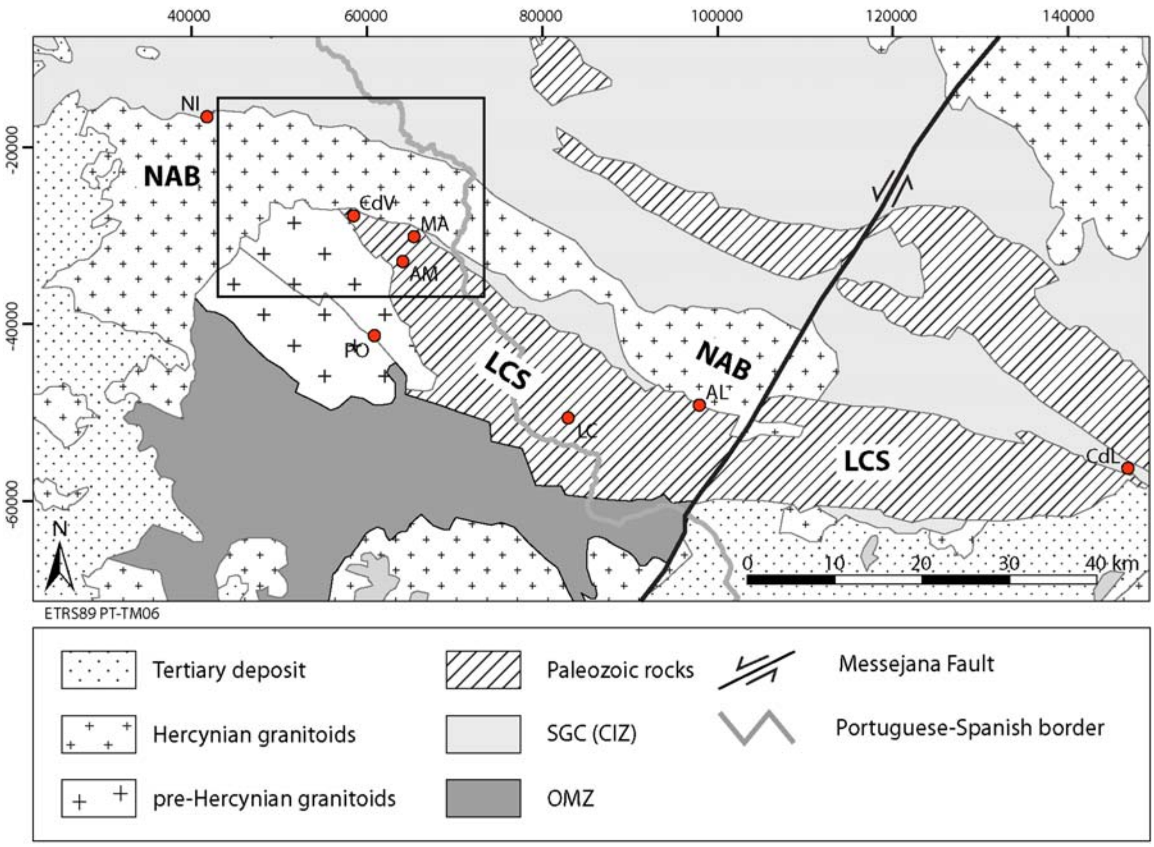

Figure 7.1 Schematic geological map of the geological situation around *Ammaia* (after Alvaro et al., 1994; Soldevila Bartolí, 1992). LCS = La Codosera Syncline, NAB = Nisa–Alburquerque Batholith, AL = Alburquerque, AM = *Ammaia*, CdL = Cordobilla de Lacara, CdV = Castelo de Vide, LC = La Codosera, MA = Marvão, NI = Nisa, PO = Portalegre. Marked area 1: see Figure 7.2, marked area 2: see Figure 7.4.

The LCS sequence starts with a quartzite formation of Arenigian age (Ordovician), known as the *Armorican Quartzite Formation*. The formation consists of pure quartzites (orthoquartzites) with *Cruziana* and intercalated yellow–red shales (Soldevila Bartolí, 1992). These Lower Ordovician quartzites form the steep ridges of the *Serra de São Mamede*. On top of the *Armorican Quartzite Formation*, Ordovician to Devonian quartzites, sandstones and shales were deposited, with conglomerates, carbonates and interlayered basic volcanic rocks towards the top (Soldevila Bartolí, 1992).

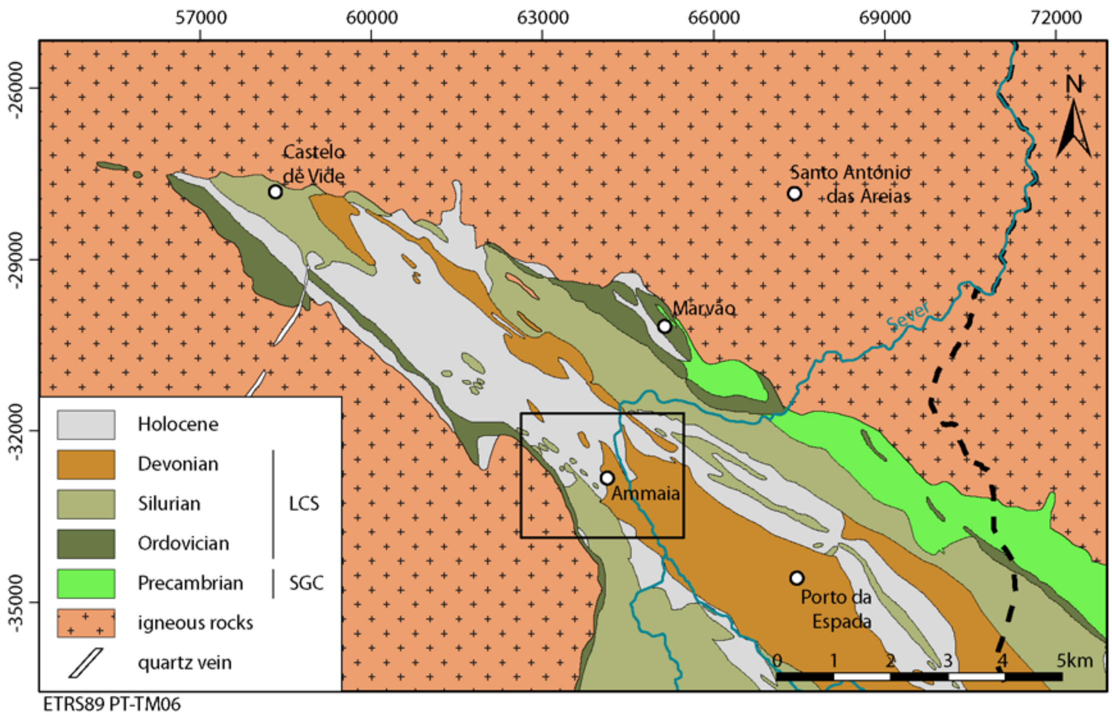

Figure 7.2 Simplified geological map of the northwestern part of the La Codosera Syncline (after Correira Perdigão and Peinador Fernandes, 1976; Peinador Fernandes et al., 1973). Marked area: see Figure 7.3.

Upper Ordovician–Lower Silurian quartzites are white–yellow to light grey. Upper Silurian–Lower Devonian quartzites and sandstones (Ludlovian–Siegenian) are generally grey and frequently display red colours as a result of a high Fe-oxide content. Shales are generally dark grey to black and are sometimes micaceous and rich in fossiliferous nodules with graptolites (Llanvirnian to late Wenlockian). Unfossiliferous shales and siltstones from the Silurian also occur. Near *Ammaia*, the core of the syncline is formed by Devonian shales, sandstones (sometimes with trilobites, brachiopods, etc.) and dolomitic limestones (Limpo de Faria and Pinto de Mesquita, 1962; Lopéz-Moro and Murciego, 2007; Piçarra et al., 1999; Sanderson et al., 1991; Soldevila Bartolí, 1992). In the syncline core, the Devonian deposits are covered by Holocene alluvial deposits, slope deposits and valley bottom deposits. Alluvial deposits are mainly sands and silts, slope deposits result from the weathering of the quartzite ridges, and valley bottom deposits are river cobbles and pebbles (essentially quartzite) (Correira Perdigão and Peinador Fernandes, 1976)(Figure 7.2 and Figure 7.3).

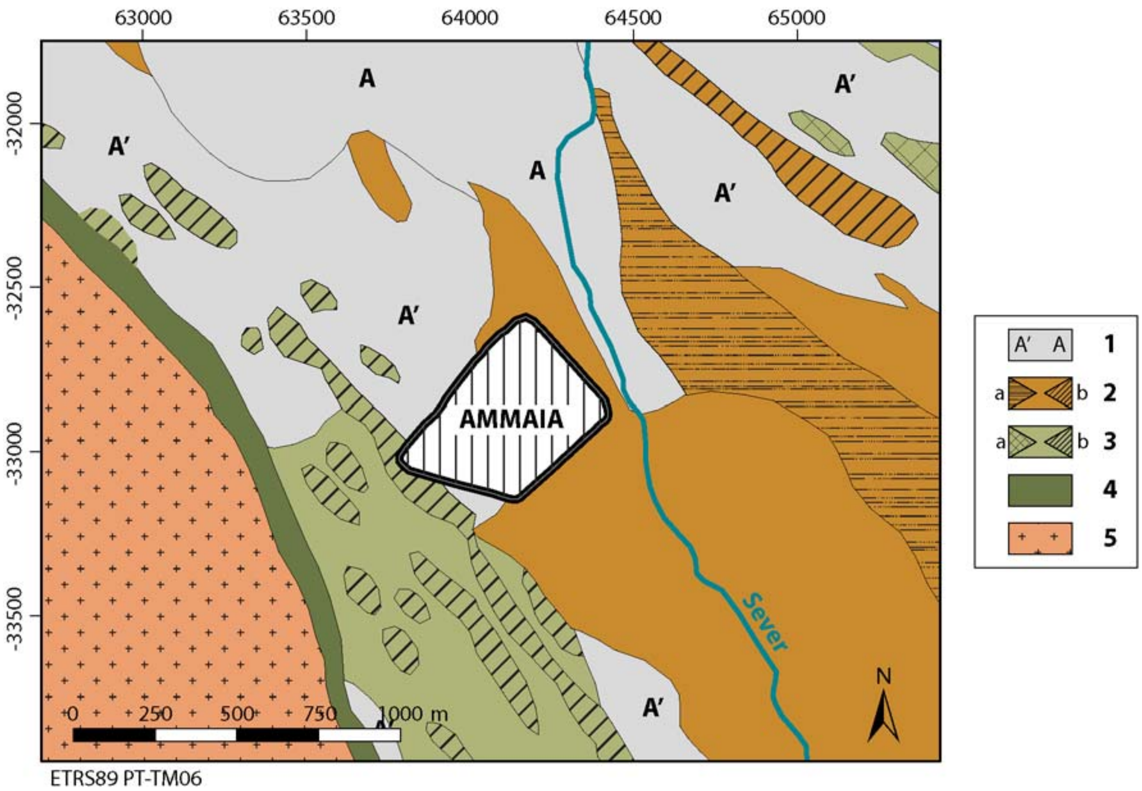

Figure 7.3 Geological situation around *Ammaia*. Legend: (1) Holocene slope deposits (1A') and valley bottom deposits (1A); (2) Devonian shale, with dolomite (1b) and quartzite (1b); (2) Silurian shales, with quartzite (2a) and sometimes Monograptus (2b); (3) Ordovician quartzites; (5) pre-Hercynian granitic orthogneiss (after Correira Perdigão and Peinador Fernandes, 1976; Peinador Fernandes et al., 1973).

Along the northern and western side of the LCS, the intrusion of the NAB results in a contact–metamorphic aureole of c. 1 km wide with pelitic and quartz–pelitic hornfelses and spotted slates (Dekkers et al., 1989; Limpo de Faria and Pinto de Mesquita, 1962; Ratola Duarte, 2002; Solá et al., 2009; Soldevila Bartolí, 1992) (Figure 7.1).

In Chapter 1, it was already mentioned that several large syn- to post-kinematic plutons intruded the OMZ, CIZ and OM–CI transition zone (Francisco Pereira et al., 2010; Ramirez and Menéndez, 1999; Solá et al., 2010; Solá et al., 2009; Villaseca et al., 2008). For the area of *Ammaia*, the most important of these plutons is the NAB, a late Hercynian intrusion (309.0 ± 4.6 Ma) that crops out over an area of c. 1000 km^2 (Solá et al., 2009). The NAB has an elongated, arcuate shape and crops out just a few kilometres north of *Ammaia* (Menéndez, 2002; Menéndez et al., 2011) (Figure 7.1).
From a petrographic perspective, four peraluminous, granitoid facies are identified in the NAB, three of which occur close to *Ammaia* (Figure 7.4). The principal is a

porphyritic, coarse-grained, two-mica monzo- to syenogranite that covers about 70 % to 85 % of the outcrop area and that hosts the other units. The granite consists of quartz, K-feldspar, plagioclase, biotite, muscovite, and minor amounts of cordierite, tourmaline and andalusite. K-feldspar and plagioclase are present as phenocrysts. Biotite is dominant over muscovite. The three other facies are a fine-grained granitoid, the so-called central granite A and the so-called central granite B. These appear as intrusions and/or magmatic enclaves within the host granite. Except for central granite B, which includes hornblende and titanite as accessories, the mineralogy of the facies is similar to that from the coarse-grained variety. Variations between these rocks are mainly due to textural features and the proportions of the constituent minerals. The fine-grained facies is an equigranular, two-mica tonalite to granodiorite (muscovite > biotite). The biotite content is lower than in the coarse-grained granite. Central facies A is a fine- to medium-grained, equigranular, two-mica granodiorite to monzogranite with muscovite and biotite forming less than 8 % of the rock volume and muscovite being dominant over biotite. Central facies B exhibits similar textural properties to central facies A, but consists of syenogranites. Again, it is a two-mica granite. The muscovite content is, however, a lot higher than that of biotite (in total, both being around 10 %) (Menéndez et al., 2011; Ramirez and Menéndez, 1999; Solá et al., 2009).

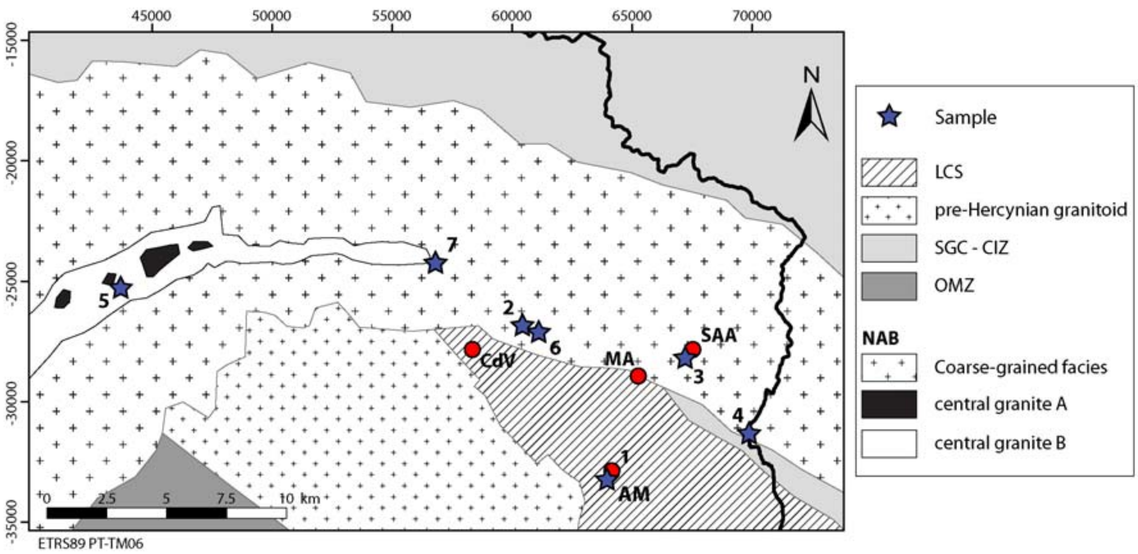

Figure 7.4 Geological map showing the different granite facies in the NAB (after Alvaro et al., 1994; Menéndez and Azor, 2006; Solá et al., 2009). Places: AM = *Ammaia*, CdV = Castelo de Vide, MA = Marvão, SAA = Santo António das Areias. Sample locations: (1) *Ammaia*, (2) Lajes, (3) Santo António das Areias, (4) Pitaranha, (5) Alpalhão, (6) 2.5 km east–northeast of Castelo de Vide, (7) 4 km north–northwest of Castelo de Vide.

Within the four granitoid units of the NAB, small textural and compositional changes occur over short distance (Menéndez, 2002; Menéndez et al., 2011; Ramirez and Menéndez, 1999). The specific characteristics of the rock at a particular location can therefore be determined only by megascopic observation in the field and subsequent examination of thin sections.

7.3 Provenance determination and stone characterisation

7.3.1 Granite

Ancient granite quarries in the *Ammaia* hinterland

Field surveys within a 10-km radius of *Ammaia* located four potentially Roman granite quarries at Marvão, Lajes, Santo António das Areias and Pitaranha (Figure 7.1). Even though the nature of the extraction techniques used at all four sites suggests an ancient, preindustrial exploitation, proposing a detailed chronology for the extractive activities at the quarries remains difficult as a result of scarce datable archaeological material and the conservative nature of quarrying techniques until the first half of the 19th century CE, when the mechanisation of the quarrying industry started (Bédon, 1984; Bessac, 1993). To assess the possibility of the sites for supplying *Ammaia* with the necessary building stone and to evaluate if the quarry could have operated in Roman times, all aspects related to extraction, organisation and logistics were studied.

The abandoned **Marvão** quarry lies on the western flanks of the Sapoio hill. The site is located about 3.5 km north of *Ammaia*, alongside the modern road from São Salvador da Aramenha to Marvão. Traces of ancient exploitation consist of a small hillside quarry with pickaxe cutting marks on a small quarry face of about 8 m high and 10 m wide (Figure 7.5). The nature of the pickaxe marks, the weathered state of the quarry face and the presence of slowly growing lichens on the quarry face indicate a historical exploitation (Taelman et al., 2009; Taelman et al., in press). The local granite outcrop is characterised by a very dense and irregular joint pattern and the presence of a small quartz vein with occasional rock crystal. The size of quarry, the well-developed joint pattern in the granite, the occurrence of rock crystal and the presence of several small debris heaps consisting predominantly of small quartz blocks suggest that the site was intended for obtaining quartz and rock crystal, rather than granite.

Figure 7.5 Quarry face at the Marvão quarry showing clear pickaxe cutting marks (location: 39.400584° N, 7.390149° W (WGS84)).

Small-scale quarrying was also attested at **Lajes**, some 6.9 km northwest of *Ammaia*. Ancient extraction is illustrated by negative traces of extracted blocks and by the presence of a large, abandoned, roughed-out millstone (Figure 7.6). The local granite landscape consists of low-angle, domed inselbergs that display secondary fractures parallel to the topographic surface resulting from pressure release after rock exposure (Migon, 2006). These exfoliation joints greatly facilitated block extraction at the Lajes quarry as they reduce the additional effort for cutting trenches (Deprez, 2009; Taelman et al., 2009; Taelman et al., in press).

Figure 7.6 Abandoned, roughed-out millstone at the Lajes quarry (length hammer: 30 cm) (location: 39.424727° N, 7.431854° W (WGS84)).

A third quarry is situated on a steep hillside just south of **Santo António das Areias**, about 5.8 km northeast of *Ammaia*. Evidence in support of ancient quarrying is comparable to that reported for the Lajes quarry and consists of negative traces of extracted blocks. No tool marks have been observed (Taelman et al., 2009; Taelman et al., in press). The most important advantage of the local granite is the advanced development of natural joints that are oriented almost perpendicularly, resulting in naturally formed blocks that could easily be detached from the bedrock with levers and crowbars (Figure 7.7). No trench-cutting or wedging was necessary (Deprez, 2009; Taelman et al., 2009; Taelman et al., in press).

Figure 7.7 Quarry front in the Santo António das Areias quarry with clearly visible natural joints (location: 39.410939° N, 7.351032° W (WGS84)).

The final site is located near the present-day border between Portugal and Spain, some 200 m northeast of the village of **Pitaranha** and about 6.5 km east of *Ammaia*. The quarry lies on the western slope of a semicircular hill of outcropping granitic rock. Features related to ancient quarrying are numerous and consist essentially of quarry faces, processing floors, abandoned roughed-out blocks, wedge holes and spoil heaps (Figure 7.8). In total, the site occupies an area of roughly 10 ha. The granite landscape at the quarry is dominated by ubiquitous irregularly distributed core stones of variable sizes and rounded shapes (i.e. boulder outcrops). Just as for the Marvão quarry, there is evidence of quartz mining at Pitaranha (Deprez, 2009; Taelman et al., 2009; Taelman et al., in press).

Figure 7.8 Unused wedge sockets (scale: 20 cm) and an abandoned, roughed-out block at the Pitaranha quarry (length trowel: 20 cm) (location: 39.369911° N, 7.313503° W (WGS84)).

Petrographic analysis

Due to the petrographic diversity of the NAB granite, thin section analyses were carried out to determine the provenance of the granite used in *Ammaia*. As all granites used in *Ammaia* have similar macroscopic properties, only one sample – from the Western Aqueduct – was selected for further examination under the polarising microscope in view of a thorough mineralogical and petrographic characterisation (Deprez et al., 2006). At the same occasion, rock specimens from the discovered preindustrial (potentially Roman) granite extraction sites (Lajes, Santo António das Areias and Pitaranha) and three modern quarries (located at Alpalhão, 2.5 km east–northeast and 4 km north–northwest of Castelo de Vide) were studied using the same method (Figure 7.4, Table 7.1). The granite from the Marvão quarry was excluded from petrographic observations, as the site was probably mined for quartz and rock crystal only.

The aqueduct specimen (sample 188/1) is a peraluminous, pale brown, medium-grained two-mica granite (brown to reddish brown biotite and muscovite) with sodium-rich plagioclase, quartz and K-feldspar. Accessory minerals include zircon and rare traces of magnetite. Plagioclase is generally zoned, with a calcic core, and shows albite and Carlsbad twinning. Sericitisation is not uncommon and affects especially the calcic core of the crystals. K-feldspars are composed dominantly of microcline–perthite and orthoclase, and both feldspar types are usually unaltered. Plagioclase and K-feldspar occur in equal proportions and a few subhedral grains are as much as 5–7 mm long. Some biotite crystals show pleochroic haloes caused by alpha–particle bombardment from zircon inclusions with radioactive impurities. Chloritisation of biotite is a rather uncommon feature. The muscovite crystals are always clean (devoid of opaque iron oxides), and rarely bent or kinked (De Paepe, 2009).

All of the other examined samples are peraluminous granites as well and resemble the aqueduct granite regarding mineralogy and petrography. The main differentiation of the specimens is situated in minor mineralogical characteristics of the rocks and in their megascopic properties (e.g. grain size). Regarding mineralogical constituents, the Lajes granite (sample 202/1) hardly differs from the sample of the Western Aqueduct.

Texturally, however, the Lajes granite tends to be finer in texture. The specimens sampled at Santo António das Areias (sample 179/1) and Pitaranha (sample 178/1) and the sample from *Ammaia* differ slightly as for the degree of sericitisation of the plagioclase and the state of chloritisation of the biotite. From a megascopic point of view, the samples look like the granite from *Ammaia* (medium-grained and hypidiomorphic–granular). The Alpalhão sample (sample 198/1) is also a mica granite, but differs in many respects from the other studied rock specimens. It is rather greyish and fine-grained, relatively rich in biotite and, moreover, contains epidote, apatite and magnetite as accessory minerals. Several biotite flakes are fully transformed into chlorite (penninite). Thin section analysis also shows the occurrence of cuneiform quartz and orthoclase intergrowths, and some interstitial patches built exclusively of fine-grained, equal-sized quartz crystals. The granite sampled 2.5 km east–northeast of Castelo de Vide (sample 201/1) (Figure 7.9) is mineralogically similar to the aqueduct granite. From a textural point of view, it has a weakly developed porphyritic appearance due to some large feldspar crystals in the rock. The two samples collected 4 km north–northwest of Castelo de Vide (sample 207/1 and 207/2) (Figure 7.9) are also two-mica granites. The first specimen is by far the coarsest and its muscovite to biotite ratio varies considerably from place to place. The reddish brown biotite embedded in the rock mass is currently chloritised and may display pleochroic haloes. Accessory minerals are apatite, iron ore and secondary calcite. The rock contains a few feldspar phenocrysts, up to 20 mm across. From a mineralogical point of view, the second granite sample contains epidote group minerals and much less primary white mica (De Paepe, 2009).

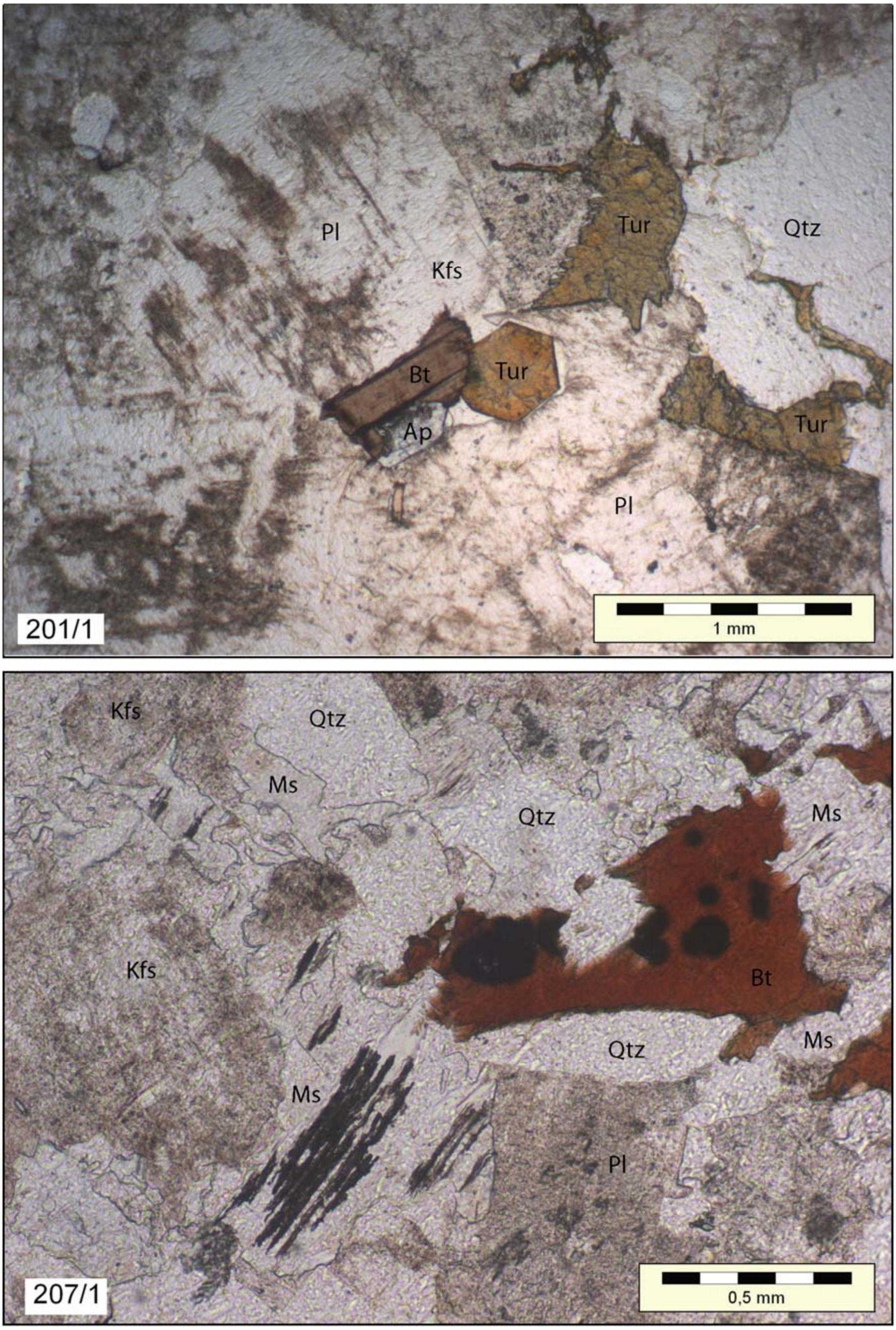

Figure 7.9 Microphotographs of granite sample 201/1 and 207/1 (in plane polarised light). Apatite (Ap), biotite (Bt), muscovite (Ms), K-feldspar (Kfs), plagioclase (Pl), quartz (Qtz), tourmaline (Tur).

Table 7.1 Mineralogical-petrographical description of the archaeological and geological granites sampled in and around *Ammaia*.

ID (map)	Location	Grain size[1]	Texture	Main mineralogy[2]	Mica types[2]	Accessories[2]
188/1 (1)	*Ammaia*	M	hypidiomorphic-granular	Na-rich Pl, Kfs, Qtz, Mca	red-brown Bt (sometmes with pleochroic halos), Ms	Zrn, Mag (traces)
202/1 (2)	Lajes	M	hypidiomorphic-granular	Na-rich Pl, Kfs, Qtz, Mca	red-brown Bt, Ms	Zrn, Mag (traces)
179/1 (3)	Santo António das Areias	M	hypidiomorphic-granular	Na-rich Pl, Kfs, Qtz, Mca	red-brown Bt, Ms	Zrn, Mag (traces)
178/1 (4)	Pitaranha	M	hypidiomorphic-granular	Na-rich Pl, Kfs, Qtz, Mca	red-brown Bt, Ms	Zrn, Mag (traces)
198/1 (5)	Alpalhão	F-M	hypidiomorphic-granular	Na-rich Pl, Kfs (Or), Qtz, Mca	relatively rich in red-brown Bt, Ms	Ep, Ap, Mag
201/1 (6)	2.5 km ENE of Castelo de Vide	M	hypidiomorphic-granular (slightly) porphyritic	Na-rich Pl, Kfs, Qtz, Mca	red-brown Bt, Ms	Zrn, Mag (traces), Tur
207/1 207/2 (7)	4 km NNW of Castelo de Vide	M	hypidiomorphic-granular (slightly) porphyritic	Na-rich Pl, Kfs, Qtz, Mca	red-brown Bt (with pleochroic haloes), Ms	Ap, Mag, (secondary) Cal, Ep (207/2)

[1] F = fine-grained, M = medium-grained;
[2] Mineral abbreviations, according to the Subcommision on the Systematics of Metamorphic Rocks (SCMR): Pl = plagioclase, Kfs = K-feldspar, Qtz = quartz, Mca = mica, Or = orthoclase, Bt = biotite, Ms = muscovite, Zrn = zircon, Mag = magnetite, Ep = epidote, Ap = apatite, Tur = tourmaline, Cal = calcite.

Conclusion

The exploratory characterisation of the four ancient extraction sites eliminated the Marvão quarry as a potential source for the granite used in *Ammaia* as the site was probably mined for quartz and rock crystal. While the other three localities (Lajes, Santo António das Areias and Pitaranha) show clear marks of preindustrial granite exploitation, the limited size of the two former quarries make it highly unlikely that they provisioned *Ammaia*. They probably served a nearby small-scale construction. There is no doubt that the Pitaranha quarry was the only quarry large enough to supply a town like *Ammaia*. This hypothesis is further strengthened by the strong petrographic resemblance between the granite from Pitaranha and *Ammaia* (Taelman et al., in press).

7.3.2 Gravelstones

Most material used for constructing the wall cores and foundations in *Ammaia* are gravelstones with a subrounded to rounded shape. The shape and nature of the stones points to detrital sedimentary material that was transported and deposited in a fluvial environment. The size of the gravelstones ranges from 10–15 cm up to 40 cm across. Their composition is normally quartzite, but some sandstone examples occur as well. Colour ranges from yellow–beige to brown–red (see Chapter 4 and Chapter 6).

The main sources for river gravelstones near the *Ammaia* are the Sever River and the *Ribeira do Porto da Espada*. The size of the gravelstones observed in the riverbed of both rivers ranges from small pebbles to large boulders (over 50 cm diameter). Dominant lithology of the stones is quartzite, but sandstone gravelstones can be found as well. The geological origin of the stones is traced back to the quartzite and sandstone units that make up the high ridges of the LCS. Like the stones used for the architecture, colours are yellow–beige to red–brown.

Quarrying the gravelstones simply involved collecting the loose stones from the riverbed. Stones were selected essentially on the basis of their size, with preference given to stones that were small enough to be carried using burden baskets, but that were large enough to allow efficient building (i.e. between 10 cm and 40 cm on average). As no bedrock extraction was needed and transport was straightforward, acquiring large amounts of gravelstones was very economical and did not need any elaborate infrastructure. Moreover, river gravelstones make an ideal building material because of their sizes and regular shapes. The miscellaneous appearance of the stones was no obstruction for its use, as these stones were generally used in non-visible architectural elements such as wall cores and foundations.

7.3.3 Shale

Different shale lithologies crop out abundantly in the LCS. The provenance study of the shales was limited to an area within a radius of 1 km around the town site. Within this zone, two different shale lithologies can be distinguished: (1) a grey–brown shale of Emsian age that is sometimes micaceous and sublucent; (2) a dark grey to black carbonaceous shale from the Upper Silurian (Llandoverian to late Wenlockian) that is locally micaceous and rich in graptolites (Correira Perdigão and Peinador Fernandes, 1976). As a result of long-time exposure to the atmosphere, the dark grey–black colour of the shales sometimes displays a more yellowish–brown colour (Soldevila Bartolí, 1992). The Emsian shales occupy a large area in the core of the LCS, especially southwest of *Ammaia*. Upper Silurian shales are found in small units intercalated in sandstone or quartzite units along the northern flank of the syncline (Correira Perdigão and Peinador Fernandes, 1976; Peinador Fernandes et al., 1973; Piçarra et al., 1999).
Recent geomorphological corings (De Dapper, 2011) (see Chapter 1) and archaeological excavations (see Chapter 4) have illustrated that underneath the alluvial (max 30 cm) and colluvial (up to 120 cm) sediments that form the present-day topographic surface, most of the geological substratum of the town consists of the Emsian shale. Further evidence of the shale geological substratum is visible in the Sever

riverbed (Figure 7.10-A&B). Moreover, archaeological evidence has indicated that the shale bedrock was exposed in the suburban area between the eastern town wall and the Sever River in Roman times (Figure 7.10-C&D and Chapter 4).

Figure 7.10 Shale outcrops near *Ammaia*: (A) Shale bedrock in the Sever riverbed (length hammer: 30 cm); (B) Hand specimen of the dark grey shale from the Sever riverbed; (C) Foundations of mausoleum in the suburban area between the town and the Sever River dug into the shale bedrock; (D) Hand specimen of the dark grey shale from the suburban area.

The macroscopic resemblance of the shale used for the architecture of *Ammaia* and the shale outcropping in the eastern part of the town and in the Sever riverbed indicated the exploitation of these local ouctcrops in Roman times.

Traces of shale extraction have been observed in relation to the few excavated structures in the area. For example, the main waste ditch of the town and the foundation trenches of the town wall and the extra-mural funerary monument were dug directly into the shale bedrock (Figure 7.10-C&D). As a result, large volumes of shale became progressively available during the constructions of these structures (see Chapter 4). In addition, a circular anomaly of about 20 m in diameter detected in the geomagnetic survey data of the fields between the town and the Sever River probably represents a local accumulation of rock material that might be interpreted the infill of an abandoned pit quarry (Eastern atlas, 2010).

Like for the gravelstone quarrying, no sophisticated exploitation and transport infrastructure was needed. Quarrying was probably rather opportunistic.

7.3.4 Sandstone

A full review of the bibliographical data of the local geology indicated only few sandstone units near *Ammaia*. Ferruginous sandstones (Siegenian age) are found together with quartzites about 9 km southeast of *Ammaia* on the flanks of the *Serra Fria*, near the village of São Julião. Ludlovian sandstones occur along the ridges west of *Ammaia* (Correira Perdigão and Peinador Fernandes, 1976). Recent geomorphological corings (De Dapper, 2011) (see Chapter 1) and geological field observations have illustrated that the flanks of the Malhadais hill, which is partly incorporated in the urban area, are made up of a fine-grained and well-cemented sandstone with a yellow–red–brown colour with the same characteristics as the sandstone used in *Ammaia*.

Within this latter sandstone unit, vertical aerial photographs and subsequent field observations revealed a semicircular, ancient quarry along the slopes of the Malhadais hill just north of the urban area (Figure 7.11). Originally, the semicircular feature was interpreted as the *cavea* of an ancient theatre with the seating area built into the hillside (Figure 7.11-A). The absence of architectural remains or even stone material on the surface was explained by later spoliation or the presence of a wooden theatre building (Pereira, 2005; Vermeulen et al., 2005). Recent observations, however, seem to disprove the hypothesis of a theatre in this location. A magnetometer survey conducted in 2011 revealed no clear evidence for archaeological structures (Eastern atlas, 2010) (Figure 7.11-B). In addition, two geomorphological corings provided no evidence whatsoever of structural remains in the area and support the identification of the area as a hillside quarry (De Dapper, 2011).

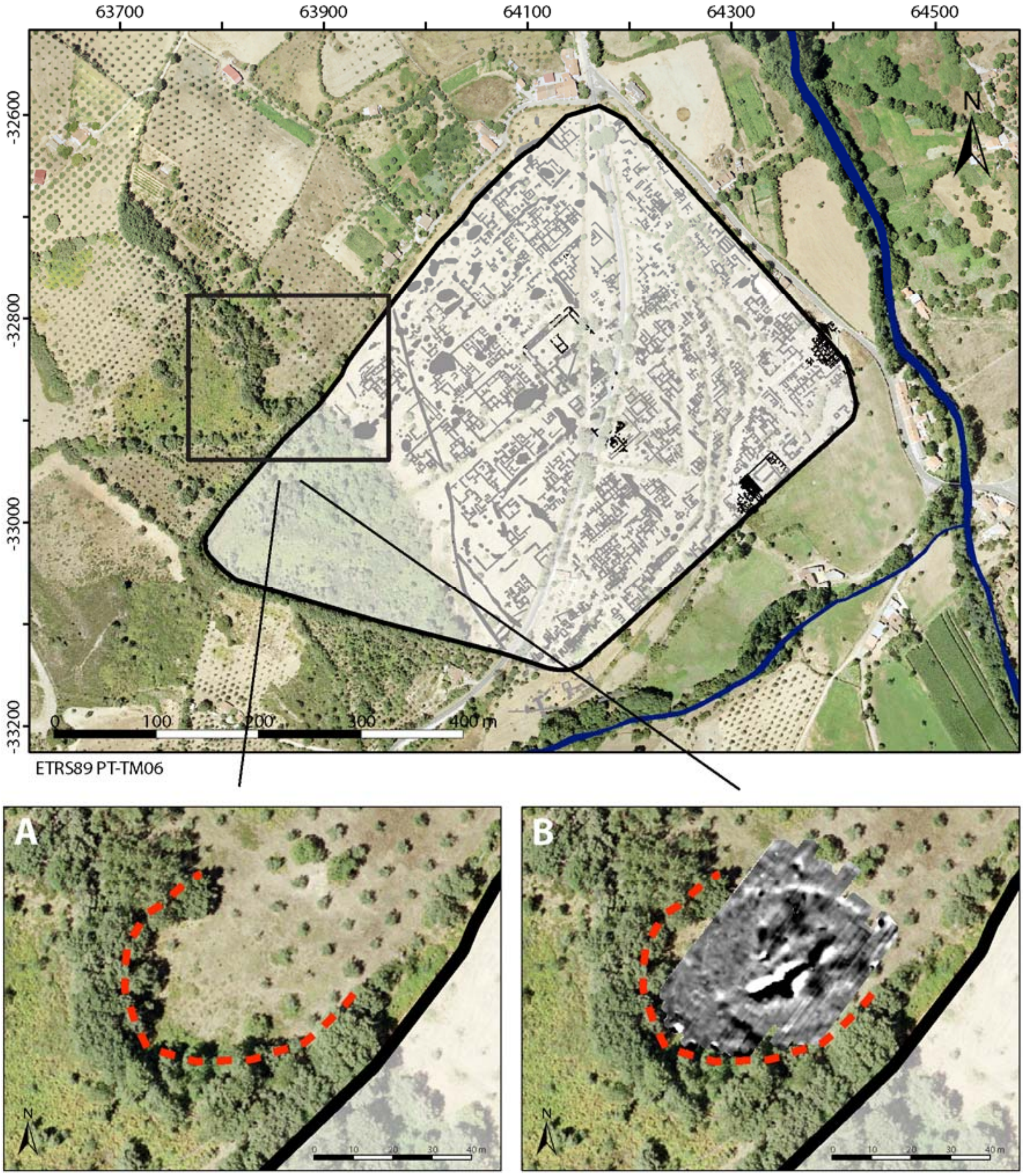

Figure 7.11 Aerial view of *Ammaia* and the sandstone quarry northwest of the urban area: (A) aerial view with extent of the final exploitation front, (B) aerial view overlain with greyscale image of the processed magnetometer survey data. The strong magnetic anomaly in the centre of the image refers to geology structures (Eastern atlas, 2010).

Initially, an extraction front of roughly 60 m long was exploited (Figure 7.11-A). As quarrying proceeded, the site developed into a semicircular hillside quarry with a final vertical quarry face of about 11.2 m high (Figure 7.12). The open area that was thus created in front of the quarry face was used as a processing floor. At present, the processing area is covered by a 60–85 cm thick cover of colluvial sediments. In front of the open area of the quarry floor, a small, elongated platform in the topography probably results from a covered debris heap of unusable sandstone chips discarded during the exploitation process.

Figure 7.12 (A) Part of the final extraction front of the sandstone quarry; (B) retaining wall of an artificial platform for easy access to the upper parts of the exploitation front.

At two locations along the final front, retaining walls were constructed using the local sandstone to create an artificial platform that allows easy access to the upper parts of the exploitation front. The retaining walls were constructed in dry wall masonry and could easily be broken down when the lower parts of the front needed to be quarried. The retaining wall along the southern side of the quarry measured approximately 17.6 m in length and was maximally 1.5 m high. The retaining wall along the western side of the quarry was 3.7 m long and between 1 m and 1.5 m high (Figure 7.12).

As quarrying was aimed at obtaining rubble stones (see Chapter 4), quarrying was not organised in a systematic and standardised way. The absence of wedge holes suggests that sandstone was extracted using the natural faults of the rock. It needs to be noted, however, that intensive weathering of the exposed rock outcrops, as a result of long-time exposure the atmosphere, has obliterated most traces of the ancient tool marks.

Volume estimates of the extracted stone at the quarry were determined on the basis of data obtained from a detailed topographic survey of the area (Figure 7.13 and Figure 7.14). Using the digital elevation model (DEM) and by extrapolating the original slope of the hill (c. 15 %), the maximum extracted volume of sandstone was estimated at around 15000 m^3 or some 34000 kg, calculated using an average mass density for sandstone of 2.24 kg/m^3 (Hunt et al., 1995). This large volume certainly exceeds the amount that was detected in the excavated buildings thus far, indicating that the local sandstone must have been used in several other architectural realisations in the Roman town.

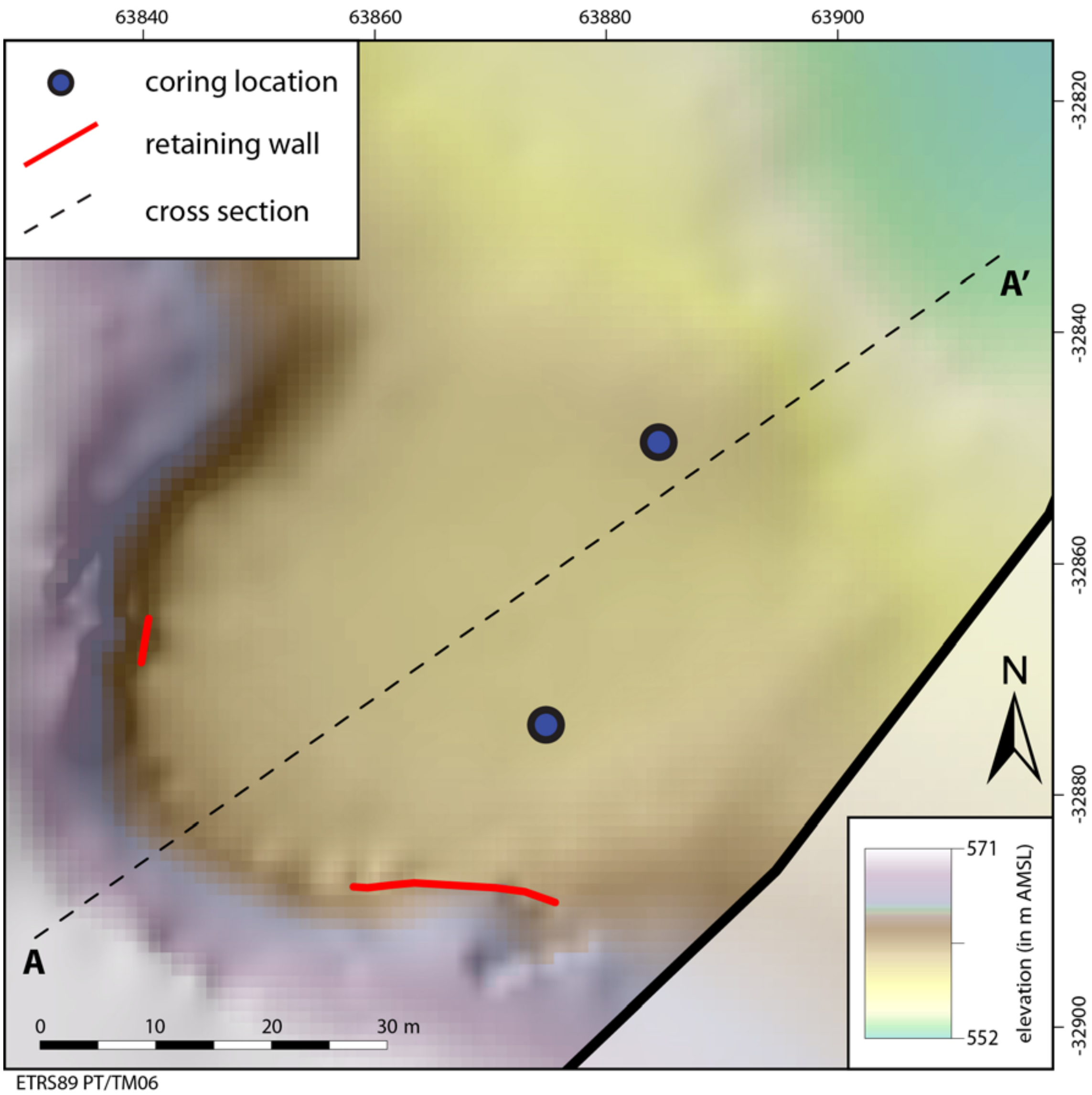

Figure 7.13 DEM of the sandstone quarry. Cross section A–A': seeFigure 7.14.

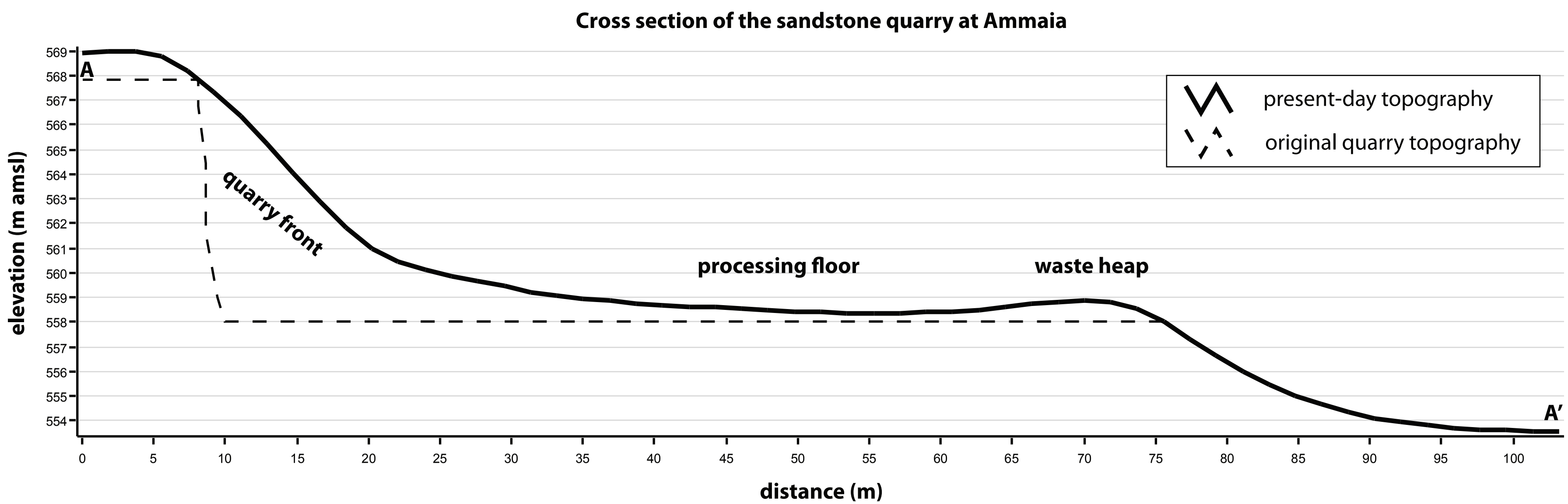

Figure 7.14 Cross section of the sandstone quarry at Ammaia, showing the original quarry topography and the present-day topographic situation (vertical exaggeration: 1.5x).

7.4 Organisation of building stone supply

In this final section of Chapter 4, the relationship between the town and its hinterland in view of the exploitation of building stones are discussed in more detail. Questions concerning the provenance determination of the building stones and the location of the quarries have already been discussed. The main aim of this final part is to define why particular areas or quarries were chosen for exploitation and how the stone exploitation and supply was organised in the resource landscape of the town.

7.4.1 Site catchment: a theoretical background

In the introduction to this chapter, the importance of a well-organised building stone supply system was already noted for the urban development of a town like *Ammaia*. This suggests that the exploitation happened in an economically efficient manner. Sources should be easily accessible (distance, methods and routes of transportation). Other important factors include the reliability and sufficiency of the sources, quality of the material and the costs and feasibility of obtaining the material (Fitchen, 1986).
These principles concur well with the basic concepts of site catchment analysis (SCA), as defined by people like Vita-Finzi & Higgs (1970) Jarman et al. (1972) and Jarman (1972; 1972), for Prehistoric subsistence economies. The authors describe 'catchment area' as the area around a settlement that was exploited regularly and profitably by a settlement's occupants. Fundamentally, SCA assumes that resource exploitation happened in an economically efficient manner and that the further a resources is located from the settlement, the less likely it is exploited (Flannery, 1976a; Metcalfe and Barlow, 1992). In other words, a settlement occupies a central position in an exploitable territory. Beyond the limits of this territory, exploitation becomes unprofitable and is

less likely to have occurred. The size of this exploitation territory depends on a complex set of factors, including the intrinsic value of the particular resource, the technology used for exploitation, the nature of the overall economic system of the society, and especially accessibility and available means of transportation (Jarman, 1972; Jarman et al., 1972). This latter aspect is the essential focus of SCA. For example, pack animals or ox carts can greatly reduce the costs of transportation in comparison with human transport, as more goods can be conveyed at the same time (Arnold, 1985).

Costs of accessibility or transportation can be described fundamentally as distance, as time or as energy (Arnold, 1985; Conolly and Lake, 2008; Jarman et al., 1972). In establishing the costs of reaching a certain location, the impact of the topography needs to be taken into consideration. Rather than the absolute or geodesic distance needed to reach a particular resource, the critical factor is the time or energy involved in travelling a specific distance (Jarman et al., 1972; Vita-Finzi and Higgs, 1970). For example, two locations at an equal distance from a source location may require a different time or effort to reach as a result of the terrain topography (walking uphill versus walking on a flat terrain) (Arnold, 1985; Wheatley and Gillings, 2002). Catchment areas therefore vary depending on local/regional conditions such as topography.

Regardless of the method for describing these costs, a degree of uncertainty and variability needs to be taken into account when interpreting the modelled results. These constraints not only originate from, for example, differences related to biological factors such as varying individual walking pace or energy expenditure, but also from the many unknown factors that influence the results of the calculated models. The SCA models should therefore not be regarded as absolute, but rather as indicative or relative values that allow establishing and comparing the relative accessibility of different locations in the exploitation landscape of an archaeological site (Conolly and Lake, 2008; Jarman, 1972).

Early SCA studies were carried out by using a simple distance radius to define a catchment areas or by manually plotting distance or time contours on a map that were calculated by field walking along transects outwards from a site in the four cardinal directions for a given time (Ullah, 2011; van Leusen, 2002). Recently, the improvement of computational power and the proliferation of geographical information systems (GIS) in archaeological have greatly enhanced site catchment modelling. This is coupled with the availability of high-quality DEMs that allow a more realistic digital representation of the physiographic landscape that better fits the complexity of the actual landscape (Hunt, 1992; Ullah, 2011).

The first step in determining the catchment area for a given site consists in generating a *cost surface map*. A cost surface map is a digital model of the landscape in which each cell of the raster map is assigned a cost value needed to cross the cell (van Leusen, 2002). To create realistic and effective models, a combination of criteria that influence the energy or time needed to cross the landscape can be used to the define this cost value (Howey, 2007; van Leusen, 2002). Nevertheless, it needs to be considered that even the GIS-generated cost surfaces are only a hypothetical representation of the reality and that also these do not incorporate all criteria that determine the way people travelled in the past (Siart et al., 2008). Therefore, even the results of a GIS-based SCA should not be taken as absolute (see above).

At present, many different methods or algorithms exist to calculate a cost surface map, most of them designed for modelling human walking. Among these algorithms, a distinction can be made between isotropic and anisotropic algorithm, where isotropic algorithms are independent of the direction of travel and anisotropic algorithms incorporate the effect of direction of movement in determining travel cost (Conolly and Lake, 2008; Wheatley and Gillings, 2002). The most used algorithms for generating a cost surface are the equation of Tobler (1993) that models cost as a function of time, and the equation of Pandolf et al. (1977) that models cost as a function of energy.

Following, a cumulative cost algorithm is applied to the cost surface map in order to generate a cumulative cost surface map where the minimum cost of moving from a specified origin, i.e. the archaeological site, to each cell in the new raster map is defined (Conolly and Lake, 2008; Llobera et al., 2011). Based on this cumulative cost surface map, the relative accessibility in the landscape of different locations from a specified origin can be compared.

7.4.2 Digital elevation model of the study area

Aster data was used to produce the necessary topographic data for the site catchment analysis. The Aster-DEM was reprojected into the ETRS89 PT/TM06 national coordinate system of Portugal with a 30 m pixel size for incorporation with all other spatial data gathered during the geoarchaeological surveys for the stone exploitation and supply of Roman *Ammaia*.

An area of 30 km by 30 km, centred on the Roman site of *Ammaia*, was selected for the SCA study, in which focus was set on the area within a 10-km radius of the town. The size of the study area was chosen as this certainly includes the area in which economic activities were oriented towards the town. Roman town are generally located within close distance of suitable sources of building stone. On average, towns are located no more than 10–15 km away distance from their primary quarries. In some rare cases, this distance can attain up to c. 30 km (Bédon, 1984; Bessac, 1988a; Goodman, 2007; Russell, 2008). For example, the granite quarries of *Emerita Augusta* are generally located at a distance of 5–7 km from the town, with two exceptions at a distance of 12 km and 18.25 km (Pizzo, 2010a). A similar view can be seen in other preindustrial societies; for example, Flannery (Flannery, 1976b) proposes a maximum distance of 15 km for the procurement of building material for Mesoamerican villages.

7.4.3 Cost surface map and cumulative cost surface map

The cost surface map and cumulative cost surface map were generated using ESRI's ArcGIS 9.3 and the open source GIS software gvSIG 1.11.0. For the cost surface map, the metabolic cost of walking was modelled using the equation of Pandolf et al. (1977):

$$M = 1.5W + 2.0(W + L)(\frac{L}{W})^2 + N(+L)(1.5v^2 + 0.35vG)$$

in which M is the metabolic rate in watt, W is the body weight of the person in kg, L is the load carried in kg, N is the terrain factor, v is the velocity of walking in m/s, and G is the slope in %.

For the terrain factor, a default value was taken as it is assumed that all movement in Roman times would have taken place over similar roads. A value of 1.0 for metalled roads, as defined by Givoni & Goldman (1971), was selected. To prevent constant crossing of rivers, the terrain factor for rivers was artificially raised to 22.0, a value proposed by van Leusen (2002) for larger streams.

In slope calculation, no distinction was made between upslope and downslope travelling (see above for discussion on isotropy and anisotropy). Since the study focused on the town of *Ammaia* as central place from which the exploitation of building stones was organised, it is believed that movement between the town and its quarries was a round trip. As a result, the same slope is travelled both uphill and downhill and an isotropic algorithm could be used. For this reason, the calculated cumulative cost values were multiplied by 2 to get the metabolic cost for a round trip.

The remaining variables (*W*, *L* and *v*) were kept constant. Values were taken similar to the ones used by van Leusen for the Wroxeter Hinterland Project (van Leusen, 2002), with body weight of 70 kg, a load of 4 kg and velocity of 1.33 m/s (4.8 km/h).

7.4.4 Result and discussion

A visual inspection of the cumulative cost surface map (Figure 7.15) immediately reveals the importance of the LCS and of the Sever River Valley for the accessibility of the area around *Ammaia*. The central part of the syncline, with its flat plains, and the Sever River Valley form the main transportation corridors, with the high quartzite ridges of the *Serra de São Mamede* acting as natural barriers.

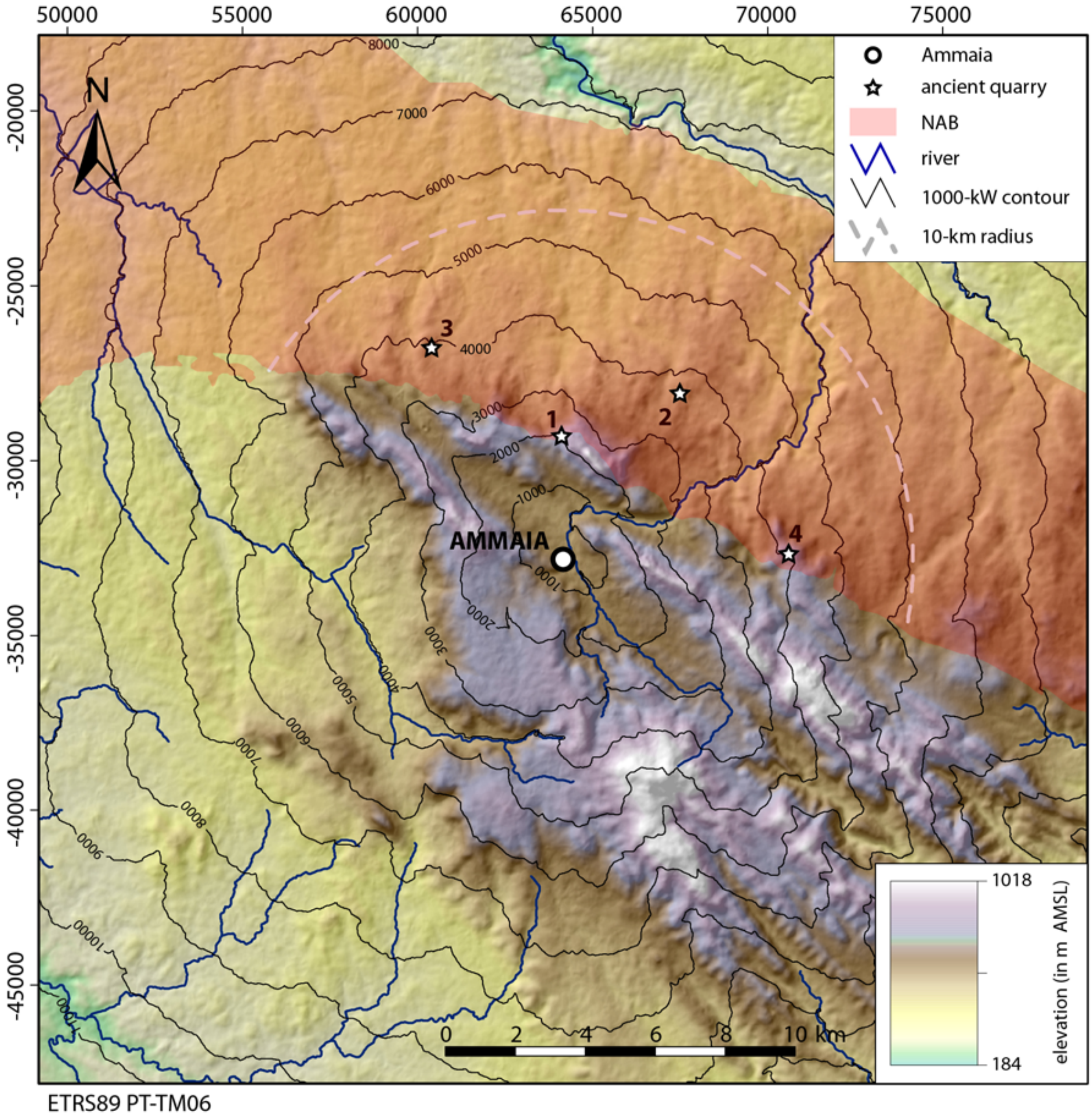

Figure 7.15 DEM of the study area with indication of the four ancient granite quarries in relation to the cumulative cost surface results (contours), the NAB (red) and the 10-km survey radius (light grey dashed line).

In studying the location and accessibility of quarries in the *Ammaia* hinterland, it is clear, even without modelling the catchment area of the town, that proximity and ease of transport were the keywords for obtaining most natural building stones used for the architecture of *Ammaia*. For wall foundations and wall cores, gravelstones, shale and sandstone were the primary stones. These were obtained either on-site or in the immediate suburban area, at a distance of less than a few 100 m. Proximity and ease of procurement and transportation were clearly decisive in the choice of the raw material for these non- visible parts of the architecture, while the miscellaneous appearance of these natural building stones was of little importance. The importance of ease of transportation is also illustrated by the use of rubble stones that could be conveyed by human porters with carrying baskets or by donkeys or mules with panniers. As no complex transportation methods were required and transportation distance was short, costs of transportation would not have been costly.

The situation for granite is somewhat more complex. Thin section observations of the granite used in *Ammaia* have revealed the use of the granite from the NAB, of which the closest outcrops can be found about 2.5 km north of *Ammaia*. The relative accessibility of the four potential Roman quarries in the NAB (Marvão, Santo António das Areias, Lajes and Pitaranha) was defined by comparing the metabolic cost for reaching the quarries with the metabolic cost for reaching a set of 28456 points in the NAB arranged in a grid of 100 m by 100 m.

Table 7.2 Metabolic cost (M) for reaching the identified ancient quarries and a set of points in the NAB in a grid of 100 m by 100 m.

M – NAB (kW)		M – 10-km (kW)		M – quarries (kW)	
min	3728.28	min	3728.27	Marvão	3992.76
max	20199.63	max	14376.61	Santo António das Areias	7239.59
mean	12828.10	mean	9444.46	Lajes	7719.70
st.dev.	3461.16	st.dev.	2131.51	Pitaranha	10022.32
n	28456	n	10588		

Even though the petrographic and geoarchaeological observations have revealed the Pitaranha quarry as the main granite supplier for *Ammaia*, it is remarkable that the other three quarries – Marvão, Santo António das Areias and Lajes – are significantly easier to reach. Moreover, petrographic examination has not yet detected the use of the granite from the three smaller quarries at *Ammaia*. However, this could result from the state of the research; it is possible that these smaller quarries were exploited for specific projects or buildings that have not been excavated yet.

In comparing the cost of reaching Pitaranha with the cost of reaching a set of random locations in the NAB and within a 10-km radius from *Ammaia*, it becomes evident that not the closest granite outcrop was selected to supply *Ammaia*. Several reasons can be proposed as to why the Pitaranha granite was selected in favour of the many granite outcrops that were located in more accessible locations, among which the geological and geomorphological properties (e.g. joint pattern) of the particular Pitaranha granite is the most plausible explanation (see Chapter 8). The ancient stonecutters actively procured good quality granite building material for the construction of the public and monumental building complexes in *Ammaia*, even if this meant a higher to transportation effort or cost. In addition to the general geological and geomorphological advantages offered by the local granite, the joint occurrence of granite and quartz and rock crystal certainly was a major asset for the exploitation of the Pitaranha quarry. Finally, it should be kept in mind even though more accessible granite outcrops exist in the study area, the Pitaranha quarry was still located relatively close to *Ammaia*, at a distance of 6.5 km.

Chapter 8
The Pitaranha quarry

In Chapter 7, the importance of the Pitaranha quarry for supplying Roman *Ammaia* with its necessary granite building material was illustrated. In this chapter, the results of a detailed mapping and survey approach for the Pitaranha quarry is presented, with the aim of defining the ancient technological and social organisation of the extractive activities. A detailed quarry study gives an important insight in the processes involved in stone selection, the production of stone blocks, and the logistics related to transportation of the stone material and the social aspects of the quarrying works (Heldal, 2009). In addition to a detailed investigation of the local geomorphological and geological characteristics, aspects like quarry organisation and layout, extraction techniques, chronology and transport inside the quarry and to *Ammaia*, and administration of the quarry works are discussed. For this, a detailed survey approach for the site was adopted, based on a newly developed, straightforward and cost-effective mapping strategy that served as a base for all further field work.

8.1 Mapping the Pitaranha quarry

As archaeology is to a large extent a spatial discipline, the recording of the spatial data component is in most cases of the utmost importance for scientific archaeological research. For complex sites such as the quarry of Pitaranha, this can be a difficult, time-consuming and very expensive operation. To fully comprehend the particular quarry mechanisms and for an in-depth archaeological interpretation, a detailed mapping and survey of the site is, however, indispensable. The complex morphology and topography of the quarry landscape at Pitaranha, as well as the severe modification of the terrain configuration by both intensive quarrying and the intricate logistical extraction infrastructure complicate the site survey. Since an accurate digital representation of the topographic surface is elementary for the spatial analysis of the quarry and the availability of an orthophoto map a necessary prerequisite for fast and effective site navigation, the acquisition of such information is a crucial component of efficient quarry research.

To date, different institutions and practitioners from a variety of scientific fields have focused on the production and usage of DEMs and orthophotos. Many technologies and approaches exist, but all are characterised by certain disadvantages. A standard surveying with total station (cf. De Wulf, 1996) and GNSS (global navigation satellite system) receivers is often inadequate for this purpose. These techniques are often too time-consuming and generally do not provide the required data density to enable high-detail archaeological investigation. Availability and financial considerations prohibited a vertical aerial photographic coverage and a terrestrial or airborne laser scanning approach. Moreover, the processing of LiDAR data often necessitates a thorough technical understanding and appropriate (i.e. costly) software. As a result of the disadvantages of the mentioned techniques, a straightforward and cost-effective hard- and software methodology was developed for the accurate mapping of the Roman quarry of Pitaranha. The methodology applies an unmanned low-altitude aerial photography system to gather aerial views of the quarry. Recent technological improvements in hardware configurations and state-of-the-art computer vision and photogrammetry algorithms were exploited to process the far-from-optimal airborne images. Since it is known that the quality of a spatial data set can significantly affect the subsequent GIS analyses, both the horizontal and vertical accuracy of the produced results are also assessed.

8.1.1 Low-altitude photographic mapping

Ground control

Since the aim was to map the quarry using an airborne digital camera, there was a need to establish a dense network of well-distributed ground points. In total, 88 targets were marked on the ground and their positions determined using a total station survey (applying a Nikon DTM-520). On the relatively flat and sandy surfaces, highly visible 40 cm by 40 cm square cardboard tiles were used as markers. Since these tiles could not be fixed to the rocky granite surfaces, most ground points were created by a combination of highly reflective pink-and-white painted triangles. These marks proved to be easily visible on the aerial images (Figure 8.1).

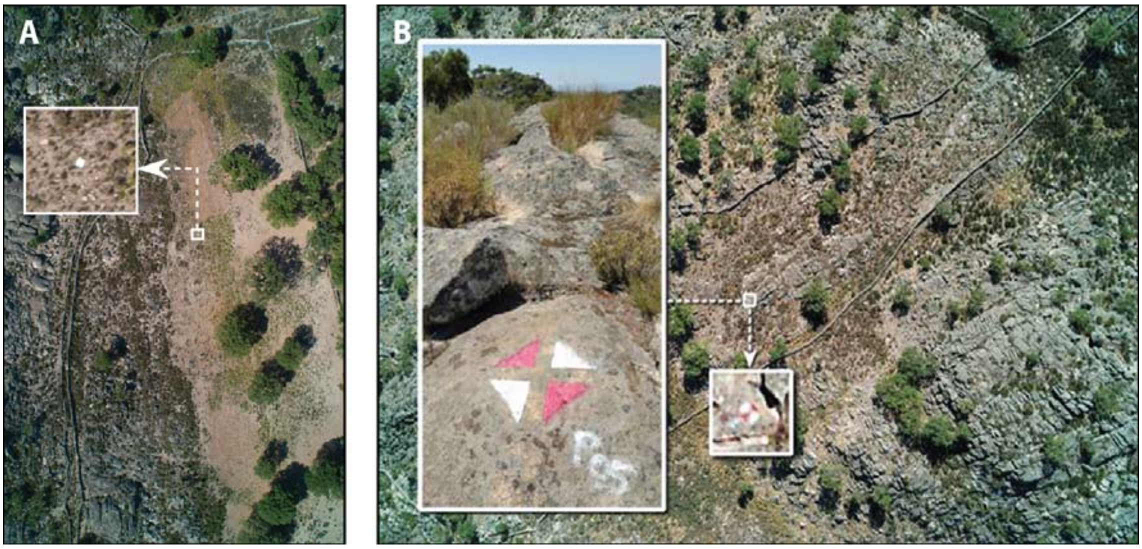

Figure 8.1 Two oblique aerial images taken with the Helikite platform. The insets show the two types of ground points used for georeferencing and accuracy evaluation: (A) square cardboard tiles; (B) highly reflective pink-and-white painted triangles.

A small subset of the marks was used as ground control points (GCPs) to georeference the generated reconstruction, while the remaining ground points functioned as a highly accurate data set of check points (CPs), to assess the positional accuracy of the generated orthophotograph and 3D model. The accuracy of each surveyed ground point was expected to be better than 2 cm in all dimensions, with all coordinates expressed in a Pitaranha-specific, Euclidian reference frame (Verhoeven et al., 2012).

Helikite aerial photography

For data capture, an unmanned Helikite-based aerial system (Helikite aerial photography or HAP) was used, developed by the Archaeology Department of Ghent University (Verhoeven and Loenders, 2006; Verhoeven et al., 2009) (Figure 8.2). The HAP-platform was equipped with a 10 MP Nikon D80 reflex camera fitted with a Nikkor 20 mm *f*/3.5 AI-S). Although this lens suffers from quite extensive radial and tangential distortions, it offers a large angular field of view (61° by 43°) and is very light (235 g).

As a result of unstable wind conditions (thermal airstreams alternating with windless periods) and strong electromagnetic interference during camera and platform control, an unstructured collection of about 1400 digital photographs was necessary to cover almost the entire quarry site. The scale of these images varied enormously, while the camera orientations – and to a certain extent the flight path – were almost random, and certainly not as structured as initially intended (Figure 8.3). Since the ground–sampling distance (GSD) varied between approximately 3 cm and 8 cm, this variation was expected to be challenging, because high-resolution detail would be attenuated with low-resolution geometries extracted from the images taken at high altitudes. Obviously, all these factors are normally not encountered in the highly structured data sets acquired by conventional aerial survey. This meant that a processing approach had to be found that could deal with this large unorganised photo collection.

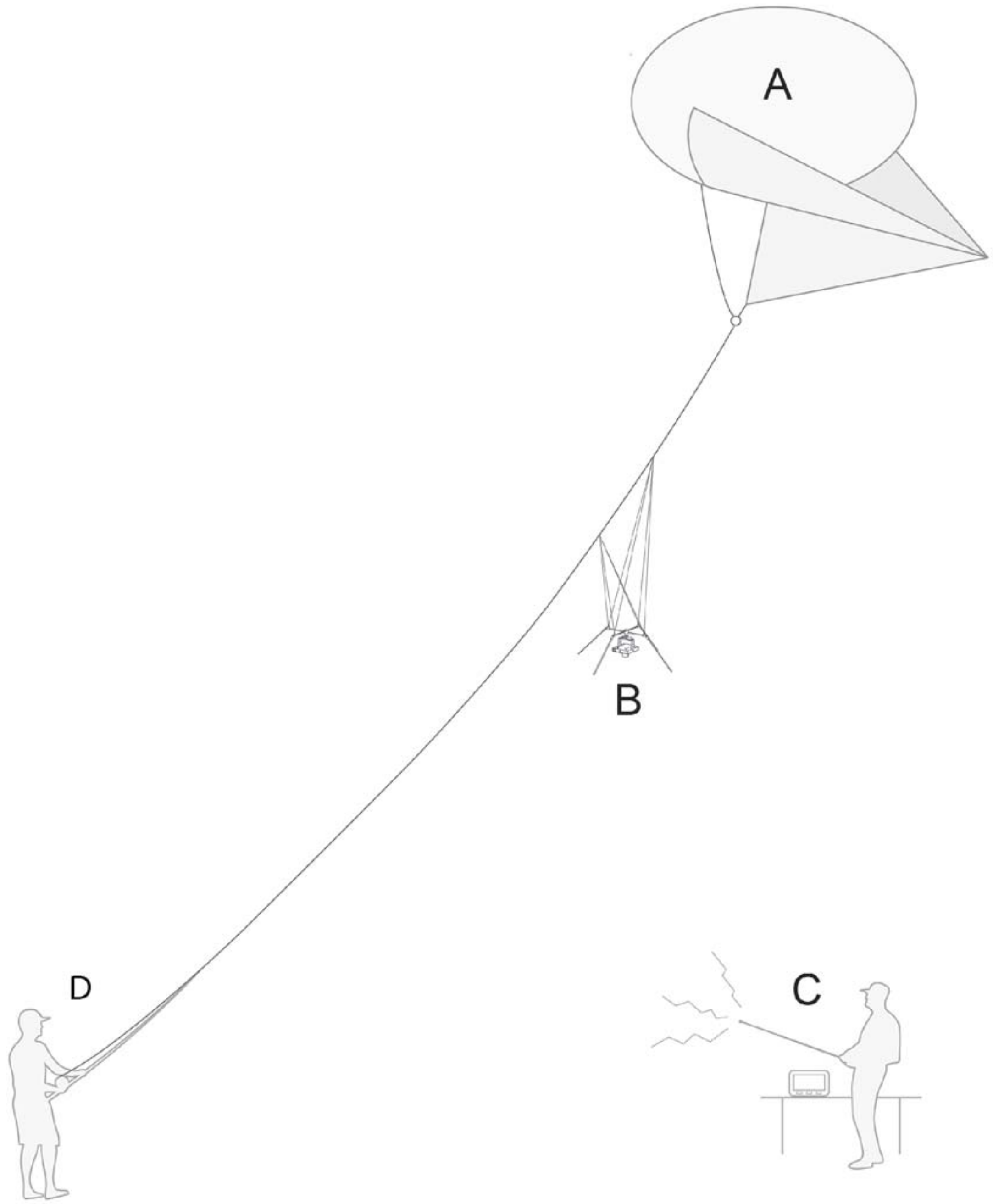

Figure 8.2 Schematic overview of the Helikite aerial photography (HAP) system: (A) a Helikite; (B) a remote-controlled digital still camera; (C) a camera operator with live video; (D) the HAP operator.

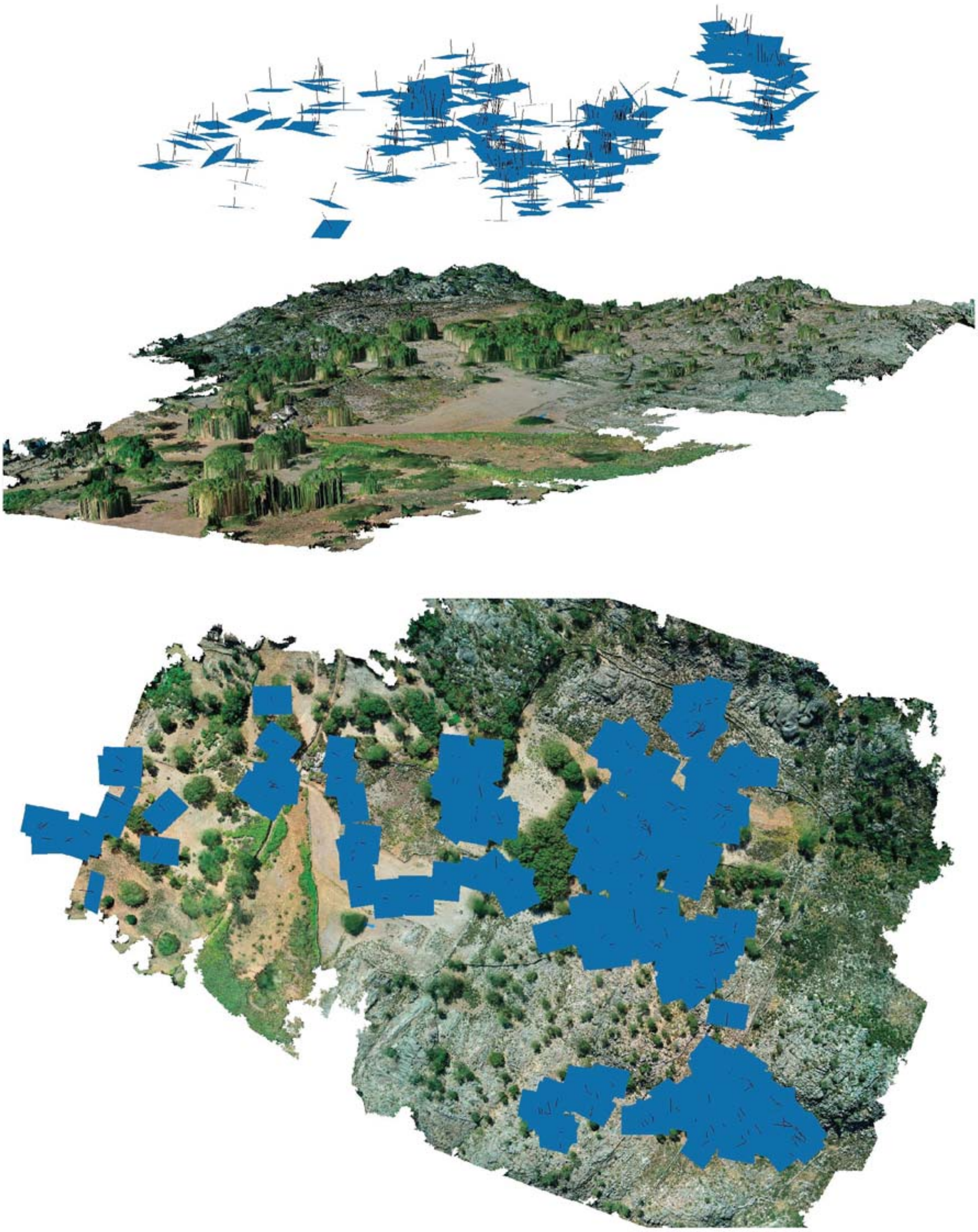

Figure 8.3 Perspective and orthographic view of the Pitaranha quarry illustrating the unstructured data acquisition. The blue squares indicate the locations of the camera for the 377 images that were selected for further processing.

Structure from Motion

Many tools and methods exist to obtain information about the geometry of 3D objects and scenes from 2D images. One of the possibilities is to use multiple image views from the same scene. Using techniques such as triangulation, an image point occurring in at least two views can be reconstructed in 3D. However, this can only be performed if the projection matrices of the images are known. These projection matrices express the interior calibration parameters of the camera used (the focal length, the principal point location plus lens distortion coefficients) and camera poses (i.e. the location of the projection centre and the image orientation defined by the six exterior orientation parameters) at the moment of image acquisition. While photogrammetry derives these parameters mainly from well-distributed GCPs, a structure from motion (SfM) (Ullman, 1979) approach allows simultaneous computation of the relative projection geometry and a set of 3D points, using only corresponding image features from a series of overlapping photographs captured by a camera moving around the scene (Fisher et al., 2005; Quan, 2010; Szeliski, 2010). SfM relies on algorithms that detect and describe local features for each image – called image feature points – and that subsequently match those 2D points throughout the multiple images. This results in a number of potential correspondences (often called tie points). Using this set of correspondences as input, SfM computes the locations of those feature points and renders them as a sparse 3D point cloud that represents the geometry/structure of the scene in a local coordinate frame. As mentioned before, the camera pose and internal camera parameters are also retrieved (Hartley and Zisserman, 2003; Szeliski, 2010). There is thus no need to use calibrated cameras and optics during the image acquisition stage (Quan, 2010), which makes the procedure very flexible and well suited for almost any kind of imagery; in particular, an unordered photo collections such as the one dealt with in this case study.

SfM algorithms are used in a wide variety of applications but were developed in the field of computer vision, which is often defined as the science that develops mathematical techniques to recover a variety of spatial and structural information from images. Recently, SfM received a great deal of attention due to Bundler (Snavely, 2010) and Microsoft's Photosynth (Microsoft Corporation, 2010): two SfM implementations that are freely available on the Web. To date, several SfM-based packages can be applied to obtain a (semi-)automated processing pipeline for image-based 3D visualisation. In this study, the commercial package PhotoScan (v. 0.8.1, build 877) from AgiSoft LLC was used, since it provides all the necessary tools in one low-cost package.

8.1.2 Data processing

In a first step, the complete image data set was reduced to a more manageable photo collection of 377 sharp and well-exposed images (Figure 8.4-A). Afterwards, 19 SfM routines were run by varying the maximum amount of feature points per image (e.g. 500, 1000 and 2000). Since PhotoScan (along with most other SfM applications) does not currently provide tools or statistical measures that allow direct inspection of the quality and accuracy of this alignment step, alignment problems can only be assessed visually. Hence, the six SfM approaches that failed in the alignment of all input images were discarded. At this stage, the point cloud and camera poses of the remaining 13 SfM solutions are still expressed in a local coordinate framework and equivalent of the original scene up to a global scale and rotation factor. To transform the SfM results into an absolute coordinate system, a Helmert similarity transformation was applied. Seven parameters (three translations, one scale, and three rotations) must be determined for this spatial transformation, so at least three GCPs with known altitude values were needed. Since measurement inaccuracies of the GCPs and the accuracy of indicating the GCPs both affect the final transformation parameters, it is advisable to use a few more points to assure a better georeferencing. In this case, seven well-distributed and clearly visible points out of the 88 target points were treated as GCP and applied in the georeferencing of all 13 SfM solutions. Only the SfM solution that proved to be most accurate was kept for the subsequent processing steps (Figure 8.4-B). This approach differs from the standard aerial photogrammetric approach, in which georeferencing – which is achieved by aerotriangulation, possibly assisted by data from a GNSS receiver and inertial measurement unit (IMU) data (Jacobson, 2004; Kraus et al., 2006) – precedes the 3D model generation. As georeferencing is the second (or most often final) workflow stage of the presented approach, any remaining distortion in the 3D model (due to erroneous image alignment in the SfM stage) will not be corrected by georeferencing. The low georeferencing errors (6.1 cm, 3.8 cm and 7.3 cm as mean residuals between the true and calculated values in the x, y and z dimensions, respectively), however, indicated that no large systematic distortion was present in the reconstructed scene, and that a detailed and continuous 3D surface could be calculated from the SfM result (Verhoeven et al., 2012).

Since PhotoScan is tailored towards high-level 3D model generation, the SfM approaches are complemented with a variety of dense multiview stereo (MVS) algorithms. One could, for example, interpolate the sparse set of 3D SfM points, but this would yield a far from optimal result. Therefore, a MVS reconstruction is used to compute a dense estimate of the surface geometry of the observed scene. Because these solutions operate on pixel values instead of on feature points (Scharstein and Szeliski, 2002; Seitz et al., 2006), this additional step enables the generation of detailed 3D meshed models from the initially calculated sparse point clouds, hence enabling proper handling of fine details present in the scenes. More specifically, PhotoScan v. 0.8.1 offers three reconstruction methods that use a pairwise binocular stereo approach (Bradley et al., 2008) to compute a depth estimate (i.e. the distance from the camera to the object surface; see Figure 8.4-C) for almost every image pixel of each view (Mellor and Lozan-Pérez, 1996; Pollefeys et al., 2004). Fusing the resulting independent depth maps of all the images yields a single 3D model, which is subsequently approximated by a triangular mesh (Figure 8.4-D). PhotoScan's different reconstruction methods (exact, smooth and height-field) differ in the way in which these individual depth maps are merged into the final digital model. When working with aerial images, the calculated model can be considered a digital surface model (DSM): a numerical representation of the topography and all its imposed structures, such as trees and houses. As is known from conventional orthorectification, such a dense DSM is elementary when one wants to generate a so-called true orthophoto, in which all objects with a certain height (such as houses, towers and trees) are also accurately positioned (Braun, 2003; Kraus et al., 2006).

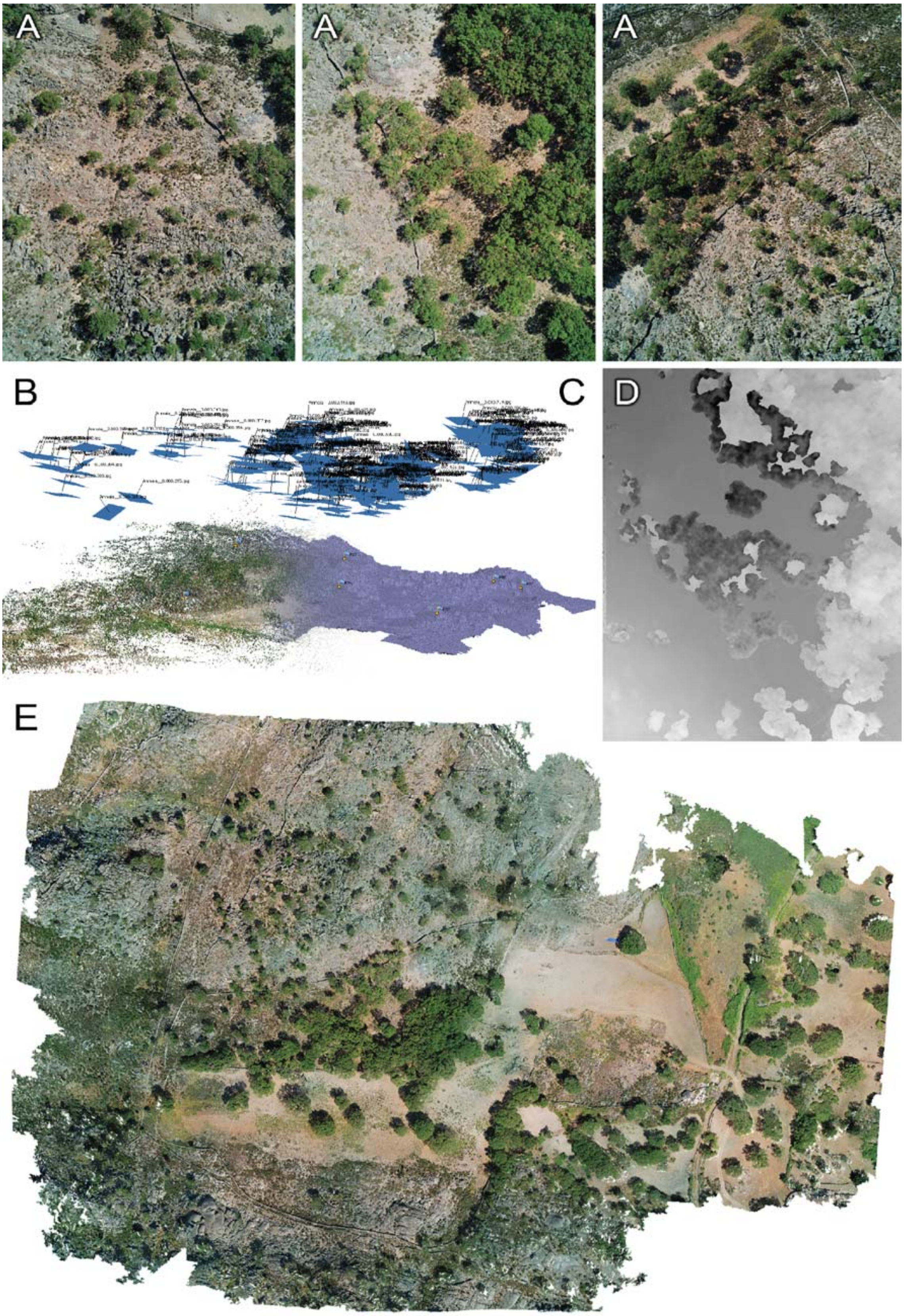

Figure 8.4 (A) Three of the 377 images used to calculate the camera poses; (B) a sparse 3D point cloud; (C) a surface model; (D) example of a depth map; (E) the final orthophotograph.

For the Pitaranha data set, the 'height field' reconstruction method was chosen, since it had previously been proven to yield good results for aerial photographs (Verhoeven, 2011). The 'exact' method, on the other hand, often recovers most terrain detail. This, however, also has implications on processing time, as more complex integration steps are included. In a final step, the DSM and subsequently computed orthophoto were exported using a raster size of 4 cm (Figure 8.4-D). PhotoScan uses the previously calculated DSM and GCPs to create the georeferenced orthophotograph. To obtain the best possible pictorial quality, the software was instructed to apply only those images with the smallest ground sampling distance (GSD) and to blend overlapping images by averaging their pixel values.

8.1.3 Result validation

The minimal prerequisites are an enormous advantage of the presented approach. Apart from a sufficient number of overlapping images covering the target and at least three GCPs to pin down the reconstruction, no other information is needed. Understandably, many factors still affect the quality of the final orthophoto: the resolving power of the complete imaging system, focus and exposure errors, and the amount of image overlap, but also the SfM results and the dense matching algorithms. Additionally, GCP selection and georeferencing influences the quality of the final orthophoto. A thorough quality assessment provides the necessary measures to verify whether a data set is fit for purpose. Besides attribute accuracy, consistency and completeness, positional accuracy is one of the key factors of the final data quality, since it describes how closely the coordinates of the calculated data set compare with their real-world location. Evaluating the general spatial accuracy of the generated orthophotograph and DSM is of the utmost importance and should always be executed before the general acceptance of use, considering the importance of these data layers in GIS-based research.

The assessment of the spatial error can be executed in a number of ways (Li, 1993), but positional accuracy of cartographic data is generally estimated by means of the mathematically simple root–mean–square error (RMSE) (Greenfeld, 2001). This statistic is calculated as the square root of the average of a set of squared differences between computed coordinate values and independent control measurements (of the same points) of superior accuracy. Since it reflects all error influences, the RMSE is denoted an absolute accuracy measure (Kraus, 2007). To perform the accuracy assessment, the set of 88 known ground points at Pitaranha was partitioned into two non-overlapping sets of 7 and 61 points, respectively. The remaining 20 points were discarded, since they were located outside the area covered by the aerial images. While the first seven points were used as GCPs for georeferencing the reconstructed model in PhotoScan, the accuracy evaluation was yielded by treating the remaining 61 points as an independent data set of highly accurate CPs to validate the positional accuracy of the orthophotograph and DSM. In statistical terms, this method is called *hold-out validation* (HOV). Although the method is known to be sensitive to the spatial distribution of the CPs, and even unreliable when only few CPs are available (Brovelli et al., 2008), HOV is considered to be a valid accuracy assessment because both the sample of CPs is significant and their location in situ was defined randomly while covering the whole quarry area. Hence, the computed RMSEs are considered to accurately reflect the error distribution in the data set. Moreover, the HOV method has the benefit of being computationally very easy, since it is simply a matter of calculating various RMSEs.

However, data analysis with the RMSE also depends on the assumption that the errors in x, y and z (i.e. the discrepancy in Euclidean distance between the calculated and the reference values, denoted Δx, Δy and Δz, respectively) follow a normal distribution (Zandbergen, 2008). Although histograms are often used for checking a deviation from the normality assumption, the so-called quantile–quantile (Q–Q) plot is often considered a better graphical tool (Höhle and Höhle, 2009). Figure 8.5 shows the Q–Q plot for all three error distributions. From these plots, it is obvious that both Δx and Δy can be considered to be normally distributed, since their Q–Q plots yield a straight line when compared to a theoretical normal distribution (with two noticeable outliers in Δy). The distribution of Δz is slightly more problematic: besides some outliers, the departure of the point pattern from a straight line indicates that this error distribution is a little skewed to the left. However, since the data series passes the powerful

D'Agostino–Pearson K2 omnibus test (D'Agostino et al., 1990) for normality ($p = 0.1995$), it is safe to assume that the distribution of Δz is also normal. As it is a good practice to evaluate graphs together with an appropriate normality test when deciding whether or not data are normally distributed, both planimetric error series were also verified to pass this normality test (Figure 8.5). Because all three distributions seem to approach the normal distribution, the RMSE can be considered an accurate accuracy measure, even without removing possible outliers (Verhoeven et al., 2012).

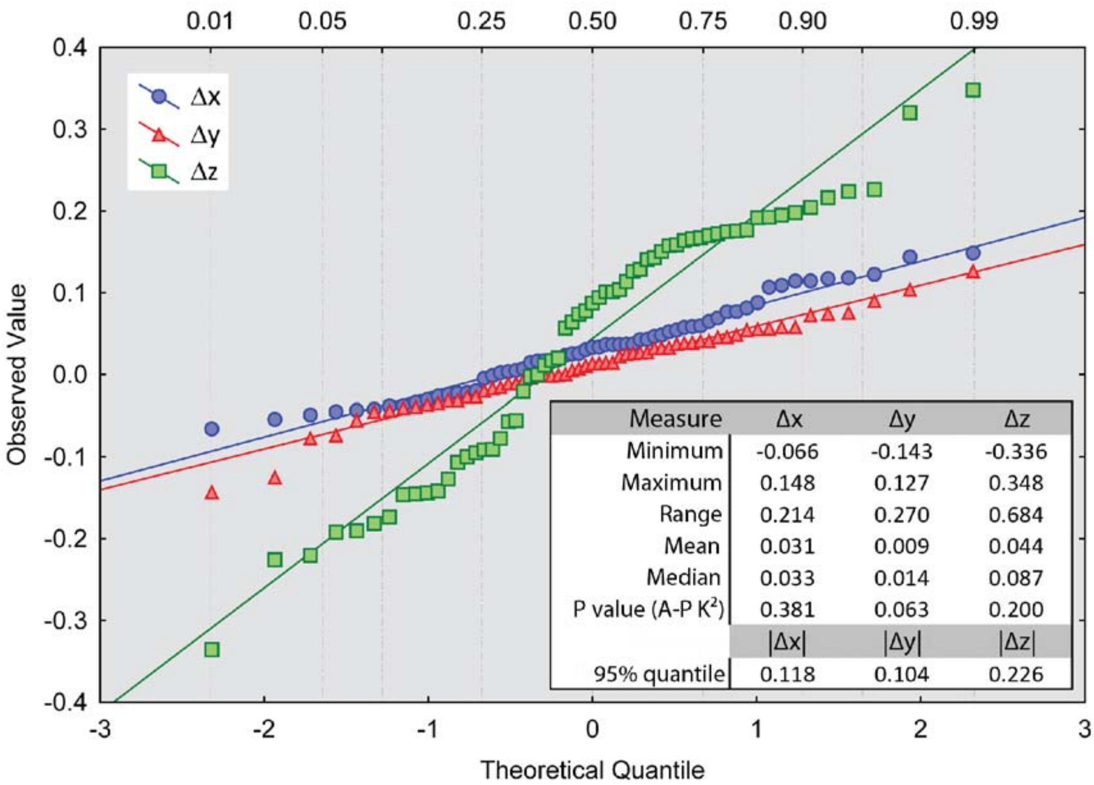

Figure 8.5 The normal Q–Q plot for all three error distributions and a summary of their descriptive statistics.

The RMSE metrics can be divided into horizontal accuracy in x ($RMSE_x$) and y ($RMSE_y$) as well as the total planimetric accuracy ($RMSE_{xy}$). Whereas the low planimetric errors are important to assess the quality of the orthophotograph, they can also induce vertical DSM errors in sloping areas. Therefore, a specific vertical accuracy metric, $RMSE_z$, was computed as well.

$$RMSE_x = \sqrt{\frac{\sum_{i=1}^{n}(x_{data,i} - x_{check,i})^2}{n}}$$

$$RMSE_y = \sqrt{\frac{\sum_{i=1}^{n}(y_{data,i} - y_{check,i})^2}{n}}$$

$$RMSE_{xy} = \sqrt{RMSE_x^2 + RMSE_y^2} = \sqrt{\frac{\sum_{i=1}^{n}\left(x_{data,i} - x_{check,i}\right)^2 + \left(y_{data,i} - y_{check,i}\right)^2}{n}}$$

$$RMSE_z = \sqrt{\frac{\sum_{i=1}^{n}(z_{data,i} - z_{check,i})^2}{n}}$$

in which $x_{data,i}$, $y_{data,i}$ and $z_{data,i}$ are the coordinates of point i in the computed orthophotograph and DSM, and $x_{check,i}$, $y_{check,i}$ and $z_{check,i}$ indicate the coordinates of point i in the CP data set; i is the number of a specific observation and ranges from 1 to n, while n is the total number of validation observations (i.e. 61). Table 8.1 shows all computed RMSE values, indicating the low spread of the computed values around the 'true' value. Additionally, some more robust accuracy metrics such as the median and the 95 % sample quantiles of the absolute error distributions (Höhle and Höhle, 2009) can be read from Figure 8.5.

Table 8.1 The computed RMSE values.

Accuracy metric	RMSE Value (m)
$RMSE_x$	0.061
$RMSE_y$	0.050
$RMSE_{xy}$	0.079
$RMSE_z$	0.158
$Accuracy_{xy}$	0.137
$Accuracy_z$	0.310

To incorporate all possible uncertainties in the computed data set (including those introduced by the control coordinates), it is, however, better to express the final accuracy values at the 95 % confidence interval. This means that 95 % of all the computed 3D points have an error with respect to the true ground position that is smaller or equal to the stated accuracy metric. Based on calculations made by Greenwalt and Schultz (Greenwalt and Schultz, 1968), the Federal Geographic Data Committee established in 1998 the National Standard for Spatial Data Accuracy (NSSDA), which applies to any digital geospatial data derived from ground surveys, aerial photographs and satellite imagery. This standard implements two formulae to report the total planimetric accuracy – $Accuracy_{xy}$ – at the 95 % confidence interval (Federal Geographic Data Committee - Subcommittee for Base Cartographic Data, 1998):

- in cases where $RMSE_x = RMSE_y$, $Accuracy_{xy}$ is be computed by: 1.7308 * $RMSE_{xy}$;
- in cases where $RMSE_x \neq RMSE_y$ (determined as $0.6 < RMSE_{min}/RMSE_{max} < 1.0$, where $RSME_{min}$ is the smaller value between $RMSE_x$ and $RMSE_y$ and $RMSE_{max}$ is the larger value), the formula reads: 1.22385 * ($RMSE_x + RMSE_y$).

Since $RMSE_x \neq RMSE_y$ in the Pitaranha case, the horizontal accuracy according to the NSSDA standard is 13.7 cm (Table 8.1). Out of 61 points, only four points have a horizontal error that exceeds this value.

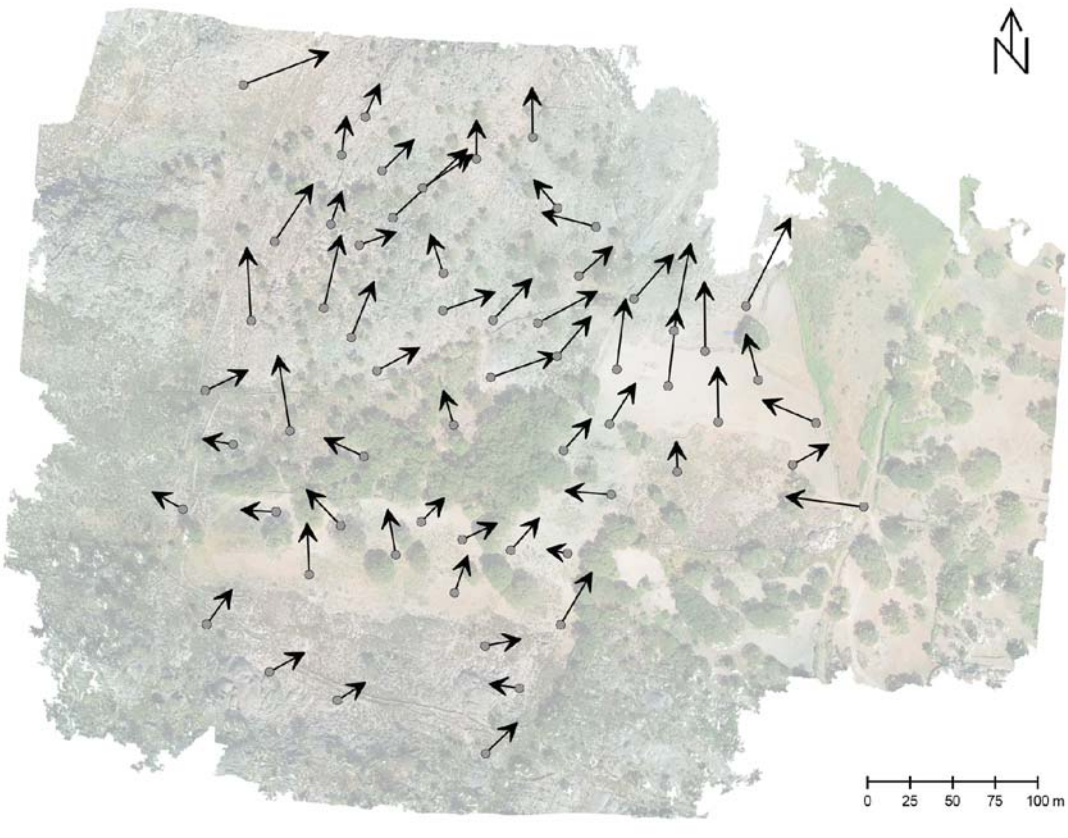

Figure 8.6 Locations of all 61 CPs. The arrows indicate the directions and relative magnitudes of their planimetric positional errors.

Figure 8.6 illustrates the distribution of these horizontal positional errors, indicating the variability in their distribution. Similarly, the overall absolute vertical accuracy value, Accuracy$_z$, was expressed according to NSSDA and calculated as 1.96 * RMSE$_z$ (Federal Geographic Data Committee - Subcommittee for Base Cartographic Data, 1998). With a 31 cm vertical accuracy at the 95 % confidence level (Table 8.1), only three points exceeded Accuracy$_z$, with residuals for the remaining 58 CPs lower than ± 23 cm, or exactly 0.5 % of the 45.6 m altitude range between the lowest and highest ground targets (Verhoeven et al., 2012).

Given that the source material consisted of an unordered image collection of vertical and oblique aerial photographs that are characterised by a maximum GSD of 8 cm and were taken with a non-metrical lens that suffered from quite some distortion, the reported positional accuracy of these data sets is considered very good (planimetric) to good (altimetric) and certainly better than initially expected. Following the accuracy guidelines of the American Society for Photogrammetry and Remote Sensing (ASPRS), these RMSE values mean that the orthophoto can be used at a Class 1 hard-copy scale of 1:200 and contour lines with 50 cm intervals can be derived from the DSM (ASPRS (American Society for Photogrammetry and Remote Sensing), 1990). As the orthophotograph and DSM generated will be used for in situ mapping and basic spatial analysis in GIS, it is prudent to relate the reported accuracy to the user context. It can therefore be stated that the presented approach yielded cartographic products that are accurate for archaeological quarry mapping and future research.

8.1.4 Some considerations

This cost-effective and straightforward approach has proven that it is also possible to map the topographically challenging Pitaranha quarry from an unordered set of images in a semi-automated way, with a final positional accuracy that approximates that of the standard photogrammetric approaches.

However, the used approach also has some disadvantages. So far, the computed height model is a DSM, as it still incorporates all the points that do not belong to the terrain surface. First, off-terrain points such as trees should be eliminated. Subsequently, ground-based photographs will complement the aerial data set in those zones that presently are covered with trees, to finally create an accurate digital terrain model (DTM).

Obviously, high-quality reconstructions with large image files are very resource intensive. All processing was, therefore, run on a computer with a hexacore processor, 24 GB of RAM and a 64-bit operating system. However, the most important hardware element that helped in shortening processing times is a high-end graphics card. Since PhotoScan supports the OpenCL (Open Computing Language) programming platform, it can access the graphics processing unit (GPU) when intensive computing tasks have to be executed. Therefore, an NVIDIA® GeForce® GTX 580 video card was used to speed up the reconstruction considerably.

In addition to hardware constraints, erroneous image alignment can occur. Very large photo collections always hold images that suffer from excessive blur or noise, highly oblique photographs or photographs that have a very dissimilar appearance (e.g. due to changing topographic terrain parameters or major underexposure). Currently, PhotoScan and most other SfM applications lack tools for the direct inspection of the quality and accuracy of the alignment step; the user can only visually assess any alignment problems. These can always be tackled by disabling the images that cause the error or inserting accurate camera calibration parameters before the SfM step. The latter can also prevent the reconstructed surface from being too curved, since such distortion is often related to a poor estimation of the interior camera calibration parameters for large image sequences. Because georeferencing in the current approach occurs after building the 3D model, any previous distortion will also remain after assigning absolute spatial coordinates to the DSM. If a few absolute exterior camera orientation parameters or GCPs are added as constraints in the SfM process, this could prevent possible drift in the recovered camera and point locations (Snavely et al., 2006).

8.2 Survey strategy

A topographic grid system with 16 fixed base points spread over the entire site was established using a Nikon DTM 520 and a 1101 TCRA Leica total station. This grid served as a basis for further measurements. Through GPS, the grid was incorporated into the ETRS89 PT/TM06 national coordinate system of Portugal, allowing to correctly locate all spatial data, as well as enabling the incorporation of all data into a GIS.
Using the orthophoto map and with the aid of GPS and total station, the location of all archaeological features, such as quarry faces, roughed-out blocks, wedge holes, debris heaps, as well as all elements related to transportation and social infrastructure were mapped and described. Special attention was given to the spatial distribution of the numerous wedge holes. The length, width, depth and general shape of the wedge holes were recorded. A systematic linewalking survey was also done to assess the distribution of surface artefacts. Finally, where surface artefact concentrations indicated the possible presence of subsurface archaeological remains, a magnetometer survey was undertaken. The entire area surveyed geomagnetically measured approximately 1100 m^2. Using a Nikon DTM 520 total station, two full 20 by 20 m and some partial grids were set out. The survey data were collected using a Geoscan Research FM256 Fluxgate Gradiometer, with sensor separation of 0.5 m. Readings were taken at 0.25 m intervals along 1 m traverses. Marked ropes were used along every traverse to improve positional accuracy. Data were logged in the internal memory of the geophysical instrument and later processed in Geoplot 3.0 software.

8.3 Topography and geomorphology

The remains of the granite quarry of Pitaranha can be observed on the flanks of the *Penha da Esparoeira*, one of the highest quartzite ridges of the *Serra de São Mamede*.

The Roman quarry is located on the present-day border between Portugal and Spain, some 200 m northeast of the village of Pitaranha. From a geological point of view, the site is situated near the southern limit of the NAB (Taelman et al., in press) (Figure 8.7).

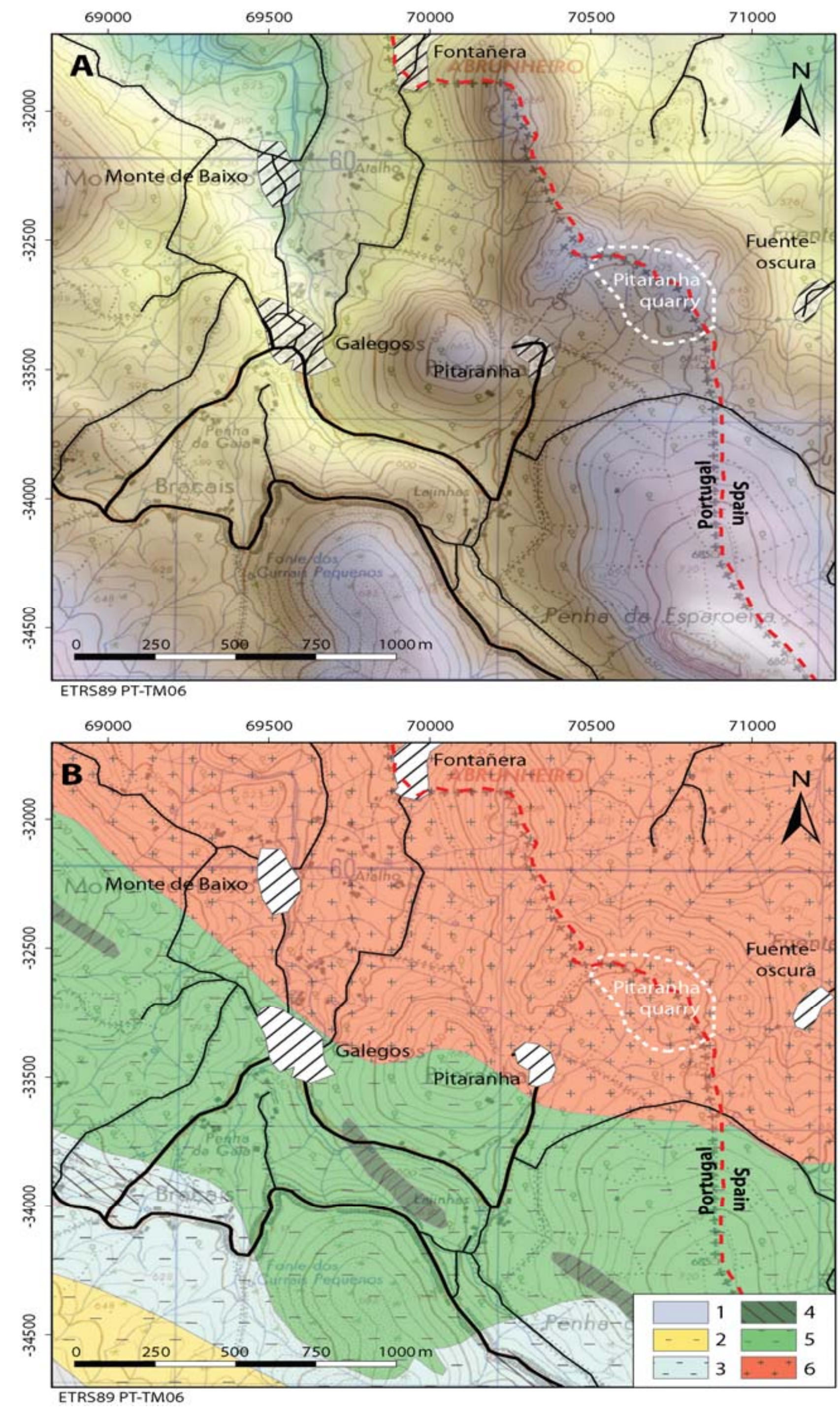

Figure 8.7 The Pitaranha quarry in relation to the topographic situation (A) and geological situation (B). Legend: 1. slope deposits (Holocene), 2. shale (Devonian), 3. hornfels and spotted slate (Silurian), 4. Quartzite (Ordovician), 5. hornfels and spotted slate (pre-Ordovician), 6. NAB-granite (Hercynian).

Features related to ancient quarrying are numerous and consist essentially of quarry faces, processing floors, abandoned roughed-out blocks, wedge holes and spoil heaps (Taelman et al., 2009; Taelman et al., in press). While the actual stone extraction was concentrated on the western slopes of a semicircular hill, quarry-associated activities are found on the gently sloping (3°–5°) and flat grounds west of the hill (Figure 8.8 and Figure 8.9). In total, the site occupies an area of roughly 10 ha with terrain altitudes ranging from an average of 646 m amsl for the flat and gently sloping terrain to maximally 677 m amsl on the top of the quarry hill. The gradient of the quarry hill is generally between 17° and 30°.

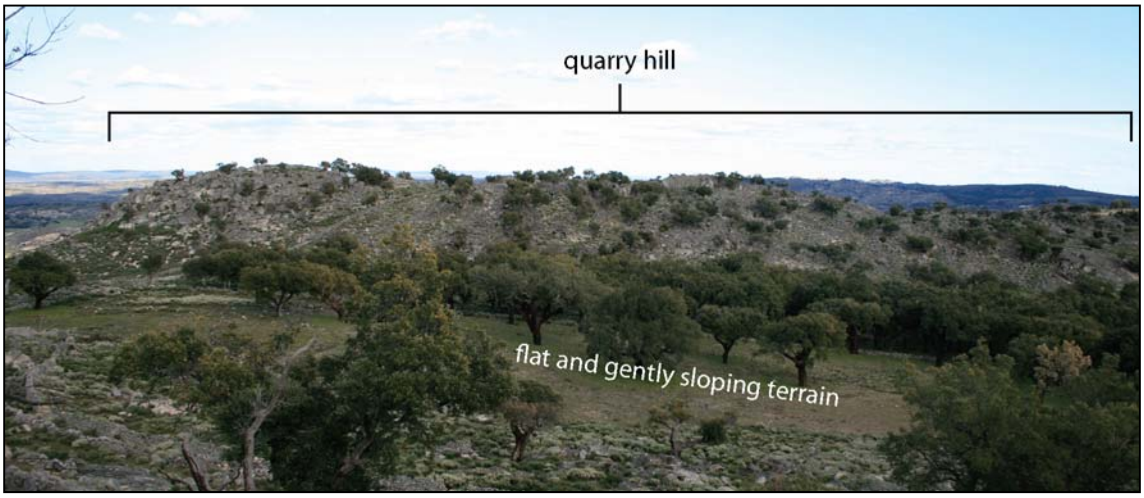

Figure 8.8 View of the Pitaranha quarry with the quarry hill in the back and the flat and gently sloping terrain for the quarry-associated activities in the front (location: 39.371378° N, 7.315686° W (WGS84), view to the SE).

The granite landscape at the quarry is dominated by ubiquitous well-rounded to subangular boulder inselbergs of various sizes and shapes (Figure 1.5-B). Some larger boulders can attain up to 20 m in diameter. Relatively thin and generally poorly developed unloading or exfoliation joints occur as well. The primary jointing pattern of the granite rock mass consists of three main joint sets with variable but roughly normal relative orientations. The horizontal spacing between the fractures ranges from one to a few metres (in all sets) with subvertical joints having a spacing of 1 m to 2 m. Finally, the lower-lying plain is cut by a N22°E oriented quartz vein, composed of milky quartz and occasional rock crystal. Mineralisations of iron and manganese are associated with the quartz vein (Figure 3.9-C) (Deprez, 2009; Taelman et al., in press).

Modern land use consists essentially of cork production and goat pasture. In addition, several recently abandoned pastoral walls are visible.

8.4 Quarry organisation and layout

The quarrying strategy and the internal organisation of the quarry were to a large extent influenced by the complex topography of the terrain and the distinct outcropping pattern of the granite rock. The rock mass was essentially exploited from superficial boulder outcrops or corestones. Cost and effort for the removal of topsoil in order to prepare the site for extraction were therefore low. The site developed into a boulder quarry with many smaller extraction spots dispersed over the quarry hill. As a result, quarrying was not systematic or standardised. A similar exploitation strategy is observed, for example, at the Roman Prosperina quarry of *Emerita Augusta* (Pizzo, 2010a).

At least sixteen exploitation spots have been recognised at Pitaranha, all concentrated along a well-designed transportation network for the internal movement of people and stone blocks. The paths had a minimum width of 2.3 m and connected the exploitation fronts with the processing areas and the flat and gently sloping terrain at the foot of the quarry hill. In areas with a challenging topography, the tracks were paved with a mixture small stones (quarry debris) and earth. The trace of the tracks was generally marked with larger stones and upstanding granite slabs (Taelman et al., in press) (Figure 8.10).

The length of the quarry faces ranges from 1.1 m to 36.2 m for the larger ones. Likewise, the height of the faces is very irregular and varies between 0.5 m and 2–3 m (Figure 8.11). This variation in size of the exploitation fronts is determined by the size of the boulder outcrops. Quarrying stopped when the boulder was exhausted or when the rock mass became too solid for easy exploitation.

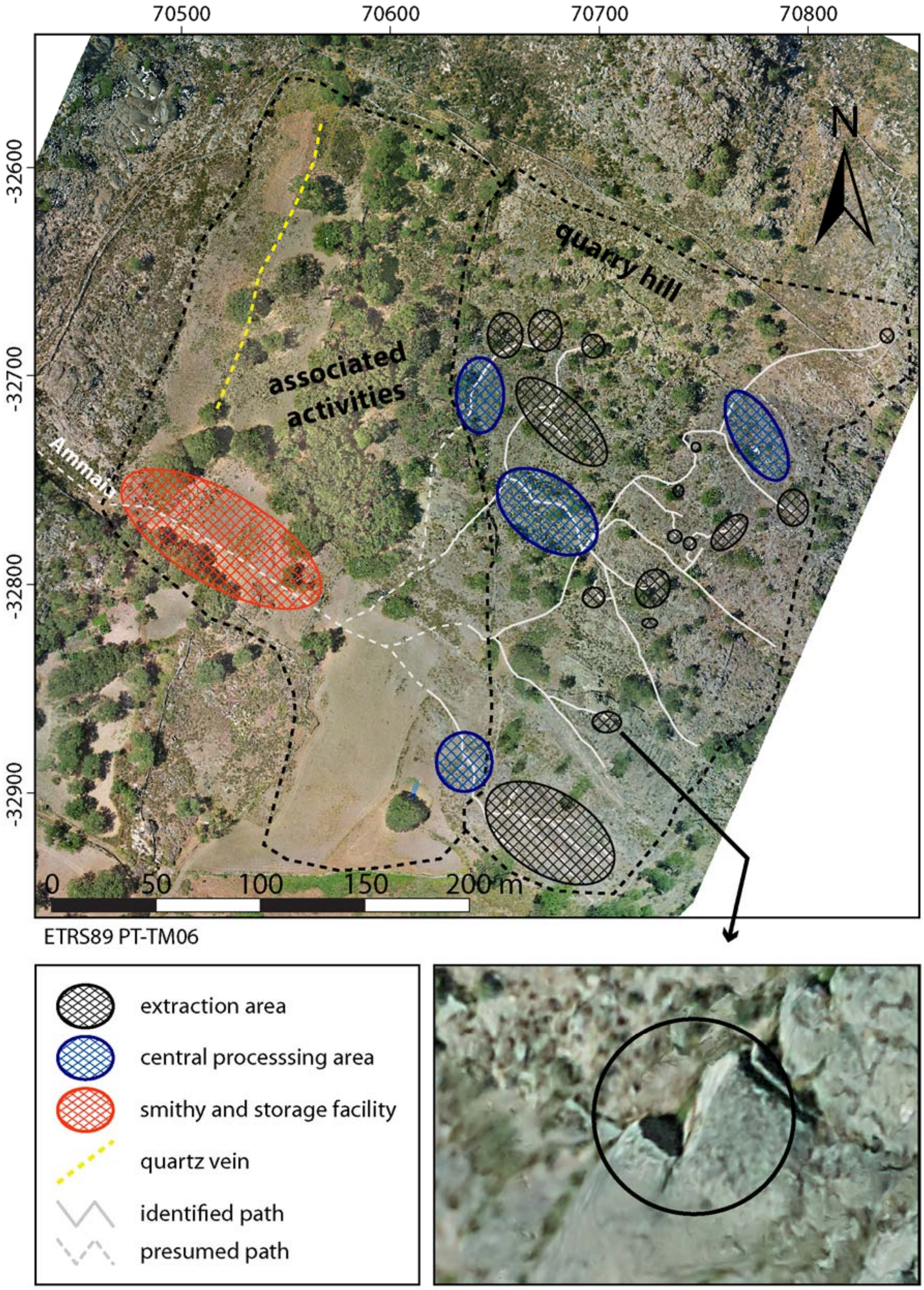

Figure 8.9 Orthophotograph of the Pitaranha quarry showing the quarry hill on the right and the gently sloping and flat terrains for the associated activities on the right. The inset shows a close-up of the exploitation front of Figure 8.11-A.

Figure 8.10 (A) Pathway on the quarry hill (location: 39.370569° N, 7.312011° W (WGS84), view to the E); (B) Quarry path at the foot of the quarry hill, bordered by standing granite slabs (location: 39.370366° N, 7.312178° W (WGS84), view to the E); (C) Well-constructed quarry path with a mixture of larger granite stones on the outside and smaller granite stones and earth on the inside (scale: 10 cm) (location: 39.368766° N, 7.312925° W (WGS84)). Dashed line indicates the trace of the path.

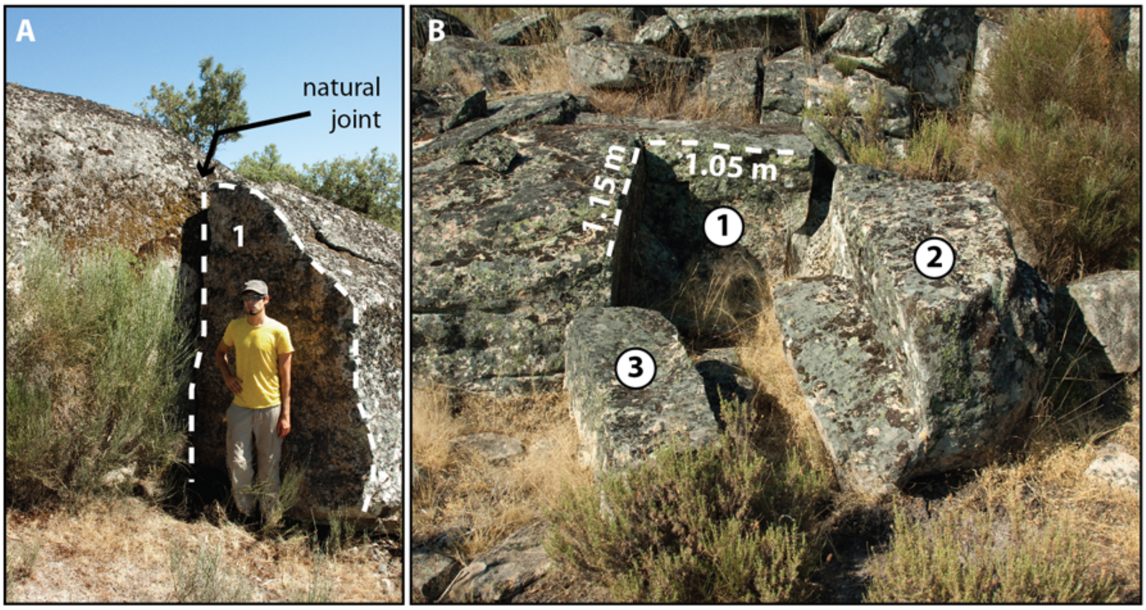

Figure 8.11 (A) Abandoned quarry face (location: 39.369329° N, 7.312659° W (WGS84)); (B) Quarry face with extracted block in front. Dashed line indicates the limits of the quarry face. Numbers indicate the sequence of quarrying and block reduction: (1) quarry face, (2) extracted block, (3) roughed-out block detached from the extracted block (location: 39.370503° N, 7.312135° W (WGS84)).

After extraction, the stones were moved to small processing floors in front of the quarry faces where they were reduced in size and a preliminary shaping and dressing was carried out (Figure 8.11-B). The roughed-out blocks were subsequently transferred to central processing areas, where they were further prepared prior to transport to the building site (Taelman et al., in press) (Figure 8.12).

Archaeological observations on the gently sloping and flat grounds at the foot of the quarry hill point to a zone where all types of secondary or quarry-associated activities were organised. A circular, kiln-like structures and a small basin (73 cm x 25 cm x 10 cm) cut into the granite bedrock for tempering heated iron prove the presence of a smithy (Figure 8.13) Smithies are often found on ancient quarry sites and are absolutely necessary for tool repair as quarry tools are subject to fast wearing because of the hardness of the quarried rock and therefore often require restoring or renewing (Dworakowska, 1983). Experimental tests in extracting a block of marble at the Thasos quarries (Greece) illustrated that eleven different chisels were required during the process of defining the block and the cutting of the wedge sockets because the cutting edge became blunt. Tool reparation happened by reheating and reshaping the chisel points, followed by tempering in water. The time needed to repair a chisel was c. 15

min (Kozelj, 1988). The absence of slag material in the Pitaranha quarry indicates that only tool reparation and not production occurred on the quarry site.

Figure 8.12 Roughed-out ashlar blocks in different stages of dressing and finishing. (A) location: 39.369768° N, 7.312511° W (WGS84) (length hammer: 30 cm); (B) location: 39.369739° N, 7.312483° W (WGS84) (scale: 20 cm).

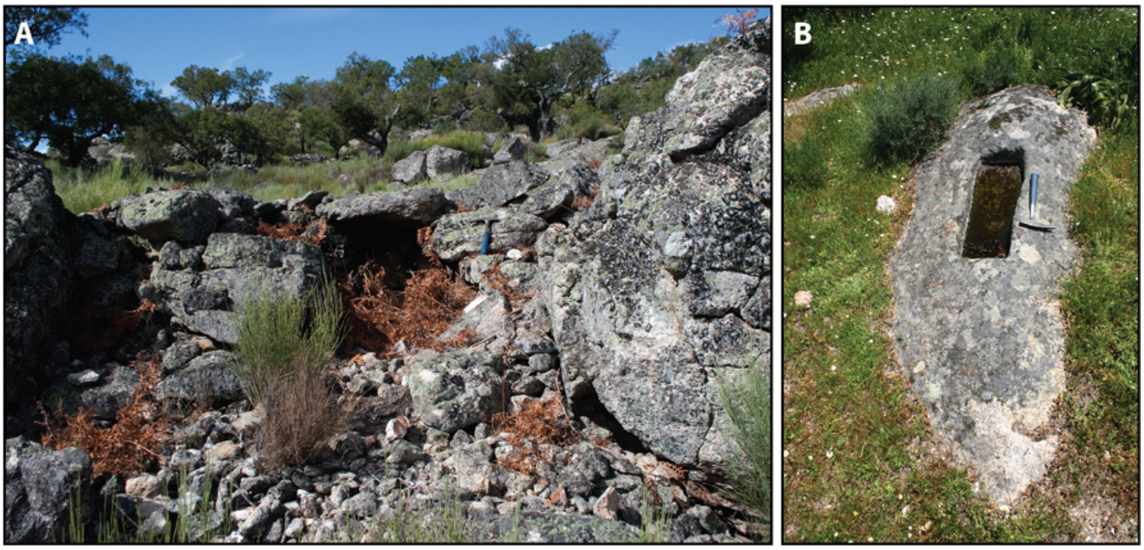

Figure 8.13 Structures indicating the presence of a smithy on the flat and gently sloping terrain at the foot of the quarry hill: (A) possible remains of kiln (length hammer: 30 cm) (location: 39.370366° N, 7.315397° E (WGS84)); (B) water basin for tempering the heated metal of the repaired tools (length hammer: 30 cm) (location: 39.369932° N, 7.314580° W (WGS84)). Photo-B by S. Deprez.

Surface concentrations of tile and *dolia* or storage jars fragments near the smithy point to the existence of storage facilities, perhaps for food and water for the quarry men (Figure 8.9). The results of the magnetometer survey in this area, however, revealed only geological structures, indicating that the storage facilities were probably erected with wood or other perishable material (Taelman et al., in press).

The plain was also the setting for rock crystal mining. A large quartz vein (2–3 m wide) (Figure 8.14 and Figure 8.9), that cuts the sector from north to south, was intensively exploited in search for rock crystal (see Chapter 3).

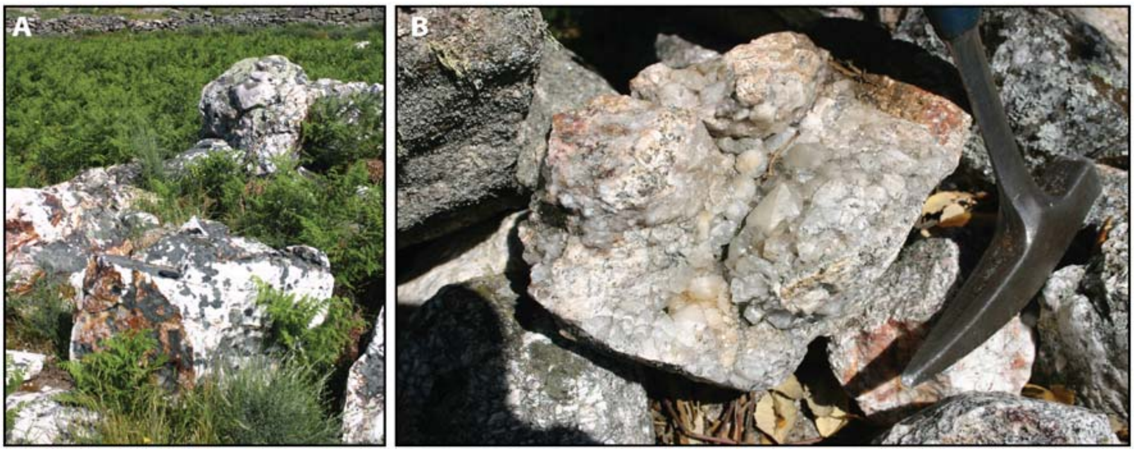

Figure 8.14 (A) Large blocks of the outcropping quartz vein at the Pitaranha quarry (location: 39.371885° N, 7.314232° W (WGS84)); (B) Block of milky quartz with a rock crystal core (length hammer head: 15 cm). Photos by S. Deprez.

Spread over the entire quarry site, a large number of spoil or debris heaps can be seen. In total, 72 heaps have been documented. Their size ranges from 2–3 m to c. 25 m in diameter (Figure 8.15). Depending on the location in the quarry, the composition of the heaps consists of granite debris, quartz debris or a combination of both (Taelman et al., in press).

Heaps that contain predominantly quartz fragments are found on the plain next to the quarry hill. Since pure quartz generally crystallises in the centre of the vein and only a small portion of the quartz body attained the level of purity the Romans pursued, large amounts of the mineral had to be discarded. The unusable chips and fragments were gathered and piled on carefully constructed debris heaps with larger blocks on the outside and smaller ones in the centre (Taelman et al., in press) (Figure 8.15-B).

Granite heaps are located on the quarry hill and are generally associated with a particular quarry face or exploitation front. Most granite waste results from the dressing and shaping of the roughed-out blocks on the processing floors in front of the quarry faces. These debris heaps contain mainly smaller granite fragments with an occasional larger block (Figure 8.15-B). Considering the rubble masonry construction technique used at *Ammaia* (see Chapter 4 and Chapter 6), not much waste material must have been generated at the Pitaranha quarry and the total volume of debris that remained on the quarry site was rather low. Moreover, a significant amount of debris was certainly reused in the nearby town of Pitaranha and for the post-Roman pastoral walls that cross the site (Taelman et al., in press).

Figure 8.15 Quarrying and mining debris heaps at the Pitaranha quarry: (A) carefully constructed debris heap of granite waste material (location: 39.369859° N, 7.313474° W (WGS84)); (B) small fragments of milky quartz resulting from rock crystal mining (location: 39.370162° N, 7.313587° W (WGS84)).

8.5 Extraction technique

It was already noted that the location of the individual extraction spots was strongly influenced by the topography of the terrain and the morphology of the boulder outcrops. Similarly, the extraction technique was determined by the nature of the local outcrops, especially by the jointing pattern and the occurrence of natural faults in the granite rock mass. Whenever possible, natural faults appear to have been used to facilitate block extraction. The presence of these natural faults or fractures on two or three sides of the blocks eliminated the need for channelling and for extraction using only wedges. A good example of the method can be observed in the southernmost zone of the quarry hill, where unloading joints resulting from the pressure release when the granite rock mass reached the surface (Migon, 2006), produce sheets of approximately 0.5 m thick (Figure 8.16). This type of weathering is ideal for producing slabs or blocks, similar to the ones used for paving the monumental square of the South Gate (see Chapter 4).

Figure 8.16 Unloading or exfoliation joints exploited for producing granite slabs (scale: 20 cm) (location: 39.368788° N, 7.312846° W (WGS84)).

Extraction by using only wedges was not common in Roman times, especially in comparison with the channelling method where wedges were used only to detach the final side of the block from the bedrock. On the Iberian Peninsula, the wedge method has thus far only been detected in some sites in northeastern Spain (e.g. in Ampurias and Olèrdola) (Gutiérrez Garcia-Morena, 2009) and in the granite quarries of *Emerita Augusta* (De la Barrera, 2000; Pizzo, 2010a;b).

At Pitaranha, wedge sockets were generally carved directly into the boulder outcrops. The practice of cutting the wedge socket at the base of a shallow channel to guide the splitting was detected only at one location, at the foot of the quarry hill (Figure 8.17). Considering that the block for which this method was applied was never fully extracted, it seems that this location was used by the quarry men to test different extraction techniques prior to the proper exploitation of the Pitaranha quarry.

Figure 8.17 Shallow channel for placing wedges and guiding the splitting (scale: 20 cm) (location: 39.369034° N, 7.313209° W (WGS84)).

In total, 294 wedge sockets have been identified on 95 blocks or quarry fronts, spread out over the quarry hill. Twenty-nine sockets belong to six blocks that were not fully extracted from the bedrock. Remains of the wedges proper were not found. However, judging from the shape and size of the sockets (Figure 8.18), iron V-shaped wedges with an elongated and rectangular top surface can be presumed (Bessac, 1988b; Gutiérrez Garcia-Morena, 2009; Kozelj, 1988). The length of the sockets is typically between 15 cm and 18 cm, while the depth is between 8 cm and 11 cm on average. Extreme values of 9 cm to 27 cm for the length and 6 cm to 18 cm for the depth have been observed. The width of the fully preserved sockets measures between 5 cm and 11 cm, averaging 8 cm. Overall, the spacing between the sockets is very variable and measures between 2 cm and 29 cm, with an average of 13 cm.

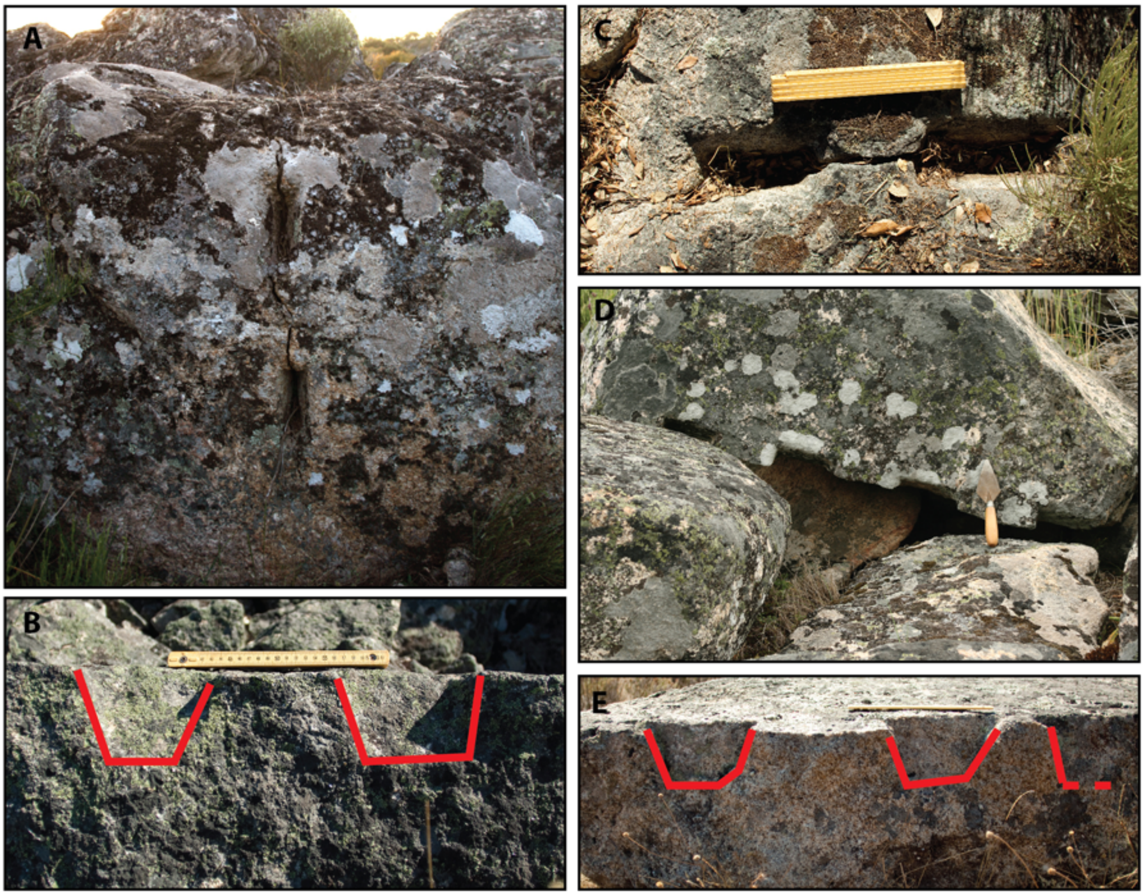

Figure 8.18 Examples of used and unused wedge sockets at the Pitaranha quarry. (A) location: 39.369034° N, 7.313209° W (WGS84); (B) location: 39.371003° N, 7.311136° W (WGS84) (scale: 20 cm); (C) location: 39.371003° N, 7.311136° W (WGS84) (scale: 20 cm) ; (D) location: 39.369032° N, -7.313224° W (WGS84) (length trowel: 20 cm); (E) location: 39.369032° N, 7.313224° W (WGS84) (scale: 20 cm).

Judging from the spatial distribution of the different types of wedge sockets, there is no relation between wedge type and chronology or different teams. This agrees with the observations of J.C. Bessac (Bessac, 1988b) that dimensions and spacing of sockets is related essentially to the local rock properties, for example density of fracturing of faults in a specific location.

After extraction, the quarried blocks were reduced into roughly finished products that could be transported to the construction site. This reduction was commonly carried out by splitting with wedges, similar to the extraction technique (Figure 8.19). Additional dressing of the blocks happened with a carver's pick.

Figure 8.19 Two blocks from the same 'core' block separated using wedges. Traces of used wedge sockets can still be seen on the right block (length hammer: 30 cm) (location: 39.370881° N, 7.313383° W (WGS84)).

Taking into account the applied extraction and processing technique, the principle tools at the Pitaranha quarry were without a doubt the iron wedge, the chisel and the hammer. The latter two served to prepare the wedge sockets (Adam, 2003). Finally, the carver's pick was used for preliminary dressing of the roughed-out blocks.

8.6 Chronology of the quarrying activities

It was already noted in Chapter 7 that it is very difficult to propose an exact chronology for the operation of an ancient quarry. Tool marks and other traces of the quarrying

technique are generally the only archaeological evidence at quarry sites. Quarrying techniques have, however, not undergone any significant changes between Antiquity and the first half of the 19th century CE when the quarrying industry was mechanised (Bédon, 1984; Bessac, 1993). For example, in preindustrial quarrying, the variation in tools and techniques used was often greater for different types of stones (soft versus hard stones) than for different chronological periods.
The best evidence for deducing the age of quarries is yielded by indirect evidence, such as the consumption of the quarried stone. Provenance assessments of building stones from well-dated buildings and monuments provide a *terminus ante quem* for the time of operation of the quarry. In addition, pottery found in association with quarries and quarry inscriptions are useful dating methods. While the former of the two is generally scarce and sometimes even absent on industrial sites such as quarries, the latter is normally found in Imperial quarries only (Hirt, 2010; Ward-Perkins, 1992).

In dating the Pitaranha quarry, the wedge extraction technique and the degree of weathering and the presence of well-developed slowly growing lichens on the quarry faces, roughed-out blocks and debris heaps provide the first evidence of the historic nature of the granite exploitation. However, the most useful instrument for dating is the evidence of consumption of the Pitaranha granite. As discussed in Chapter 7, petrographic observations have proven the extensive use of the Pitaranha granite as building stone in Roman *Ammaia*. Moreover, the absence of a proper pre-Roman stone architecture in the region using dimension stones or ashlars provides a *terminus post quem* for the time of operation of the quarry. In addition, except for the villages of Marvão, Galegos and Pitaranha, there are no other major consumption centres in the area that could justify the large volume of granite exploited at the Pitaranha quarry. While preliminary observations in Marvão illustrate the use of mainly local quartzite for building purposes, the villages of Galegos and Pitaranha were founded only in Modern times and do not justify the degree of weathering and the presence of slowly growing lichens on the quarry faces and extracted blocks. Furthermore, unlike the roughed-out ashlars that were used in Roman and post-Roman constructions, a roughed-out column drum is architectural elements typical of the Roman period. Column drums of similar dimensions have been observed in *Ammaia* (see Chapter 5) (Figure 8.20).

Figure 8.20 Roughed-out column drum at the Pitaranha quarry (location: 39.369394° N, 7.312680° W (WGS84)).

Finally, pottery found in the area of the smithy and the storage facilities confirm the hypothesis of a Roman date. Besides some modern pottery left behind by goat herders, a considerable amount of ancient ceramic material has been found, including roof tiles and sherds of *dolia* or storage jars of a similar fabric and typology as material found in *Ammaia*.

All these elements suggest the start and the main time of operation at Pitaranha in the Roman period. Later quarrying, however, cannot be excluded.

Even though the evidence from the quarry site provides only a broad chronology for the time of operation of the quarry, the study of the architectural remains from *Ammaia* gives more detailed information. From the foundation of the town in late Julio–Claudian period onwards, the construction workers from *Ammaia* employed granite as the main building stone. The opening of the quarry therefore needs to be dated in the same period. A peak in the building economy in the Flavian to early Antonine period, when several pre-existing buildings were dismantled and replaced by (monumental) public buildings such as the forum bathhouse and the South Gate suggests intensive quarrying at Pitaranha. A decline in building activity from the late 2nd century CE onwards implies less intensive quarrying. Moreover, the reuse of granite blocks from dismantled buildings must have been considerable in this later period.

8.7 Transporting the Pitaranha granite

Since transporting bulky and heavy goods such as building stone was difficult, expensive and time-consuming, long-distance transport of building stone was an exceptional phenomenon in preindustrial times and was avoided as often as possible (Russell, 2008). Few Roman urban centres were located more than a day's travel from their main source of building stone, so to avoid logistical problems during transport such as lodging and food and water supply (Russell, 2009). If possible, water transport (sea and/or river) was preferred. In most cases, because of the absence of navigable waterways or the inland location of towns, stone could only be conveyed overland. Compared with water transport (ships, barges, etc.), the load-bearing capacity of land transport is significantly lower, therefore making the overland movement of stone more expensive (Adams, 2007). In many cases, transport constituted a major expense on a construction project, sometimes even exceeding the costs of the actual raw material and its quarrying (Ogburn, 2004; Russell, 2008).

8.7.1 Means of transportation

In the absence of navigable waterways between Pitaranha and *Ammaia*, pack animals and animal-drawn carts (mainly ox carts), were the most likely means of transportation for the stone products from the Pitaranha.

Pack animals such as mules and donkeys could be used for conveying a load of rubble stones that could be equally divided over two panniers or a packsaddle balanced on the animal's back (Landels, 1978; Raepsaet, 2008; Russell, 2008). Donkeys and mules are sure-footed, economical, and cheap to feed and maintain. They can carry a maximum load of 120–150 kg at a travelling speed of c. 4–5 km/h on easy terrain (Adams, 2007; Landels, 1978).

Ox carts were the preferred means of transport for heavy and bulk burdens (Burford, 1960; DeLaine, 1997; Raepsaet, 2008; Rockwell, 1993). Carts were normally hauled by one pair of oxen; for exceptionally heavy pieces, multiple teams could be harnessed in the same span (Raepsaet, 2008; Russell, 2009) (Figure 8.21). As the walking speed of oxen generally does not exceed 3 km/h or even as low as 1.67 km/h when heavily loaded (DeLaine, 1997; Deshpande and Ojha, 1985; Raepsaet, 2008), ox cart transport was only useful in circumstances where speed was not of primary importance. Considering the terrain topography, the large volume and the nature of the conveyed stone blocks, ox carts are the most likely means of transportation between the Pitaranha quarry and the town of *Ammaia*.

Figure 8.21 Early 20th century CE stone transport in the Estremoz Anticline (Portugal) using seven teams of two oxen harnessed in the same span and combined by with small tractor (Photo owned by Solubema, Sociedade Luso-Belga de Mármores, Bencatel, Portugal).

8.7.2 Transportation route

The total length of the route between the Pitaranha quarry and the town of *Ammaia* amounts to c. 9.5 km and is characterised by a moderate descent without major altitude differences with *Ammaia* as practically the lowest point. Uphill segments occur, but are generally less than 200 m in length. The longest uphill segments measures 400 m in length and has an average gradient of 6 % (with a maximum of 17 %) (Figure 8.22 and Figure 8.23).

The first part of trajectory that connected the quarry with the main Roman road was determined through a GIS-based slope analysis and field observations and partly coincides with an early 20th century CE contraband route between Santo António das Areias (Portugal) and Valência da Alcántara (Spain) (Trinidad et al., 1996). The path measures approximately 1.5 km in length and has an overall descent of 130 m.

For most of the trajectory between Pitaranha and *Ammaia*, the Roman road leading to *Norba Caesarina* (modern Cáceres, Spain) could be used (see Chapter 3). Along the route, the terrain topography is generally gently undulating with an average gradient of 6 %. After crossing the Sever River at Ponte Velha (literal translation: old bridge), a stretch of about 2 km was characterised by local steeper slopes with a gradient up 18 %. Most of the steep slopes were, however, only over a short distance. The final 2.5 km of the trajectory runs through the plains of the Sever River Valley and reached the town of *Ammaia* through the North Gate or perhaps the River Gate.

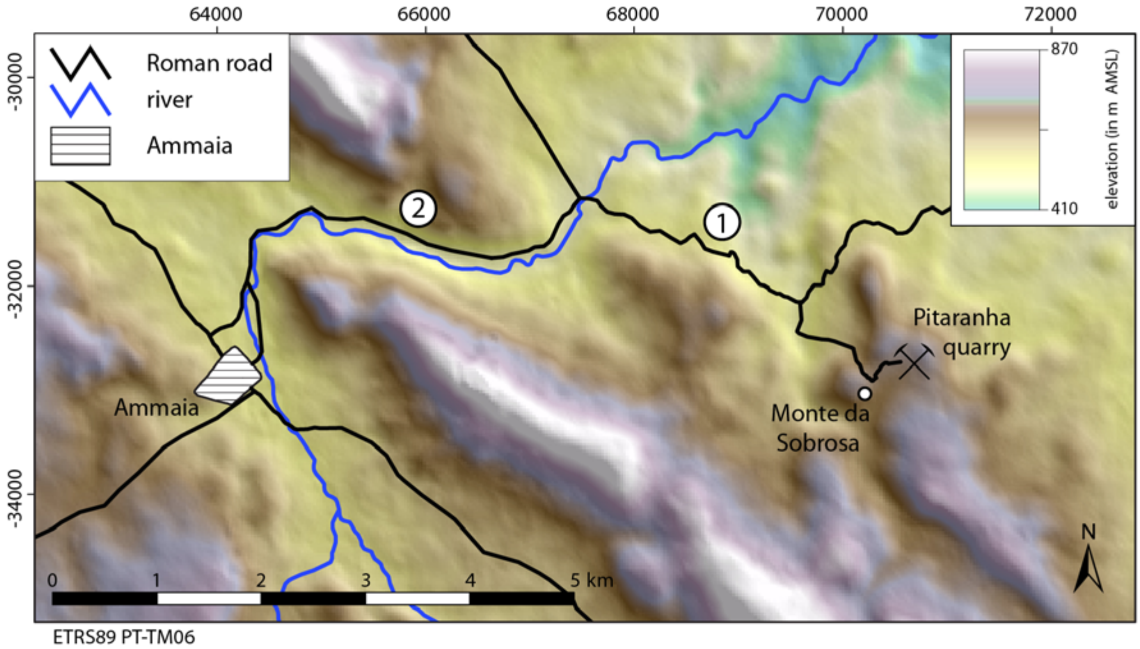

Figure 8.22 Transport route from the Pitaranha quarry to *Ammaia*: (1) quarry road, (2) Roman road from *Ammaia* to *Norba Caesarina*.

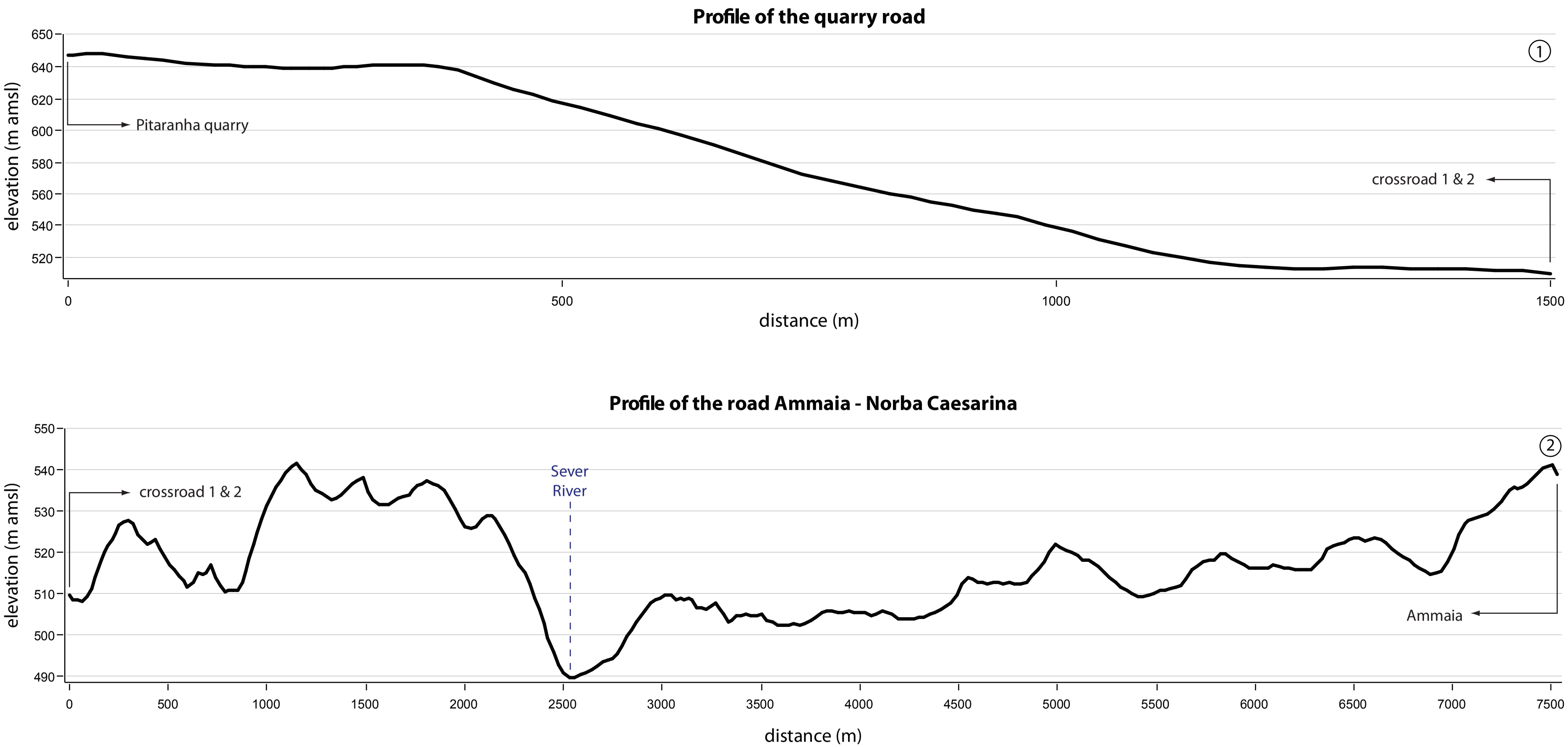

Figure 8.23 Profile of the transport route between the Pitaranha quarry and *Ammaia*: (1) quarry road (vertical exaggeration: 1.5x), (2) road between *Ammaia* and *Norba Caesarina* (vertical exaggeration: 20 x)

8.7.3 Draught force

Animal traction is influenced by a wide range of factors, including biological factors such as animal type, sex of the animal, animal condition, size, nutrition, ambient temperature, but also mechanical factors such as harnessing system, implement design and angle of pull (Chawatama et al., 2003). However, very little is known on the exact influence of these factors.

In general, it is assumed that oxen are capable of producing a sustained draught force of roughly 10–12 % of their body weight. For short periods, the force produced can be slightly higher (Chawatama et al., 2003; Harrigan et al., 2002; Raepsaet, 2008). When spanning multiple oxen in one yoke, a loss of efficiency of 7.5 % needs to be taken into account for each extra animal (Chawatama et al., 2003).

On level terrain, the minimum energy required for hauling a cart at a constant speed equals the energy needed for overcoming the rolling resistance of the cartwheels. For upslope transport, the additional energy required for overcoming gravity approximately equals the slope percentage multiplied by the total transport load (i.e. weight of the cart + weight of the load) (Harrigan et al., 2002; 2009).

The rolling resistance of a cart is determined principally by three components: the road surface, the wheel type and the transport load. A hard surface such as a paved road has a lower resistance than a loose surface such as grassland. Regarding wheel type, the surface area of the wheels is important. Narrow wheels have a smaller contact surface and therefore have a lower rolling resistance, but exert more pressure and therefore sink deeper into the road surface. Larger wheels have the opposite effect. Besides wheel size, the material of the wheel surface is of importance. Little research has, however, been carried out on the exact influence of wheel type, but it is suggested that the rolling resistance is increased by 50 % to 100 % for wheels with a steel surface in comparison with pneumatic tyres. Finally, the influence of the transport load is straightforward; the higher the load, the higher the energy needed (Harrigan et al., 2002; 2009).

8.7.4 Maximum transport load

In the previous paragraph, it is mentioned that oxen are capable of producing a sustained draught force of roughly 10–12 % of their body weight. For the purpose of simplicity, an average value of 11 % is here chosen. When accounting for a loss in efficiency of 7.5 % when teaming oxen, the total draught force for a team of heavy oxen of 900 kg can be calculated as follows:

1) mass of the ox (kg) * gravitational field strength = weight of the ox (N)
2) 11 % * weight = sustained draught of 1 ox (SusDr)
3) 2 * SusDr - 7.5 % * (2 * SusDr) = sustained draught force of ox team

Recent osteometric studies (Davis, 2008; Davis et al., 2008) have illustrated that in Roman times the cattle in southern Portugal was slightly smaller than present-day animals. It was not until around the 12th–13th century CE that cattle size started to increase. While nowadays an average heavy ox weighs about 900 kg, an average mass of 700 kg is more realistic for the oxen used in the transport of the Pitaranha stone material in Roman times. An approximate sustained draught force of 1397 N for a team of oxen can be calculated as follows:

1) 700 kg * 9.81 kg/N = 6867 N
2) 11 % * 6867 N = 755 N
3) 2 * 755 N - 7.5 % * (2 * 755 N) = 1397 N

Using the formulas and tables from Harringan et al. (Harrigan et al., 2002; 2009) (Table 8.2), it is then possible to calculate the maximum stone load for the transport route between the Pitaranha quarry and the town of *Ammaia*. Calculations are presented for a metalled road surface and a cart equipped with wheels with a steel surface. As maximum slope, a value of 6 % was chosen, as this corresponds to average gradient of the longest uphill segment (see above).

Table 8.2 Draught force (in N) required for pulling a full load (i.e. cart + payload) of 1000 kg on a cart equipped with steel tyres. Data adapted from Harrigan et al. (2002; 2009).

slope	**0 %**	**10 %**	**20 %**	**6 %**
metalled road	530	1510	2491	1118

In Table 8.2, it can be seen that a draught force of 1118 N is needed for pulling a total load of 1000 kg up a 6 % slope in a cart with steel tyres on a metalled road. Using a total draught force of 1397 N for a team of two oxen weighing each 700 kg, a maximal load of c. 1250 kg could be transported without difficulty over the route between the Pitaranha quarry and *Ammaia*. Assuming for a 400 kg–cart, a payload of roughly 850 kg of stone material could be transported per trip.

The detailed assessment of the architectural and archaeological remains from *Ammaia* (see Chapter 4 and Chapter 6) has illustrated that both the public and private architecture was dominated by walls with a facing of irregularly shaped and roughly dressed granite facing stones (*opus incertum*) set into a core of mortared rubble (*opus caementicium*). Granite facing stones generally measure between 25 cm and 30 cm across, and have a depth of 20 cm. Average weight is thus roughly between 21 kg and 65 kg (calculated using an average mass density for granite of 2640 kg/m^3 (Hunt et al., 1995)). With a payload of 850 kg for the Pitaranha carts, 0.32 m^3 of granite stone or approximately 1.6 m^2 of facing stones could be transported per trip.

The use of dimension stones in *Ammaia* was less profuse. Ashlar masonry is detected only in monumental buildings such as the forum temple, the towers of the South Gate and funerary monuments. Ashlars were also used for pavement blocks (South Gate square) and quoins to increase the stability at wall corners, wall intersections and doorways. Granite dimension stones were finally also used for column shafts and epigraphic monuments. The maximum weight recorded for the ashlars in *Ammaia* is around 850 kg, with an average between 450 kg and 500 kg (see Chapter 4, Chapter 4 and Chapter 5). As a result, only one large or two small ashlars could be transported from the Pitaranha quarry to *Ammaia* per cart ride. Some larger blocks weighing little over 1000 kg had to be transported using two teams of oxen.

For example, for paving the monumental square of the South Gate, a total of 540 blocks – each weighing c. 693 kg – were needed. In addition, 22 smaller blocks with an average weight of 430 kg were used to define the square in the northwest. For bringing all these blocks from the Pitaranha quarry to *Ammaia*, 551 cart rides would have been necessary; 540 for the pavement blocks and 11 for the blocks on the outside of the square.

8.7.5 Transport time

A final aspect of the transportation of the Pitaranha granite is the travel time of the ox carts. With a maximum walking speed of 1.67 km/h for a heavily loaded cart (DeLaine, 1997), the trip between the quarry and the town would have been 5 h 41 min. For the return trip with an empty cart, an average speed of 3 km/h yields a travel time of 3 h 10 min. Using the figures proposed by Daniels-Dwyer (2000), after J. Delaine (1992; 1997) and the 19th century CE building manual of G. Pegoretti (1869), the time for loading and unloading a full cart can estimated at less than 10 min. The total travel time for a round trip from the quarry to *Ammaia* would thus amount to approximately 10 hours, corresponding more or less to an average working day of 12 hours, including 2 hours for breaks as proposed by J. DeLaine (1997).

8.8 Quarry ownership and administration

In the Roman Republican period, all quarries were either private or municipal property (Dubois, 1908). Every *municipium* had its own territory or land and, under Roman law, all mineral resources were considered an integral part of that land. Unlike, for example, crops that were considered moveable goods, the ownership of mineral resources went hand in hand with the ownership of the land. The landowner could either exploit the resources directly but more often the rights of exploitation were leased out to a contractor (Fant, 1988). For towns in the Iberian Peninsula, these types of contracts were probably one of the main sources of revenue (Mackie, 1983). According to the *Lex Irnitana*, the leasing out of public land and other property belonging to the community was the responsibility of the *duoviri*, the two highest magistrates of a Roman town (González and Crawford, 1986; Mackie, 1983). Contracts for stone exploitation on municipal land might have belonged to the same type of contracts. How this municipal ownership was exactly organised is, however, still unclear.

Starting under the Emperor Tiberius, according to Suetonius in 17 CE, the important marble and granite quarries gradually passed under imperial and state control (Ward-Perkins, 1972; Ward-Perkins, 1992). The great majority of quarries, however, certainly those that served essentially a local market, remained private or municipal property (Dworakowska, 1983; Ward-Perkins, 1951). Like for the mines, these small-scale quarries would not have aroused the interest of the emperor or the state, as the administrative effort required for their management or leasing out would have exceeded their potential revenue (Edmondson, 1987). In general, these quarries and mines were linked to local urban centres and should be considered as part of their periurban industry (Goodman, 2007).

Because no direct historical or archaeological evidence exists for the Pitaranha quarry, not much can be said with certainty about the ownership and administration. Quarry inscriptions, like the ones often found in the Imperial quarries (e.g. Carrara, Dokimeion and Proconessos) as part of an administration or accounting system (Fant, 1993; Hirt, 2010; Ward-Perkins, 1951; 1992), have not been found at Pitaranha. As the organisation at such smaller quarries were significantly less complex, administration and accounting information was self-explanatory and there was no need for labelling blocks (Fant, 1993; Russell, 2009). Indirectly information can, however, be derived from the quarry organisation and the extraction technique at Pitaranha. Given the local use of the

Pitaranha granite and the importance of the quarry for the building industry in *Ammaia*, a municipal ownership is likely.

In one of the previous sections, it was discussed that the quarry consisted of many smaller extraction spots defined by the outcropping pattern of the granite rock mass. Quarrying at these individual extraction spots stopped when the boulder was exhausted or when the rock mass became too solid for easy exploitation. As many of the extraction spots identified on the quarry hill were not exhausted at the time of abandonment, it seems that different teams were at work simultaneously and that the right of exploitation was leased out by the town to several private contractors, each with the right to exploit a certain area of the quarry. Similar to the organisation of the works in the Roman mines of Vipasca (near Beja, Portugal) (Edmondson, 1987), associated activities at Pitaranha, such as the smithy for tool repair, the mining for quartz and rock crystal, and the management of the (food and water) storage facilities, might have been leased to separate contractors responsible only for these aspects of the stone supply works. For the transport of the stone material from the quarry to *Ammaia*, the situation is different. While long-distance transport of stone, especially if overseas, was generally done by private carriers that were contracted to organise the transport a certain load (Fant, 2012), short-distance transport of stone quarried for a local market, such as at Pitaranha, was generally part of the same contract as the actual stone extraction (Burford, 1969).

Information on the identity of these private contractors is scarce. The epigraphic record (CIL II 163, IRCP629) mentions several immigrants from the town of Clunia (near Coruña del Conde, Spain) in *Ammaia* (Mantas, 2002). People from Clunia have been attested throughout *Lusitania* and their presence is generally related to mining activity (e.g. at *Civitas Igaeditanorum*). It is therefore not unlikely that these immigrants played a prominent role in the mining, and perhaps also quarrying, industry of the town (Edmondson, 1987). Likewise, members from the *gens Helvia* (IRCP633), a family that was often involved in mining activities in the Iberian Peninsula, have been attested in the territory of *Ammaia* (Mantas, 2002).

The coexistence of several non-exhausted quarry fronts and the numerous roughed-out blocks awaiting further finishing indicate a ‘sudden’ abandonment of the quarry, perhaps as a result of seasonal activity. At the end of the quarry season, quarry fronts and unfinished blocks were left at the quarry and made ready for continuation at the start of the next season. But for an unknown reason, the work was never resumed. Several studies have illustrated that seasonal activity for craft production was not uncommon in preindustrial economies. For example, Quinua people from Peru were often part-time farmer and part-time potter, with pottery production taking place during the periods when the agricultural fields required little or no attention. Likewise, complementary craft and agriculture was observed for economies in Thailand and for the Toro people in Uganda (Costin, 2007). In the Roman world, a similar situation appears to have been common in small-scale, local economies. During periods of little agricultural activity, surplus labourers could be employed as unskilled workers in the quarrying industry. Likewise, farmers could hire out oxen, which were expensive in upkeep, for use as hauling animals for transporting stone in times when agricultural work was limited (Erdkamp, 2005).

At the moment, there are no indications whatsoever concerning the status and nature of the people involved in the quarrying activities at the Pitaranha quarry. However, as quarrying and stone working was a specialised craft that required skilled workers with advanced knowledge of the working properties of the particular stone, it can be assumed that most quarry workers were freedmen with sufficient experience and skill in quarrying and stone working (Maxfield, 2001). Undoubtedly, unskilled workers, perhaps slaves, were surely employed at the quarry for task that required less skill such as transporting stone material and debris cleaning of the work areas (Gutiérrez Garcia-Morena, 2009; Peacock and Maxfield, 1997).

Similarly, very little is known on the living conditions for these workmen. Given the relatively large distance between the quarry and *Ammaia* (c. 9.5 km), the presence of a small settlement for the workmen can be expected. Oliveira et al. (2007) mention a large concentration of fragments of Roman building material (tiles and bricks) and sherds of Roman tableware on the *Monte da Sobrosa*, which was located some 500 m west–southwest of the quarry, along the road towards *Ammaia*. A resurvey of the indicated location and its surroundings, however, could not confirm the presence of a small Roman settlement.

8.9 Conclusion

In the first part, it is shown that a combination of a low-cost acquisition method and an uncomplicated, computer vision-based processing workflow can yield a highly accurate DSM and orthophotograph of the extensive and complex Roman quarry of Pitaranha. After a difficult data acquisition stage with a Helikite-based platform, an SfM approach automatically estimated all the necessary camera parameters and aligned the large set of unordered images. Subsequently, a dense multiview stereo algorithm was applied to generate a DSM. As a result, this method largely accounted for all possible kinds of geometrical degradations and was able to process a large, unstructured collection of aerial images into a 3D representation and orthophotograph of the quarry site. In this way, even the non-specialist in the field of photogrammetry or geodesy can create highly accurate orthophotographs using currently available and affordable technology.

The second part of this chapter illustrated the importance of a detailed survey and mapping investigation for the in-depth understanding of the technological and social organisation of the ancient stone extraction industry of *Ammaia*. The large-scale extractive activities at Pitaranha, the petrographic observations, and the few chronological indications provide sufficient evidence to ensure a Roman chronology for the exploitation of the quarry. Considering the size of the quarry and the method of extraction, it can be stated with great certainty that the site was opened to provision *Ammaia*. In addition to the general geological and geomorphological advantages offered by the Pitaranha quarry, the joint occurrence of granite and quartz/rock crystal was certainly a major asset for the economical exploitation of the site. From a technical point of view, the Pitaranha quarry clearly shows the advanced geological know-how of the ancient stonecutters. By taking advantage of the nature of the granite outcrops and the presence of naturally occurring fractures and joints in the rock, the stone deposits could be easily exploited.

Chapter 9
White marble provenance

9.1 Provenance methodology

9.1.1 Provenance approach

Despite the lithological diversity of the region in which *Ammaia* is situated (see Chapter 1 and Chapter 7), the occurrence of proper ornamental stones, such as white marbles, are restricted to two small units within carbonate formations around Alter do Chão and Assumar. Further south, two other marble outcrops are found near Elvas and Estremoz (Manupella et al., 1981) (Figure 9.1). In first instance, it was verified if a regional source for the white marble from *Ammaia* is possible. Special attention was hereby given to the marbles from the Estremoz area, given the high quality and the present-day and Roman importance of these marbles.
Besides comparison with these regionally available marbles, the mineralogical–petrographic and geochemical properties of the samples analysed from *Ammaia* were compared with those from the main Roman marbles from the Iberian Peninsula (Viana do Alentejo, Almadén de la Plata, Malaga and Almeria) and the Mediterranean area (Carrara, Hymettos, Naxos, Paros, Pentelikon, Thasos, Aphrodisias, Dokimeion and Proconnesos) (Figure 9.2).

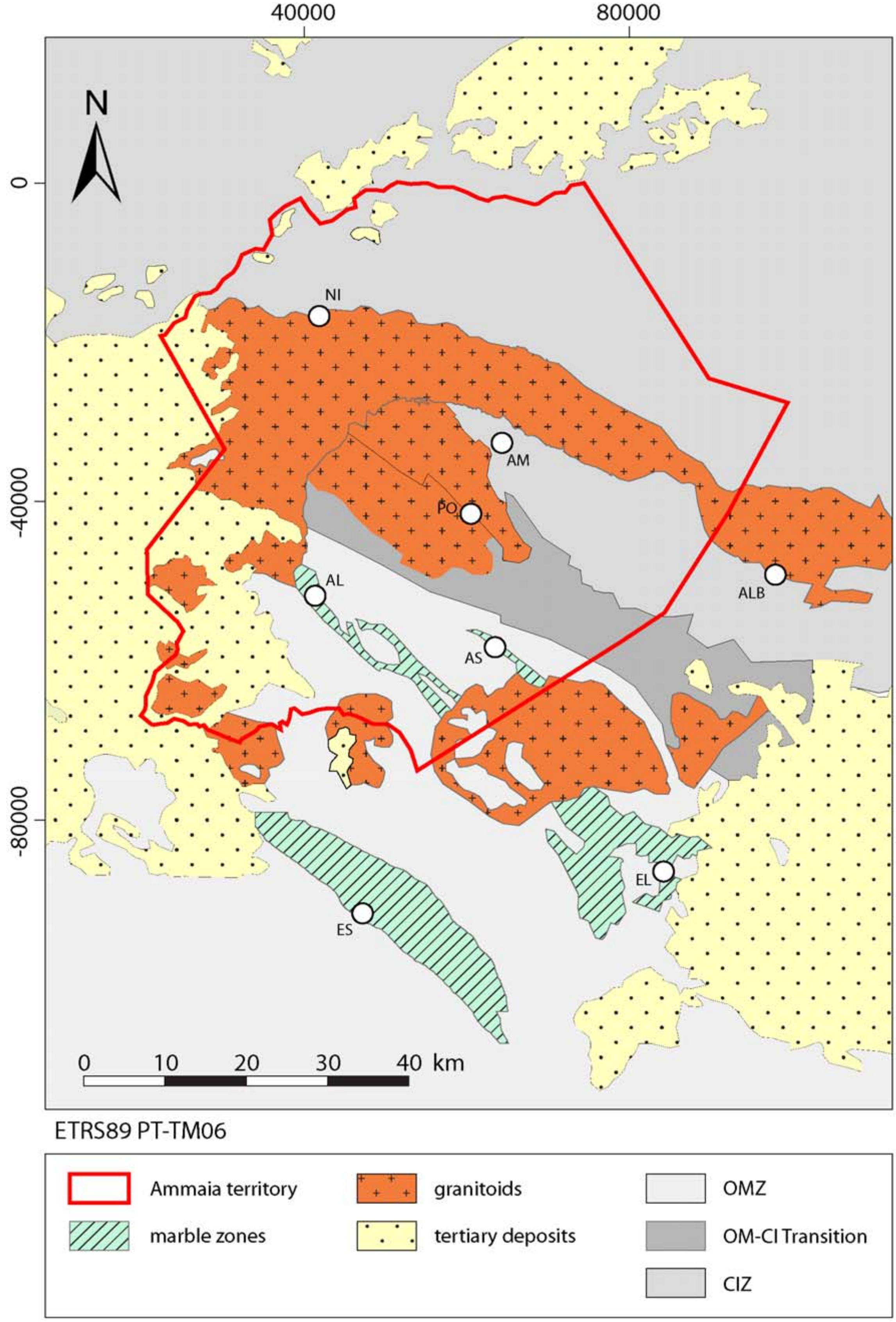

Figure 9.1 Simplified geological map of the ancient territory of *Ammaia*, with indication of the geological units with marble outcrops (after Alvaro et al., 1994; Oliveira et al., 1991; Solá et al., 2003). AL: Alter do Chão, ALB: Alburquerque, AM: *Ammaia*, AS: Assumar, EL: Elvas, ES: Estremoz, NI: Nisa, PO: Portalegre.

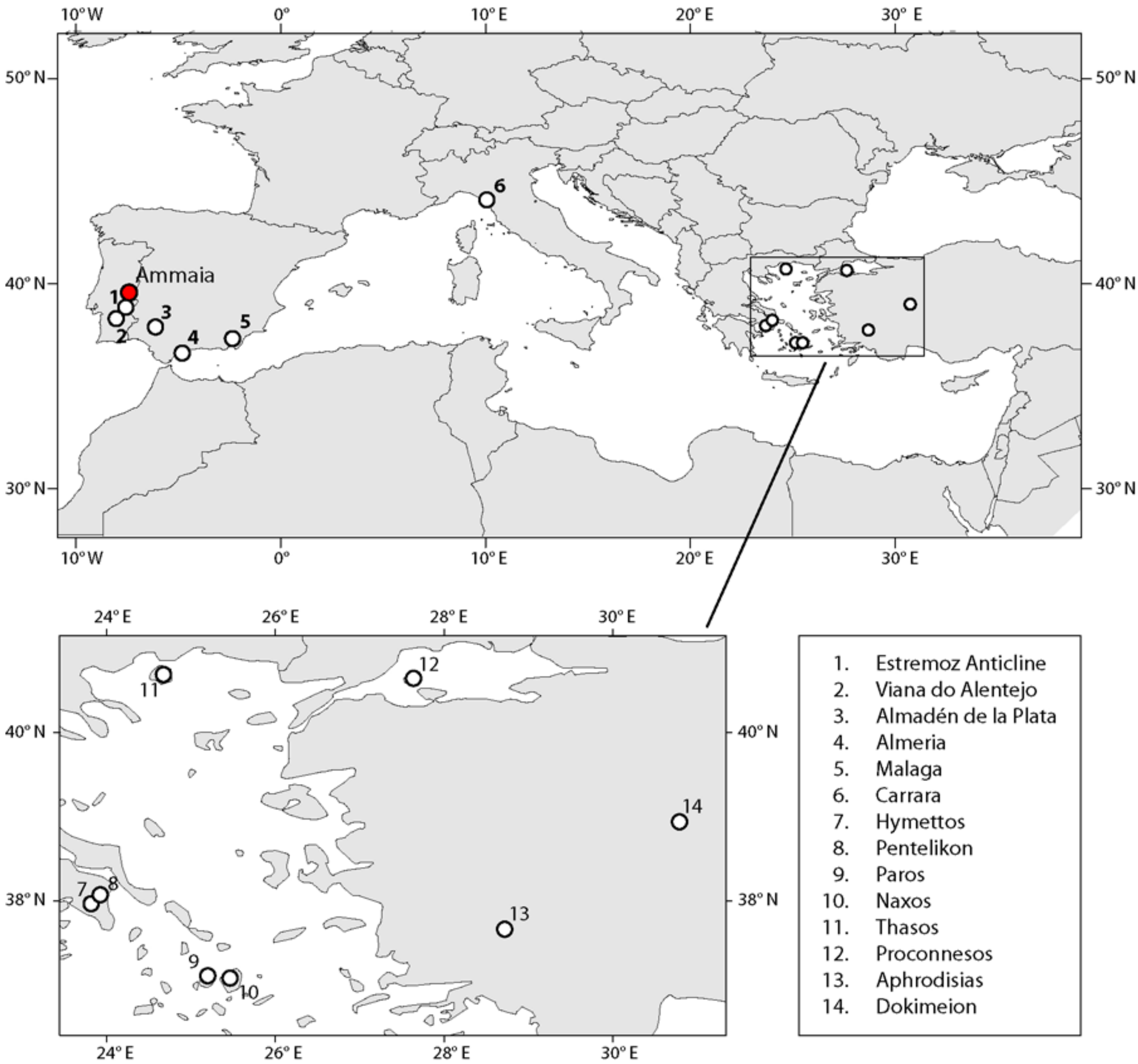

Figure 9.2 Map showing the location of *Ammaia* and of the main Roman quarries for white marble from the Iberian Peninsula and the Mediterranean area.

Until the 1960s, provenance analysis of white marbles was based exclusively on visibly distinguishable rock properties such as colour, texture and structure. These methods generally suffice for the provenance determination of multicoloured marbles, but not for white marbles given their visual similarities. For source tracing white marbles, standard petrographic methods need to be complemented with a more detailed archaeometric characterisation (Moens et al., 1995; Moens et al., 1988).

Many geochemical methods have been used for source tracing archaeological artefacts carved from white marble. Introduced in 1972 by Craig and Craig (1972), stable isotopic analysis of carbon (C) and oxygen (O) has proven to be one of the most successful methods in the provenance studies of white marbles so far. C and O isotope values reflect the metamorphic conditions ($^{18}O/^{16}O$) during the marble formation processes and the initial organic versus inorganic composition ($^{13}C/^{12}C$) of the rock. As different formation processes relate to different source areas, stable isotopic analysis of C and O can be used for source tracing marbles (Herz and Garrison, 1998; Zöldföldi and Szekely, 2009). The main advantage of the technique is that most quarry areas display a relatively homogeneous isotopic signature. The increasing stable isotopic data available has, however, resulted in an increasing overlap in the isotopic fields of different marble areas. Other methods are therefore needed to complement stable isotopic results. Since the 1980s, several new geochemical methods have been introduced, including foremost trace element analysis, cathodoluminescence, electron-spin resonance or electron paramagnetic resonance and strontium isotopic analysis.

For the case of the white marbles from *Ammaia*, standard petrographic observations were combined strontium isotopic analysis. Strontium isotopic analysis was selected, as it was believed that the Hispanic marbles would yield different results than most Mediterranean marbles because of different rock formation ages. Except for the marble from Almeria region, Hispanic marbles are all Paleozoic, whereas most Mediterranean marbles are of Mesozoic age. This approach would, in first instance, enable to verify whether the marbles from *Ammaia* were quarried in the Iberian Peninsula or whether they were imported from Mediterranean quarries. In case the combined petrography and strontium isotope observations would not provide sufficient data to allow a reliable provenance determination of the white marbles from *Ammaia*, complementary analytical methods would have been applied.

9.1.2 Petrography

The samples were first investigated macroscopically (colour, veining), followed by thin section microscopy using a polarising microscope to identify their mineralogical and petrographic properties. Calcite and dolomite were distinguished by applying a staining technique with alizarin red S. Accessory minerals, average grain size and average maximum grain size (MGS) of the calcite crystals (Moens et al., 1995), grain boundary shape (GBS) (Collerson, 1974) (Figure 9.3) and structure type (heteroblastic, homeoblastic or granoblastic) were determined.

Figure 9.3 Grain boundary shapes according to Collerson (1974): (A) straight, (B) curved, (C) embayed, (D) sutured, and (E) serrated.

9.1.3 Strontium isotopic analysis

White marbles ($CaCO_3$) are metamorphic rocks that derive from the recrystallisation of (almost) pure carbonate rocks (mainly limestone or dolomitic limestone). The primary chemical constituents of a marble are calcium (Ca), carbon (C) and oxygen (O) and to a lesser extent magnesium (Mg). Other elements also occur, but only in very low concentrations (trace and rare earth elements). One of these elements is strontium, whose isotopic composition depends on the sea in which the marble was formed (Brilli et al., 2005).

Strontium has four naturally occurring stable isotopes, with masses 84, 86, 87 and 88. While ^{84}Sr, ^{86}Sr and ^{88}Sr are non-radiogenic isotopes with fixed ratios in natural samples, ^{87}Sr is radiogenic and is formed by the radioactive decay of ^{87}Rb (Rubidium), with a half-life time of 4.88 x 10^{10} yr. The quantity of ^{87}Sr in a rock therefore depends on the initial ^{87}Sr of the rock and the amount produced by the decay of ^{87}Rb to ^{87}Sr (Veizer, 1989):

$$^{87}Sr_t = {}^{87}Sr_i + {}^{87}Rb_t(e^{\lambda t}-1)$$

where $^{87}Sr_t$ is the amount of ^{87}Sr in a rock after a period t, $^{87}Sr_i$ is the initial (i) amount of ^{87}Sr in a rock, λ is the decay constant of ^{87}Rb.

^{87}Sr values are generally normalised to the stable ^{86}Sr:

$$(^{87}Sr/^{86}Sr)_t = (^{87}Sr/^{86}Sr)_i + (^{87}Rb/^{86}Sr)_t(e^{\lambda t}-1)$$

where $(^{87}Sr/^{86}Sr)_t$ is the strontium isotope ratio after a period t, $(^{87}Sr/^{86}Sr)_i$ is the initial strontium isotopic composition, because ^{86}Sr is non-radiogenic, $^{86}Sr_i = {}^{86}Sr_t$ (Vanhaecke et al., 1999; Veizer, 1989).

Strontium isotopic composition of carbonate rocks is characteristic for the composition of the seawater and for the strontium-bearing marine precipates from which the rocks are formed. Because the oceanic residence time of strontium (5 million years) is much longer than the mixing time of the oceans (c. 1000 years), the $^{87}Sr/^{86}Sr$ ratio of seawater is sufficiently mixed and hence uniform throughout the oceans of the world at any given time (Burke et al., 1982; Hess et al., 1986; Veizer, 1989). Sr isotopic studies have illustrated that the $^{87}Sr/^{86}Sr$ ratio in seawater has constantly varied throughout geological time as a result of the contribution of sources with different strontium isotope values (Burke et al., 1982; Hess et al., 1986; Veizer, 1989). Several studies (e.g. Burke et al., 1982; Cramer et al., 2011; Hess et al., 1986; Veizer, 1989; Veizer et al., 1999) have determined the strontium isotopic curve of seawater throughout geological time (Figure 9.4), as a result strontium isotopes can be used as a geochronological tool for dating the formation of rocks.

For strontium isotopic studies of marbles, it is important to note that isotope fractionation does not occur during metamorphosis of limestone to marble because of the low relative mass differences between the strontium isotopes (Brilli et al., 2005; Degryse et al., 2006; Garrison, 2010; Pentia et al., 2002). Further, the Rb concentrations in calcium carbonates are very low. As a result, the measured $^{87}Sr/^{86}Sr$ ratios reflect the values at the time of rock formation, and age corrections are negligible as virtually no ^{87}Sr is formed by the radioactive decay of ^{87}Rb since rock formation (Duke, 1988; Hess et al., 1986). Strontium isotope ratios in marbles should therefore fall within the range of variation that has been observed for seawater throughout geological time (Brilli et al., 2005).

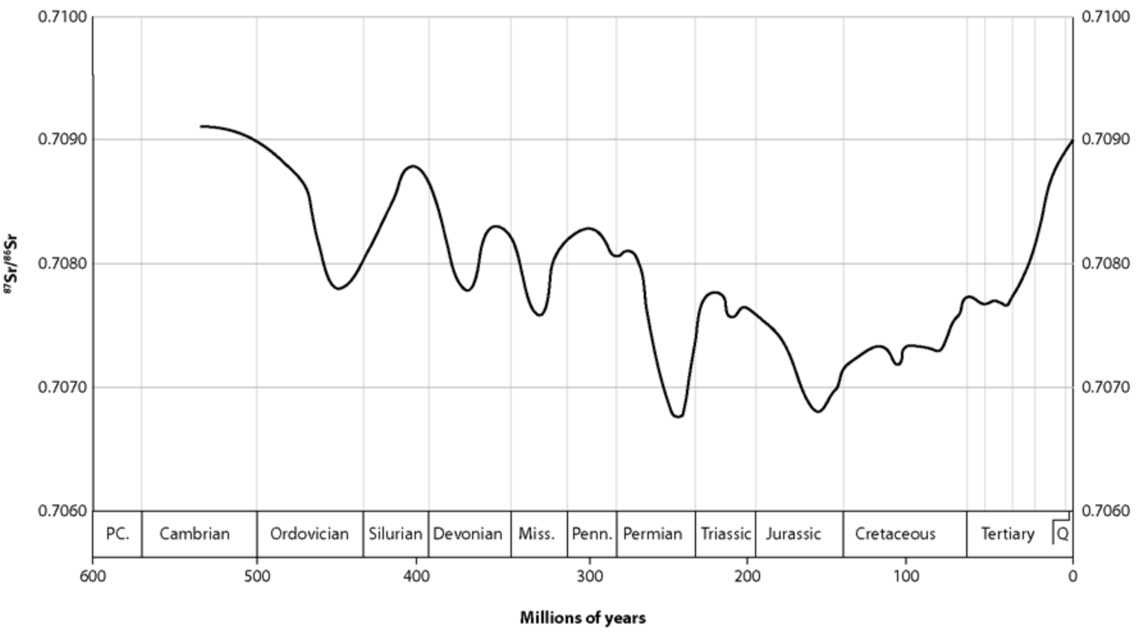

Figure 9.4 Strontium isotopic seawater curve during the Phanerozoic (after Burke et al., 1982; Veizer, 1989).

Given that the approximate strontium isotope variation of seawater at different times is known and that Sr isotope fractionation does not occur during metamorphism, the $^{87}Sr/^{86}Sr$ ratio of marble reflects the formation age of the limestone protolith and gives an indication of its geological origin and can therefore be used as a fingerprinting tool for archaeological marbles (Herz and Garrison, 1998).

9.1.4 Sample preparation and analytical procedure

About 100 mg of powdered rock sample was mixed with approximately 1.9 ml of 0.5 M HCl in flat bottom Teflon (PFA) screw cap vials. This leaching procedure ensured that the Sr isotopic signature of only the calcite fraction was measured and avoided the incorporation of radiogenic Sr from the silicate fraction. Rb is not incorporated in the calcite fraction of marble, and therefore radioactive decay over time does not affect the $^{87}Sr/^{86}Sr$ ratio of the marble. Other minerals present in the marbles, such as micas, have higher Rb concentrations and therefore influence the Sr isotopic results. An excess in Rb in the sample dissolutions therefore would indicate contamination by the non-carbonate fraction of the rock samples. For small sample volumes of marbles that contain silicate material, the non-homogeneous distributions of the silicates may lead to irreproducible results. Trace elements were determined of the calcite fraction of the marble samples to check the Rb/Sr ratio of the solution analysed for Sr isotope ratios, in order to assess whether any radiogenic Sr was leached from the micas, which would necessitate an age correction to the measured ratios. Age corrections were, however, applied, even though they were negligible and within the error of the actual measurement. In short, the results of the trace element analysis were to verify the leaching procedure.

After one hour, the dissolution was centrifuged in a cleaned centrifuge tube. Approximately 1.6 ml of the supernatant was transferred back to the rinsed Teflon vials, and this material was used for Sr isotopic analysis.

Strontium was isolated from the 1.6 ml sample leachate via extraction chromatography with Sr spec^{TM} resin. The Sr isotopic composition of these Sr fractions was then measured using a Thermo Scientific Neptune multicollector ICP–MS unit, housed at the Department of Analytical Chemistry of Ghent University. All samples were analysed in a sample–blank bracketing sequence and the blank mean value before and after each sample was subtracted from signal intensities obtained for that sample. Between two subsequent measurements, the sample introduction system was rinsed with 0.28 M HNO_3 for 200 s to reduce memory effects. Sr isotope ratios were normalised to $^{86}Sr/^{88}Sr$ = 0.1194. Repeated analyses of the isotopic reference material NIST SRM987 gave an average $^{87}Sr/^{86}Sr$ ratio of 0.710271 ± 22 (2 SD, n=8). An in-house calcite standard that was analysed by thermal ionisation mass spectrometry (TIMS) as having a value of $^{87}Sr/^{86}Sr$ = 0.717757 ± 22 and a $^{87}Rb/^{86}Sr$ ratio of 0.0001 (Elburg et al., 2002) yielded 0.717687 ± 4, and a negative Rb concentration after blank correction. The difference between the TIMS value and the one obtained in this study is likely to result from different dissolution techniques.

Sample preparation for trace element analysis involved adding 1 ml of 0.28 M HNO_3, spiked with 2.5 ppb In, and 5 ppb Tl and B, to the leached residue, and homogenisation. After centrifuging, 1 ml of the supernatant was pipetted off, and this solution was diluted with 9 ml of the same spiked 0.28 M HNO_3 solution for trace element analysis using a Thermo Scientific X–series 2 quadrupole-based ICP–MS unit, housed at the Department of Analytical Chemistry of Ghent University, using the analytical set-up routinely applied for geological trace element analysis. Although the goal of the analysis was to obtain Rb/Sr ratios for the leachates, other trace elements were determined as well, giving an additional check on the potential dissolution of other phases than calcite.

The weight of the sample in solution was calculated by drying and weighing the solids remaining after the procedure. The calculated concentrations refer to the material that was dissolved (i.e. the most easily dissolved calcite fraction), rather than the amount that was weighed in. The amount dissolved constituted between 45 and 92 wt%.

Quantification was accomplished by calibration against different dilutions of the geological reference materials BHVO-2 and AGV-2 (dissolved in $HF/HNO_3/HCl$, and taken up in the same 0.28 M HNO_3 solutions as the unknowns), plus a blank. Instrumental drift was corrected by using the internal standards for normalisation and repeated measurement of a BHVO-2 solution. An additional blank correction was applied to the samples, as the value for the leaching blank was found to be higher than the value for the blank used for the calibration line. All data reduction was done off-line in a Microsoft Excel spreadsheet.

As a result of the extraction technique used, of which the efficacy is not exactly reproducible, the accuracy of absolute element concentrations in the solutions is not better than 10 % relative. Although elemental ratios show a far better reproducibility (e.g. Ba/Sr reproduces within 0.007 % between different dissolutions of the same sample), the very low contents of Rb cause a poor reproducibility of the Rb/Sr ratio (within 15 % relative). Considering the very low values for the Rb/Sr ratios (which was the aim of the dissolution procedure), this poor precision has a negligible effect on the reported $^{87}Sr/^{86}Sr$ ratio.

9.2 The Estremoz marble

9.2.1 Geological and geomorphological setting

The Estremoz marble area, better known as the Estremoz Anticline, is the primary marble district of Portugal. It consists of a 45 km long and maximum 10 km wide anticline, with a dominant northwest–southeast orientation (Feio and Martins, 1993; Francisco Pereira et al., 2012; Gonçalves, 1972; Lopes, 2003). The high-quality marble occurs generally in the southeastern half of the structure (Figure 9.5). Besides the economically very important marbles, the Estremoz Anticline is rich in mineral resources, such as hematite and copper (Figure 9.6).

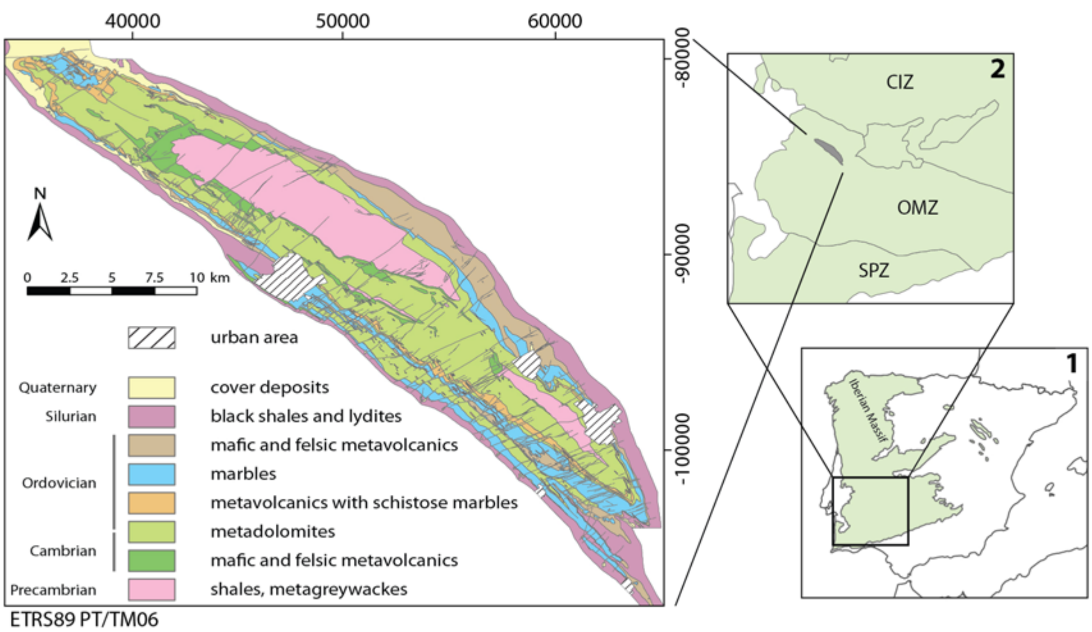

Figure 9.5 Location and geological map of the Estremoz Anticline (Moreira and Vintém, 1997). Inset 1 shows the outline of the Iberian Massif. Inset 2 shows the location of the Estremoz Anticline in the Ossa–Morena Zone (OMZ = Ossa–Morena Zone, CIZ = Central–Iberian Zone, SPZ = South–Portuguese Zone).

Figure 9.6 Copper ore found near one of the Cochicho, Lda quarries in Vila Viçosa (diameter scale: 5 cm) (location: 38.740965° N, 7.391332° W (WGS84)).

Geologically, the Estremoz Anticline is part of the Ossa–Morena Zone (OMZ). The OMZ consists essentially of metamorphosed Precambrian to Carboniferous rocks with Hercynian intrusions. In the OMZ, the marbles are found in Cambro–Ordovician carbonate series that crop out in Hercynian structures, one of which is the Estremoz Anticline (Figure 9.5) (Lapuente, 1995; 1999; Lapuente and Blanc, 2002; Lapuente and Turi, 1995).

From a tectono-stratigraphic perspective, the Estremoz Anticline consists of an late Neoproterozoic (Ediacaran) core of shales, black cherts and greywackes, known as the *Mares Formation*. This is unconformably overlain by the Lower Cambrian *Estremoz Dolomite Formation* that is composed of fine-grained grey to white dolomites, basal metaconglomerates, calc-schists and acid metavolcanics. A non-continuous siliceous horizon forms the transition between the *Dolomite Formation* and the *Estremoz Volcano-Sedimentary Carbonate Complex*. Recent U–Pb isotopic evidence has dated the rocks of this complex to the Upper Cambrian (c. 499 Ma) (Francisco Pereira et al., 2012). This unit contains the valuable Estremoz marbles, as well as basalts, rhyolites and shales. Silurian black shales with graptolitic cherts and basic metavolcanics unconformably overlie the Estremoz marbles (Figure 9.7). During the Hercynian Orogeny, the sequences underwent regional metamorphism under greenschist metamorphic conditions and were intruded by late Hercynian plutons with a northeast–southwest orientation (Carvalho et al., 2008; Feio and Martins, 1993; Francisco Pereira et al., 2012; Lamberto and Sá Caetano, 2009; Lopes and Gonçalves, 1997).

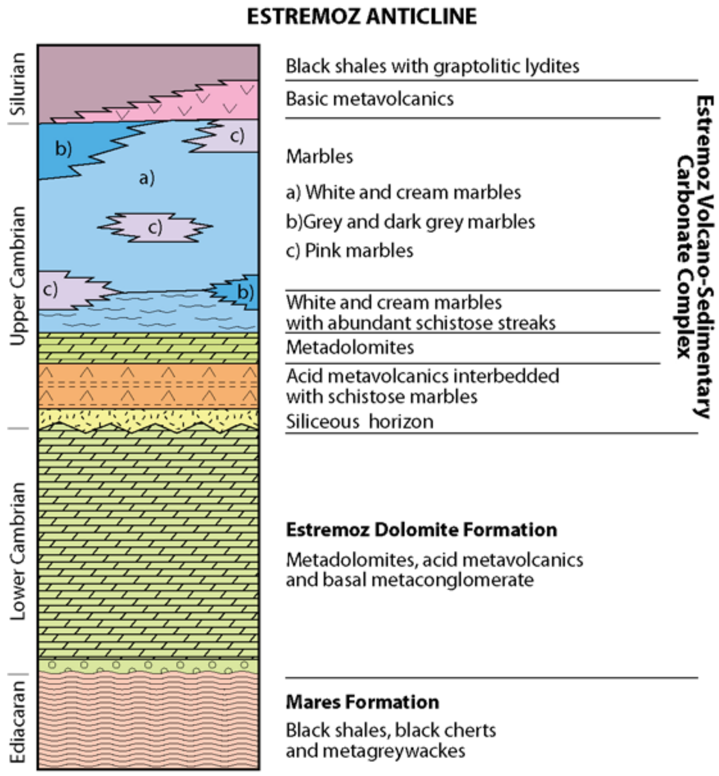

Figure 9.7 Schematic representation of the tectono-stratigraphic sequence of the Estremoz Anticline (Carvalho et al., 2008).

Elevations in the Estremoz Anticline range from about 400 m to 500 m amsl with an average of 440 m amsl, some 50 m to 100 m higher than the surrounding landscape (Feio and Martins, 1993). Originally, the Estremoz area was typified by a karstic marble landscape with irregular, weathered marble outcrops (karren or lapiés) covered by a thick layer of reddish soil – the so-called *terra rossa* (Figure 9.8).

Intensive exploitation since the 1970s, however, severely altered and scarred this original marble landscape morphology. To date, around 250 modern quarries dominate the view of the Estremoz district, some of which have extraction sites that go as deep as 150 m (Figure 9.9). Only about 50 of these 250 quarries are currently in continuous activity.

Figure 9.8 Karstic marble landscape showing lapiés covered with *terra rossa* in the Glória quarry in the Estremoz Anticline (location: 38.824694° N, 7.545747° W (WGS84)) (photo by L. Lopes).

Figure 9.9 Modern quarrying in the Estremoz Anticline (A) Calimal, Lda., Fonte Soeiro – Pardais (location: 38.734335° N, 7.394858° W (WGS84)); (B) Ezequiel Francisco Alves, Lda., Bencatel – Vila Viçosa (location: 38.755874° N, 7.445949° W (WGS84)).

9.2.2 Roman quarrying

The exploitation of the Estremoz marble started in the first half of the 1st century CE, when Roman urban development in *Lusitania* required huge amounts of ornamental stone. Since characterisation of white marble in the western part of the Iberian Peninsula was carried generally with using only petrography, very little is known with certainty concerning the distribution of the Estremoz marble. Marbles with similar petrographic properties as the Estremoz marble have been attested mainly in towns in *Lusitania* and the western parts of *Baetica* and *Tarraconensis*. Towns include *Emerita Augusta*, *Ebora*, *Conimbriga*, *Olisipo*, *Aeminium* (Coimbra, Portugal), *Mirobriga*, *Troia* (near Setubal, Portugal), *Italica*, *Hispalis* (Seville, Spain), *Colonia Patricia* (Cordoba, Spain), *Baelo Claudia*, *Gemella* (Martos, Spain), *Asido* (Medina-Sidonia, Spain), *Gades* (Cadiz, Spain) and *Regina Turdulorum* (Casas de la Reina, Spain). Outside the Iberian

Peninsula, only *Thamusida* (Kenitra, Morocco) and *Volubilis* (Meknes, Morocco) can be mentioned. So far, archaeometric studies have confirmed the petrographic observations only for *Emerita Augusta*, *Ebora*, *Asturica Augusta* (Astorga, Spain), *Thamusida* and *Volubilis* (Alarcão and Etienne, 1977; Àlvarez Pérez et al., 2009b; Antonelli et al., 2009; Cisneros Cunchillos, 1988; 1997; 2002; Cisneros Cunchillos et al., 2010-2011; Lapuente and Blanc, 2002; Lapuente and Turi, 1995; Lapuente et al., 1999; Lapuente et al., 2000; Lopes et al., 2000; Morbidelli et al., 2007; Nogales Basarrate, 2008; Nogales Basarrate et al., 1999; Nogales Basarrate et al., 2009; Origlia et al., 2011).

Unfortunately, modern extraction has destroyed most traces of ancient quarrying. Surveys carried out before the mechanisation of the quarrying industry in the Estremoz area, have, however, located ancient quarries at São Marcos, Lagoa, Monte d'El Rei, Carrascal and Vigária (Alarcão and Tavares, 1988). Other sites were mentioned near Borba, Vila Viçosa, Bencatel, Pardais, Rio de Moinhos, Barro Branco and Glória (Lopes et al., 2000). To date, vestiges of Roman exploitation can be encountered only at Vigária and Lagoa (Figure 9.10 and Figure 9.12).

Figure 9.10 Evidence of Roman quarrying in the Estremoz Anticline: (A) Small bas-relief representing a reclining aquatic divinty, cut into a vertical quarry face of the Vigária-A quarry (location: 38.68889° N, 7.461609° W (WGS84), now preserved in front of the *Museu de Caça e Arqueologia* in Vila Viçosa); (B) Used wedge holes at the Lagoa-A quarry (length hammer: 30 cm) (location: 38.744195° N, 7.415695° W (WGS84)); (C) Remains of a stepped pit quarry at the Lagoa-A quarry (location: 38.744195° N, 7.415695° W (WGS84)).

Geomorphologically, both sites are situated in a karstic landscape characterised by lapiés and *terra rossa*, two elements that undoubtedly informed the ancient quarrymen of subsurface marble deposits. Quarry features include extraction faces, abandoned roughed-out blocks and columns, and wedge holes. Both sites display a well-organised exploitation that started with the quarrying of the karstic surface. When the solid bedrock was reached, a more systematic approach was adopted, resulting in stepped pit quarries (Figure 9.10-C). Quarrying was limited to shallow depths in order to minimise block lifting, ground water problems, and other technical difficulties. The extraction technique was typical for the Roman period, with blocks being removed by cutting narrow vertical trenches on all sides, while splitting was done by hammering a series of horizontally placed wedges at the bottom of the block (i.e. the trench and wedge method) (Figure 9.10-B).

9.2.3 Sampling

A total of 34 samples were collected from 11 different quarries located in the southern part of the Estremoz Anticline, i.e. the area where the highest-quality marbles are found (Figure 9.12 and Table 9.1).

Figure 9.11 (A) In situ marble outcrop of sample DT10_AMM_001 (length GPS: 10 cm) (location: 38.68889° N, 7.461609° W (WGS84)); (B) hand specimen of sample DT10_AMM_001.

At each location, hand specimens of about 1.5 kg were collected from uncontaminated and freshly cut rock surfaces (Figure 9.11). Besides location names, the exact geographical coordinates of the sampling were recorded using a handheld GPS. To assure the correct determination of the general properties of the Estremoz marble, sample locations were chosen to maximise the petrographic and geochemical variation of the sampled marble. In addition, samples were taken in the known ancient quarries. All samples were subjected to petrographic examination in thin section, while a selection of 10 samples were made for $^{87}Sr/^{86}Sr$ determination.

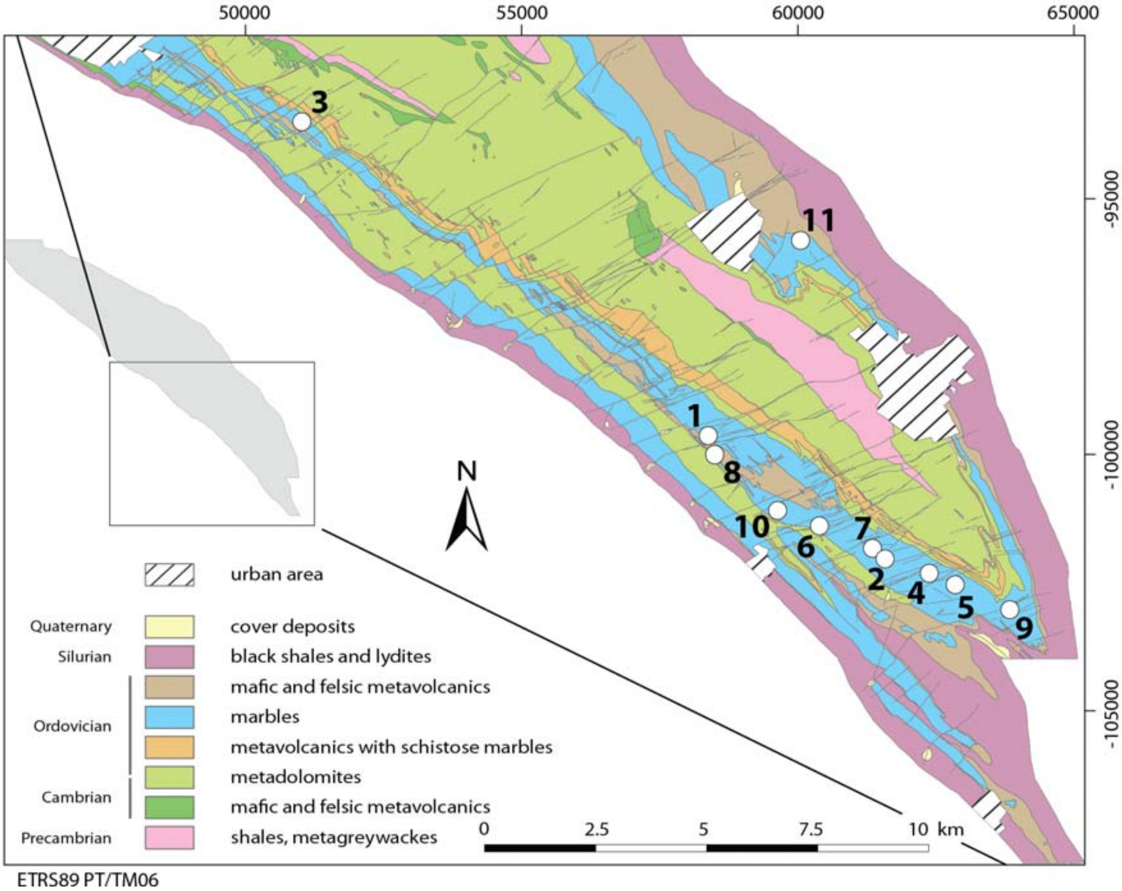

Figure 9.12 Geological map of the southern half of the Estremoz Anticline (Moreira and Vintém, 1997), with indication of the sample locations: (1) Vigária-A, (2) Florival Rocha, (3) Glória, (4) Lagoa-A, (5) Lagoa-B, (6) Monte dos Coutos, (7) Hortejo, (8) Vigária-B, (9) São Marcos, (10) Monte d'El Rei, (11) Carrascal.

Table 9.1 Inventory and geographic location of the quarries sampled.

Location	ID	Colour	Lat (WGS84)	Lon (WGS84)	Notes
1. Vigária-A	1	white + few pink veins	38.768889° N	7.461609° W	Roman
	2	white + few pink/red veins	38.768853° N	7.461597° W	
2. Florival Rocha	3	white	38.746931° N	7.424478° W	modern
	4	pinkish + green/grey veins	38.747017° N	7.424301° W	
	5	pinkish	38.747227° N	7.424489° W	
	6	grey-white	38.746384° N	7.426056° W	
3. Glória	7	white	38.824694° N	7.545747° W	semifinished sarcophagus
	8	white + red/brown veins	38.824790° N	7.545754° W	
4. Lagoa-A	9	white + few brown veins	38.744195° N	7.415695° W	Roman
	10	white + red/grey veins	38.744228° N	7.415859° W	
	11	white + few red/grey veins	38.744074° N	7.415790° W	
	12	white + grey veins	38.744382° N	7.415754° W	
	13	white	38.744489° N	7.415831° W	
5. Lagoa-B	14	white	38.742360° N	7.410410° W	Roman?
	15	white	38.742360° N	7.410438° W	
	16	white + pink veins	38.742130° N	7.409752° W	
6. Monte dos Coutos	17	white + few pink veins	38.752709° N	7.438670° W	abandoned
	18	white	38.752642° N	7.438690° W	
	19	white	38.752671° N	7.438816° W	
	20	white + few brown veins	38.752855° N	7.438508° W	

Location	ID	Colour	Lat (WGS84)	Lon (WGS84)	Notes
7. Hortejo	21	white + pink veins	38.748854° N	7.427657° W	modern
8. Vigária-B	22	dark grey	38.765463° N	7.460396° W	abandoned
	23	dark grey	38.765266° N	7.460194° W	modern
9. São Marcos	24	white + red veins	38.739280° N	7.397041° W	Roman?
	25	white + grey veins	38.739462° N	7.397264° W	
	26	grey-white	38.738831° N	7.399112° W	
	27	grey-white	38.738893° N	7.399166° W	
	28	dark grey	38.736335° N	7.401236° W	
10. Monte d'El Rei	29	white + pink veins	38.756111° N	7.448604° W	Roman?
	30	white + few brown veins	38.754510° N	7.446922° W	
	31	white + few green veins	38.754998° N	7.446605° W	
	32	pinkish	38.755596° N	7.446140° W	
11. Carrascal	33	white + few grey veins	38.803163° N	7.442250° W	Roman?
	34	white + grey veins	38.803174° N	7.442063° W	

9.2.4 Petrography

The main mineralogical–petrographic features of the 34 studied samples are reported in Table 9.2. The Estremoz marble is very diverse regarding colour, veining pattern and texture. In general, the marble is white or white, veined, medium-grained, and has a heteroblastic texture. Pinkish and grey to dark grey varieties also occur (Figure 9.13). Calcite crystals have generally curved–embayed or sutured grain boundary shapes. Homeoblastic marbles are less frequent, as are marbles with straight GBSs. Quartz (mono- and polycrystalline) and micas (muscovite) are common accessory minerals, whereas iron oxides occur only rarely. Bands with fine-grained phyllosilicates are observed occasionally.

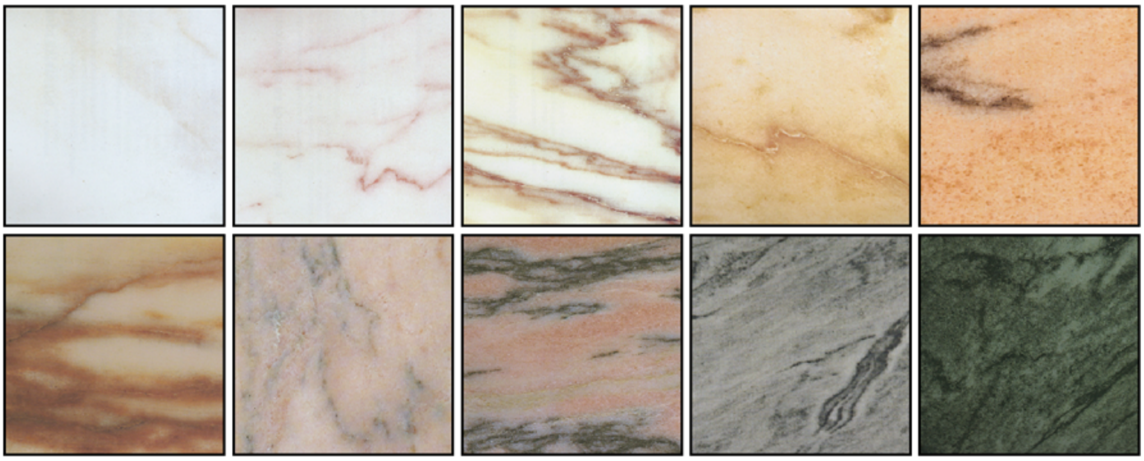

Figure 9.13 Colour and veining pattern of the different marble varieties quarried in the Estremoz Anticline (Casal Moura, 2007).

On the basis of the macroscopic and petrographic observation, the rock samples are subdivided into five different lithogroups (Figure 9.14).

Typically, the marble is white or white, veined, medium-grained, with only minor dolomitic presence (**Lithotype 1**: sample 1–3, 7–21, 24–25, 29–31). This main variety consists of 23 samples (68 %). Apart from sample 3, all have a heteroblastic texture. Zoning is generally not discernible and twins are straight. Two GBS-based subgroups are identified; one with curved to embayed grain boundaries, and one with sutured (or serrated) grain boundaries. Interesting to note is that all marble samples collected at the two Roman quarries (Vigária-A and Lagoa-A) have curved-embayed calcite grains, whereas the white marble sampled in Monte dos Coutos, Glória, Monte d'El Rei and Hortejo shows sutured boundaries.

Lithotype 2 (sample 6, 26–28) is a grey–white, medium-grained, heteroblastic, calcitic marble. GBS ranges from curved–embayed to sutured. Twins are always straight and zoning, best seen in the stained section, occurs only in sample 6.

The two samples from Carrascal make up **lithotype 3** (sample 33, 34). This is a white, veined, medium-grained marble with straight GBSs, a pure calcitic carbonate fraction, and no zoning. Sample 33 shows a homeoblastic texture with straight twins, whereas sample 34 is heteroblastic and has bended twins.

Lithotype 4 (sample 4–5, 32) is a pinkish, cream-coloured, calcitic marble. The remaining properties, however, vary considerably: average grain size is either fine- or medium-grained; GBS goes from straight–curved to curved–embayed; texture is homeoblastic or heteroblastic.

Finally, **lithotype 5** consists of two samples (sample 22, 23), both from Vigária-B. This is the only dolomitic marble and is characterised by a dark grey colour.

A final examined property concerns MGS. Despite the comparable and partially overlapping MGS ranges of most ancient marbles, this criterion occasionally allows to distinguish certain marble districts (Moens et al., 1995). On average, the calcitic marble of the Estremoz Anticline is fine- to medium-grained. MGS values of calcite crystals range from 0.80 to 2.03 mm with a mean of 1.45 ± 0.48 mm (1σ); sample 32 is, however, considerably coarser (3.50 mm). Medium-grained samples (with a MGS between 1 and 5 mm) account for 85 % (29), whereas fine-grained marbles (MGS < 1 mm) form the remaining 15 % (5). Interesting is that the mean MGS of the two Roman quarries (Vigária_A and Lagoa_A) is slightly smaller than the general MGS of the Estremoz Anticline, 1.19 mm versus 1.45 mm.

Table 9.2 Mineralogical-petrographical properties of the marble samples examined from the Estremoz Anticline.

Sample_ID	Mineralogy[1]	Accessories[2]	AGS[3]	MGS[4]	Texture[5]	GBS[6]
DT10_AMM_001	Cal-Dol	Qtz (significant amounts)	M	1.27	He	Em
DT10_AMM_002	Cal	Qtz (relatively large crystals), Ms, some Chl	F	0.82	He	Em
DT10_AMM_003	Cal	Qtz (single crystals)	M	1.70	Ho	Cu- Em
DT10_AMM_004	Cal	Qtz (mostly monocrystalline)	M	1.28	Ho	St-Su
DT10_AMM_005	Cal-Dol	Qtz (significant amounts and often polycrystalline), Ms, Pl	F	0.80	He	Cu - Em
DT10_AMM_006	Cal	Qtz (often polycrystalline)	M	1.54	He	Cu - Em
DT10_AMM_007	Cal	Qtz (some crystals and monocrystalline)	M	1.72	He	Su (Se)
DT10_AMM_008	Cal-Dol	Qtz (monocrystalline), Ms, Chl	M	1.16	He	St - Em
DT10_AMM_009	Cal	Qtz (fairly large monocrystalline, associated polycrystalline), Ms -rich bands	M	1.51	He	Em
DT10_AMM_010	Cal	Qtz (patches and polycrystalline), Ms, Op	M	1.14	He	Em
DT10_AMM_011	Cal-Dol	Qtz, Ms (patches)	M	1.22	He	Cu - Em
DT10_AMM_012	Cal-Dol	Qtz (mainly monocrystalline), Ms	M	1.22	He	Em
DT10_AMM_013	Cal-Dol	Qtz (mono- and polycrystalline), Ms	M	1.18	He	Cu
DT10_AMM_014	Cal	Qtz (polycrystalline)	M	1.17	He	Em - Su
DT10_AMM_015	Cal	Qtz (polycrystalline), Ms (few amounts)	M	1.72	Ho	Cu - Em
DT10_AMM_016	Cal-Dol	Qtz (polycrystalline), Ms (mainly in dolomitic bands)	M	1.39	He	Em
DT10_AMM_017	Cal	Qtz (monocrystalline), Ms	M	1.59	He	Su
DT10_AMM_018	Cal	Qtz (monocrystalline)	M	1.53	He	Su
DT10_AMM_019	Cal	Qtz (mainly monocrystalline)	M	1.25	He	Su
DT10_AMM_020	Cal	Qtz (mainly monocrystalline)	M	1.30	He?	Su

Sample_ID	Mineralogy[1]	Accessories[2]	AGS[3]	MGS[4]	Texture[5]	GBS[6]
DT10_AMM_021	Cal	Qtz (polycrystalline), Ms, Op	M	2.03	He	Su
DT10_AMM_022	Dol	/	F	/	/	/
DT10_AMM_023	Dol	/	F	/	/	/
DT10_AMM_024	Cal	Qtz (mono- and polycrystalline), Ms- and Op-rich bands	M	1.02	He	Em - Su
DT10_AMM_025	Cal	Qtz (polycrystalline), Ms, Op	M	1.26	He	Cu - Em
DT10_AMM_026	Cal	Qtz- and Ms-rich bands, rare Pl	M	1.46	He	Em
DT10_AMM_027	Cal	Qtz -bands (polycrystalline), Ms	F	0.82	He	Em - Su
DT10_AMM_028	Cal	significant Qtz (polycrystalline), Ms, Qtz- and Ms -rich bands	M	1.98	He	Su
DT10_AMM_029	Cal	Qtz (mono- and polycrystalline), Ms	M	1.82	Ho	Cu - Em
DT10_AMM_030	Cal-Dol	Qtz (mono- and polycrystalline), Ms	M	1.50	He	Su
DT10_AMM_031	Cal	Qtz (relatively large crystals), Ms -rich stylolites, rare Zrn	M	1.65	He	Em -Su
DT10_AMM_032	Cal	Qtz (mono- and polycrystalline), Ms	M	3.50	He	Cu
DT10_AMM_033	Cal	Qtz (monocrystalline)	M	1.48	Ho	St
DT10_AMM_034	Cal	Qtz (monocrystalline)	M	1.40	He	St

[1] Cal = calcite ≥ 90 %, cal-dol = 50-90 % calcite, dol-cal = 50-90 % dolomite, dol = dolomite ≥ 90 %;
[2] Mineral abbreviations, according to theSubcommision on the Systematics of Metamorphic Rocks (SCMR): Cal = calcite, Dol = dolomite, Qtz = quartz, Ms = muscovite, Zrn = zircon, Rt = rutile, Chl = chlorite, Op = opaques;
[3] Average grain size (AGS): fine-grained (F) < 1 mm, medium-grained (M) = 1-5 mm;
[4] Maximum grain size (MGS) in mm, average of 5 measurements;
[5] Ho = homeoblastic, He = heteroblastic;
[6] Grain boundary shape (GBS), according to the terminology of Collerson (1974): St = straight, Cu = curved, Em = embayed, Su = sutured.

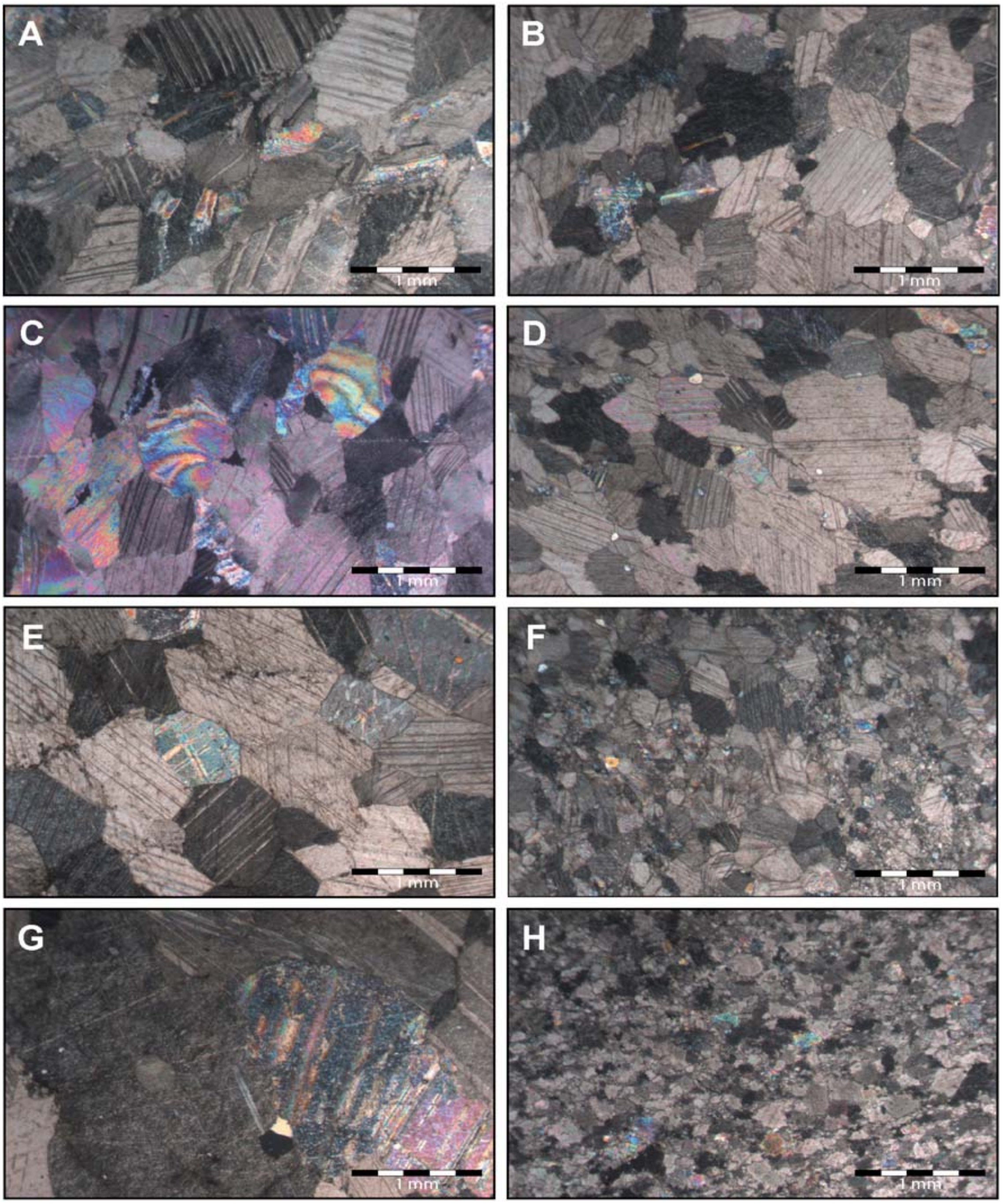

Figure 9.14 Microphotographs showing the textural features of the Estremoz marble samples: (A) Lithotype 1: white marble, heteroblastic texture, serrated GBSs (DT10_AMM_007); (B) Lithotype 1: white, veined marble, heteroblastic texture and sutured GBSs (DT10_AMM_020); (C) Lithotype 1: white marble, homeoblastic texture and curved–embayed GBSs (DT10_AMM_003); (D) Lithotype 2: grey–white marble, heteroblastic texture and serrated GBSs (DT10_AMM_006); (E) Lithotype 3: white, veined marble, homeoblastic texture and straight GBSs (DT10_AMM_033); (F) Lithotype 4: pinkish marble, heteroblastic texture and curved–embayed GBSs (DT10_AMM_005); (G) Lithotype 4: pinkish marble, heteroblastic texture and curved GBSs (DT10_AMM_032); (H) Lithotype 5: dolomitic, dark grey marble (DT10_AMM_02). Photographs taken under crossed polars, scale = 1 mm.

9.2.5 Strontium isotopic analysis

Rb and Sr concentration, as well as $^{87}Rb/^{86}Sr$ and Sr isotope ratios of all analysed Estremoz samples are listed in Table 9.3. Furthermore, $^{87}Sr/^{86}Sr$ ratios are reported backcalculated to an assumed age of 499 Ma (Francisco Pereira et al., 2012), but only for sample 25 this calculation introduced a correction that is outside of analytical uncertainty. Age-corrected values vary between 0.708502 and 0.708919, with a mean of 0.708655. Rb content has a mean of 15 ppb (range = 0–160 ppb), whereas for Sr, the mean is 160 ppm (range: 137–238). As only calcite was dissolved and analysed, element concentrations for most elements are generally very low (<1 ppm), and often below detection limits. Apart from Sr, only barium (Ba) concentrations are typically detectable (1–5 ppm), and sample 25 has an exceptionally high value of 79 ppm. This is also the sample with the highest $^{87}Rb/^{86}Sr$ ratio.

Table 9.3 Results of the trace element and Sr isotopic analysis for the marble samples from the Estremoz Anticline, showing concentrations for Rb and Sr, and $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ ratios.

Sample_ID	Rb (ppb)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}SR/^{86}Sr$ (2SE)	$^{87}SR/^{86}Sr$ (499 Ma)
DT10_AMM_001	27	175	0.00049	0.708552 (11)	0.708549
DT10_AMM_007	18	163	0.00035	0.708567 (12)	0.708565
DT10_AMM_007_2*	12	162	0.00025	/	/
DT10_AMM_012	18	202	0.00028	0.708504 (11)	0.708502
DT10_AMM_013	54	255	0.00066	0.708631 (12)	0.708627
DT10_AMM_016	BDL	193	0	0.708919 (12)	0.708919
DT10_AMM_019	22	218	0.00032	0.708563 (10)	0.708561
DT10_AMM_019bis**	30	238	0.00038	0.708558 (10)	0.708556
DT10_AMM_021	39	187	0.00065	0.708620 (10)	0.708615
DT10_AMM_021_2*	/	/	/	0.708615 (11)	0.708615
DT10_AMM_025	161	186	0.00275	0.708810 (11)	0.708790
DT10_AMM_030	9	174	0.00017	0.708907 (12)	0.708906
DT10_AMM_033	4	154	0.00009	0.708518 (11)	0.708518

* Repeated measurement of sample dissolution to verify instrument reproducibility;
** Repeated measurement of 2nd sample dissolution to verify sample dissolution procedure;
BDL = below detection limit.

9.3 Provenance of the *Ammaia* white marbles

9.3.1 Sampling

Seventeen white marble artefacts from *Ammaia* were selected to unravel their geological origin. Samples were selected to maximise the typological (i.e. all object types and excavation contexts) and chronological variation of the white, veined marbles used in *Ammaia*. For museum pieces, the amount of material obtained was often too small for thin sections. In this case, only Sr isotope ratios were analysed. In total, 13 samples were selected for thin section microscopy, whereas 7 samples were examined for their Sr isotopic signature (Table 9.4).

Table 9.4 Inventory of the archaeological white marble samples selected for thin section microscopic and Sr isotopic analysis.

Sample_ID	Colour	Object type	Thin section	Sr isotopic analysis
DT10_AMM_ARCH_001	white	plinth	X	
DT10_AMM_ARCH_002	white + few grey veins	veneer slab	X	
DT10_AMM_ARCH_006	white + grey veins	reused veneer slab	X	
DT10_AMM_ARCH_007	white	reused veneer slab	X	
DT10_AMM_ARCH_009	white	reused veneer slab	X	
DT10_AMM_ARCH_010	white	plinth	X	X
DT10_AMM_ARCH_019	white + grey veins	veneer slab	X	
DT10_AMM_ARCH_023	white	veneer slab	X	
DT10_AMM_ARCH_026	white + few grey veins	veneer slab	X	
DT10_AMM_ARCH_027	white + few red veins	veneer slab	X	
DT10_AMM_ARCH_033	white	sculpture	X	X
DT10_AMM_ARCH_034	white	veneer slab		X
DT10_AMM_ARCH_035	white	inscription		X
DT10_AMM_ARCH_036	white + coloured veins	inscription		X
DT10_AMM_ARCH_037	white + coloured veins	inscription		X
DT10_AMM_ARCH_038	white + coloured veins	inscription	X	X
DT10_AMM_ARCH_039	white	veneer slab	X	

9.3.2 Petrography

All petrographically examined archaeological marbles show similar mineralogical–petrographic properties (Table 9.5 and Figure 9.15).

The samples from *Ammaia* are calcitic marbles, sometimes with a small quantity of dolomite (samples DT10_AMM_ARCH_010 and 019). The non-carbonate fraction always includes quartz (both mono- and polycrystalline) and often muscovite. Opaque minerals, iron oxides and chlorite minerals are also identified in small amounts. In one archaeological sample (DT10_AMM_ARCH_038), thin bands of very fine-grained material, likely phyllosilicates, were associated with small grains of quartz and opaque minerals (Taelman et al., 2012).

Except DT10_AMM_ARCH_026 , which is slightly finer grained, the samples are characteristically medium-grained with a MGS between 0.98 mm and 1.82 mm, have a heteroblastic texture, and curved to embayed calcite grain boundaries. Three samples (DT10_AMM_ARCH_033, 038 and 039) display a homeoblastic texture. Sample DT10_AMM_ARCH_002 is the only marble with straight grain boundary shapes (GBS), whereas calcite crystals of DT10_AMM_ARCH_001 and 010 exhibit curved/embayed to sutured GBSs (Taelman et al., 2012).

Table 9.5 Mineralogical-petrographical properties of the archaeological white marble samples examined.

Sample_ID	Mineralogy[1]	Accessories[2]	AGS[3]	MGS[4]	Texture[5]	GBS[6]
DT10_AMM_ARCH_001	Cal	Qtz (2 %), Ms (very little), Zrn, Rt	M	1.22	He	Cu-Su
DT10_AMM_ARCH_002	Cal	Qtz (5 %, polycrystalline clusters), Ms, Chl (magnesium)	M	1.09	He	St-Em
DT10_AMM_ARCH_006	Cal	Qtz (2 %)	M	1.59	He	Cu-Em
DT10_AMM_ARCH_007	Cal	Qtz, Ms, Op	M	1.26	He	Cu-Em
DT10_AMM_ARCH_009	Cal	Qtz (< 1 %, as individual small grains), Ms, Op	M	1.15	He	Cu-Em
DT10_AMM_ARCH_010	Cal-Dol	Qtz (relatively large crystals), Ms, Op	M	1.6	He	Em-Su
DT10_AMM_ARCH_019	Cal-Dol	Qtz (polycrystalline clusters), Op	M	1.28	He	Cu-Em
DT10_AMM_ARCH_023	Cal	Qtz (few single grains), Zrn	M	1.68	He	Cu-Em
DT10_AMM_ARCH_026	Cal	Qtz (~3 %, both mono- and polycrystalline), Ms	F	0.98	He	Cu-Em
DT10_AMM_ARCH_027	Cal	Qtz (often polycrystalline, granoblastic), Ms (very little), Op	M	1.37	He	Cu-Em
DT10_AMM_ARCH_033	Cal	Qtz (mainly single crystals, but some granoblastic clusters), Ms, Op	M	1.04	Ho	Cu-Em
DT10_AMM_ARCH_038	Cal	Qtz (relatively large single crystals), Ms, Op: all occurring in bands, presumably former clay-rich stringers	M	1.6	Ho	Cu
DT10_AMM_ARCH_039	Cal	Qtz (mostly monocrystalline)	M	1.82	Ho	Cu

[1] Cal = calcite ≥ 90 %, cal-dol = 50-90 % calcite, dol-cal = 50-90 % dolomite, dol = dolomite ≥ 90 %;
[2] Mineral abbreviations, according to theSubcommision on the Systematics of Metamorphic Rocks (SCMR): Cal = calcite, Dol = dolomite, Qtz = quartz, Ms = muscovite, Zrn = zircon, Rt = rutile, Chl = chlorite, Op = opaques;
[3] Average grain size (AGS): fine-grained (F) < 1 mm, medium-grained (M) = 1-5 mm;
[4] Maximum grain size (MGS) in mm, average of 5 measurements;
[5] Ho = homeoblastic, He = heteroblastic;
[6] Grain boundary shape (GBS), according to the terminology of Collerson (1974): St = straight, Cu = curved, Em = embayed, Su = sutured.

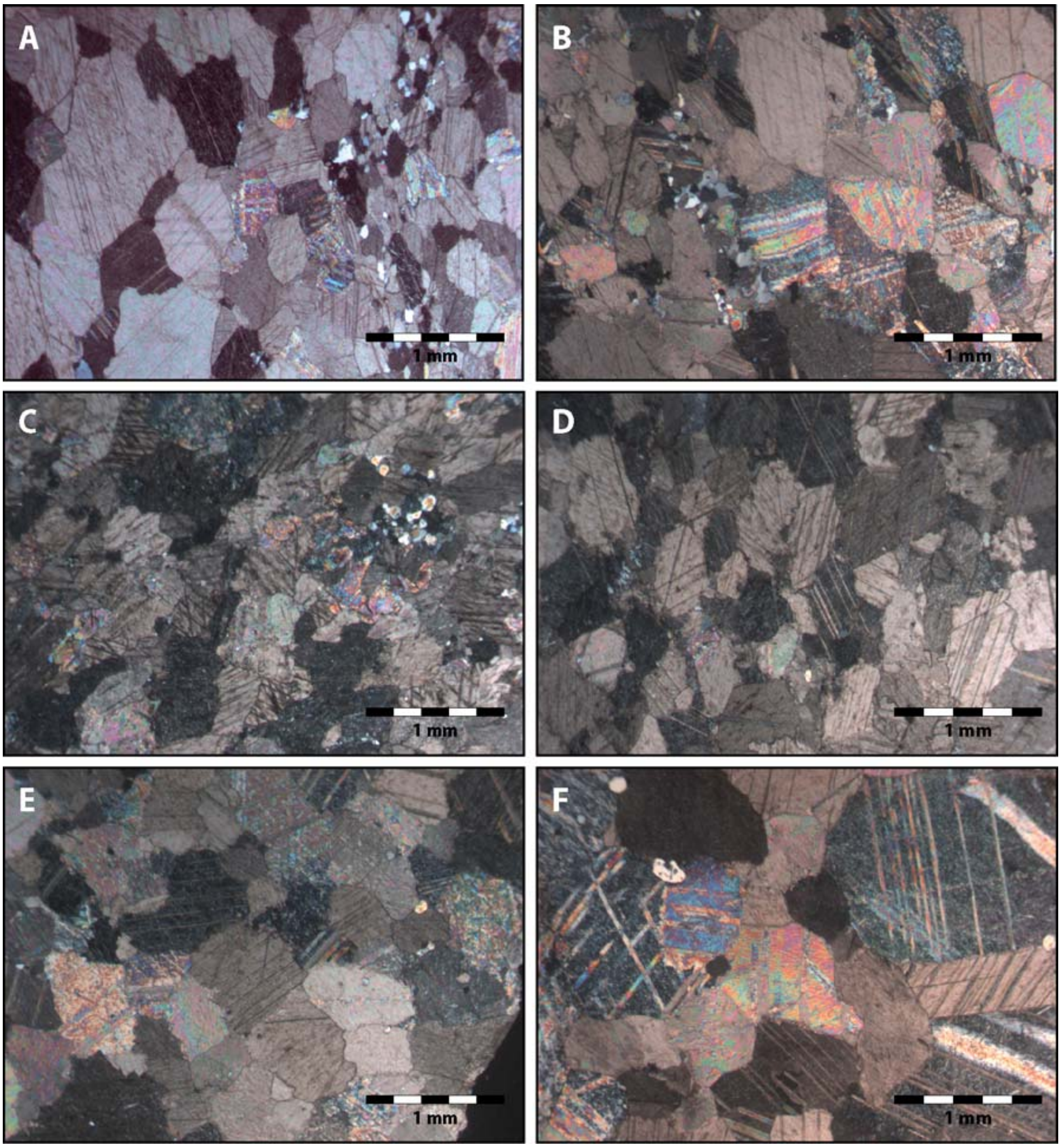

Figure 9.15 Microphotographs showing the textural features of the marble samples from *Ammaia*: (A) DT10_AMM_ARCH_002: medium-grained white marble with few grey veins, heteroblastic, straight–embayed GBSs; (B) DT10_AMM_ARCH_019: medium-grained white marble with grey veins, heteroblastic, curved–embayed GBSs; (C) DT10_AMM_ARCH_026: fine-grained white marble with few grey veins, heteroblastic, curved–embayed GBSs; (D) DT10_AMM_ARCH_027: medium-grained white marble with few reddish veins, heteroblastic, curved–embayed GBSs; (E) DT10_AMM_ARCH_033: medium-grained white marble, homeoblastic, curved–embayed GBSs; (F) DT10_AMM_ARCH_039: medium-grained white marble, homeoblastic, curved GBSs. Photographs taken under crossed polars, scale = 1 mm.

9.3.3 Strontium isotopic analysis

Rb and Sr concentrations, as well as $^{87}Rb/^{86}Sr$ and Sr isotope ratios of all archaeological samples analysed are listed in Table 9.6. Furthermore, $^{87}Sr/^{86}Sr$ ratios are reported backcalculated to an assumed age of 499 Ma. For samples DT10_AMM_ARCH_033 and specifically 038, this calculation introduced a correction that is outside of analytical uncertainty. If a younger age (e.g. 350 Ma) is assumed, the Sr isotope ratios lie within error of the ratios calculated for 499 Ma; for the worst-case scenario, i.e. the sample with the highest Rb/Sr ratio, DT10_AMM_ARCH_038, the value changes from 0.708616 at 499 Ma to 0.708658 at 350 Ma (compared to a measured, present-day value of 0.708757) (Taelman et al., 2012).

Table 9.6 Results of the trace element and Sr isotopic analysis of the archaeological marbles, showing concentrations for Rb and Sr, and $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ ratios.

Sample_ID	Rb (ppb)	Sr (ppm)	^{87}Rb/^{86}Sr	^{87}SR/^{86}Sr (2SE)	^{87}SR/^{86}Sr (499 Ma)
DT10_AMM_ARCH_010	21	113	0.00053	0.708642 (12)	0.708638
DT10_AMM_ARCH_010_2*	22	114	0.00055	/	/
DT10_AMM_ARCH_033	111	93	0.00346	0.708595 (12)	0.708570
DT10_AMM_ARCH_034	36	138	0.00076	0.708516 (12)	0.708510
DT10_AMM_ARCH_034_2*	/	/	/	0.708525 (12)	0.708525
DT10_AMM_ARCH_035	99	138	0.00208	0.708537 (14)	0.708523
DT10_AMM_ARCH_036	777	5255	0.00043	0.708491 (12)	0.708488
DT10_AMM_ARCH_037	826	2099	0.00114	0.708539 (12)	0.708531
DT10_AMM_ARCH_038	519	76	0.01983	0.708757 (16)	0.708616
DT10_AMM_ARCH_038_2*	513	76	0.01959	/	/

* Repeated measurement of sample dissolution to verify instrument reproducibility.

As mostly only calcite was dissolved and analysed, element concentrations of the samples are generally very low (<1 ppm). Only Sr and Ba concentrations are typically detectable. In general, Sr concentrations are around 100 ppm, with two samples having remarkably higher values (DT10_AMM_ARCH_036 = 5255 ppm and DT10_AMM_ARCH_037 = 2099 ppm). Rb content is in the range of 21 ppb to 826 ppb, with two groups: (1) the marbles with Rb values below 100 ppb; and (2) the marbles with values above 500 ppb. However, two of these high-Rb samples also display very high Sr concentrations and their Rb/Sr ratio is not different from the low-Rb samples.

The sample with both the elevated Rb concentrations and Rb/Sr ratio is rich in very fine-grained phyllosilicate material. Age-corrected Sr isotope ratio values fall within a small range of 0.708488 to 0.708638 (Taelman et al., 2012).

9.3.4 Provenance determination

The marble samples from *Ammaia* were first compared macroscopically and petrographically with the marbles from Alter do Chão, Assumar, Elvas and Estremoz to verify if a local/regional source was possible. Macroscopically, the first three marbles are usually coarse-grained and colour-banded. Mineralogically, the marbles often have a considerable concentration of dolomite. In addition, vesuvianite, epidote, chlorite, garnet and other silicate minerals are found that do not occur in the archaeological samples from *Ammaia* (Lopes L., personal communication). As a result, the Alter do Chão, Assumar and Elvas marble are excluded as potential sources.

Both mineralogical–petrographic and geochemical data of the analysed samples from *Ammaia* were compared with existing data from five Hispanic (Estremoz, Viana do Alentejo, Almadén de la Plata, Almeria and Malaga) and nine Mediterranean (Carrara, Hymettos, Naxos, Paros, Pentelikon, Thasos, Aphrodisias, Dokimeion and Proconnesos) marble sources that are known to have been exploited in ancient times.
Just as for most Hispanic and Mediterranean marbles, the archaeological samples from *Ammaia* are almost purely calcitic, with dolomite only as an accessory constituent. Only the marbles from Thasos (Greece) and Malaga (Spain) have dolomite as principal mineral. At Thasos, two different varieties are quarried: a pure white and dolomitic marble (referred to as Thasos_dol) that is found at the quarries of Saliara and Cape Vathy, and calcitic marble, often light grey (Thasos_cal) that is quarried on the Acropolis of Limenas, Cape Phanari and Aliki (Attanasio et al., 2006). Most marble found in the Malaguese quarries are also dolomitic, except for the Alhaurin el Grande variety that is essentially calcitic (Lapuente et al., 2002). However, until now ancient extraction and/or use of this marble is not known. Because of the dolomitic mineralogy of these

marbles, these two areas are excluded as potential sources for the marbles found at *Ammaia*.

Focusing on the Hispanic marbles, the composition of the non-carbonate fraction was compared on a more detailed level. Quartz and muscovite are the most common non-carbonate minerals in the Hispanic marbles, except for the Los Covachos marble from Almadén de la Plata, where muscovite occurs only rarely (Morbidelli et al., 2007). Plagioclase, K-feldspar and tremolite are often present in small amounts. In addition, biotite is found at Estremoz, Viana do Alentejo, Almeria and Los Covachos, but is lacking at the Las Cabreras marble from Almadén de la Plata (Casal Moura and Carvalho, 2007; Lapuente, 1995; Morbidelli et al., 2007). Finally, pyroxenes (mainly diopside) are always present in low quantities in the Viana do Alentejo marble (Casal Moura and Carvalho, 2007). All archaeological samples from *Ammaia* display similar mineralogical–petrographic properties, except that no pyroxenes have been detected, making Viana do Alentejo less likely as a source area.

In Table 9.7 and Figure 9.16, the MGS ranges of the Hispanic and Mediterranean marbles are compared. The values of the samples from *Ammaia* are all in the range of most fine- to medium-grained Classical marbles; Naxos and Thasos_cal are significantly coarser with a MGS from 2.0 mm to 8.0 mm and 2.4 mm to 7.5 mm, respectively (Attanasio et al., 2006) (Figure 9.16).

Table 9.7 Summary statistics of the MGS of the Hispanic and Mediterranean marbles (MGS in mm).

Quarry	n	min	Q1	median	Q3	max	mean	SD
Estremoz Anticline (1)	32	0.80	1.20	1.40	1.62	3.50	1.45	0.48
Viana do Alentejo (2,3,4)	11	0.30	2.00	2.60	4.00	5.50	2.81	1.62
Almadén de la Plata (2,3)	6	0.80	2.00	2.50	3.20	3.50	2.42	1.01
Almeria (2,3)	18	0.20	1.20	2.00	2.70	3.70	1.90	0.99
Malaga (2,3)	12	1.00	1.35	1.90	3.00	5.00	2.34	1.30
Carrara (5)	169	0.40	0.60	0.70	0.90	1.40	0.75	0.20
Hymettos (5)	41	0.35	0.60	0.65	0.80	1.20	0.69	0.20
Naxos (5)	43	2.00	4.00	4.50	5.00	8.00	4.76	1.44
Paros (5)	137	0.70	1.50	2.00	2.40	3.10	1.94	0.55
Pentelikon (5)	161	0.50	0.80	0.90	1.00	1.80	0.95	0.18
Thasos_dol (5)	33	0.90	1.30	1.60	2.00	3.20	1.72	0.61

Quarry	n	min	Q1	median	Q3	max	mean	SD
Thasos_cal (5)	73	2.40	3.40	3.60	4.00	7.50	3.81	0.84
Aphrodisias (5)	103	0.10	1.50	2.10	2.50	4.50	2.12	0.73
Dokimeion (5)	65	0.50	0.70	0.80	1.00	1.50	0.86	0.25
Proconnesos (5)	167	0.40	1.60	1.95	2.30	3.50	1.92	0.55

(1) Own measurements, (2) Origlia et al. (2011), (3) Lapuente & Turi (1995), (4) Lapuente et al. (2000), (5) Attanasio et al. (2006).

The strontium isotope fields of the ancient marbles clearly show two separate groups among with values above and below 0.708500, likely related to different rock formation ages (Table 9.8 and Figure 9.17). The Hispanic Paleozoic marbles (Estremoz, Viana do Alentejo, Almadén de la Plata) make up the group with the higher values, whereas the Mediterranean and Hispanic Mesozoic (Almeria, Carrara, Hymettos, Naxos, Paros, Pentelikon, Aphrodisias and Dokimeion) and the Mediterranean Paleozoic (Thasos and Proconessos) marbles have lower strontium isotope values. Exceptions are the Pentelic marble (0.707541–0.709180) that displays a remarkably large Sr isotope field. For the Paleozoic marble from Malaga, unfortunately, no Sr isotopic data is currently available.

Using the Sr isotopic data, the possibility of a Mediterranean source is excluded because of significantly lower $^{87}Sr/^{86}Sr$ isotope ratios for most Mediterranean marbles (Figure 9.17). The samples from *Ammaia* have $^{87}Sr/^{86}Sr$ values between 0.708488 and 0.708638. Partial overlap in the Sr isotope fields occurs with the Pentelic (0.707541–0.709180) and Thasos_cal (0.707260–0.708700) marbles. In addition to most Mediterranean sources, the marble quarries of Almeria are also eliminated on the basis of Sr isotopic composition.

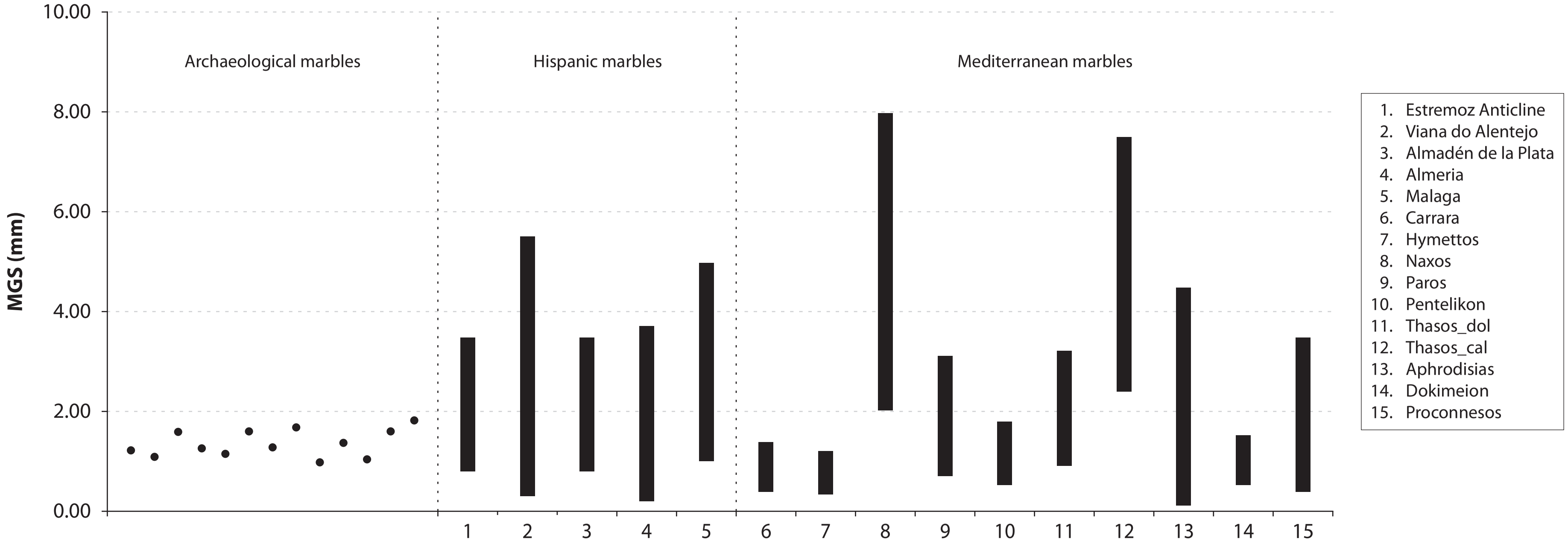

Figure 9.16 Comparison of the MGS of calcite grains of the archaeological marbles analysed with the MGS ranges of the main Hispanic and Mediterannean marbles.

Table 9.8 Summary statistics of the $^{87}Sr/^{86}Sr$ ratios of the Hispanic and Mediterranean marbles.

Quarry	n	min	Q1	median	Q3	max	mean	SD
Estremoz Anticline (1)	10	0.708502	0.708549	0.708590	0.708792	0.708919	0.708655	0.000158
Estremoz Anticline (2)	5	0.708900	0.709100	0.709280	0.709350	0.709450	0.709216	0.000218
Viana do Alentejo (2)	8	0.708850	0.709230	0.709735	0.709850	0.709920	0.709550	0.000419
Almadén de la Plata (2)	10	0.708650	0.709000	0.709260	0.709490	0.713420	0.709741	0.001417
Almeria (2)	8	0.707740	0.707755	0.707825	0.707955	0.708320	0.707891	0.000196
Carrara (3,4,5,6)	56	0.707290	0.707736	0.707790	0.707830	0.708100	0.707776	0.000155
Hymettos (3,5)	17	0.707170	0.707230	0.707320	0.707450	0.707760	0.707382	0.000182
Naxos (3,4,5,7,8)	31	0.707367	0.707483	0.707740	0.707920	0.708320	0.707739	0.000274
Paros (3,4,5)	40	0.707130	0.707240	0.707405	0.707565	0.708160	0.707459	0.000267
Pentelikon (3,4,5)	27	0.707541	0.708090	0.708160	0.708300	0.709180	0.708212	0.000351
Thasos (3,5)	48	0.707260	0.707590	0.707680	0.707885	0.708700	0.707727	0.000240
Aphrodisias (4,5)	30	0.707120	0.707630	0.707682	0.707890	0.708200	0.707756	0.000226
Dokimeion (3)	7	0.707590	0.708130	0.708160	0.708200	0.708350	0.708109	0.000240
Proconnesos (3,4,5)	12	0.707270	0.707680	0.707705	0.708005	0.708500	0.707800	0.000310

(1) Own measurements, (2) Morbidelli et al. (2007), (3) Brilli et al. (2005), (4) Castorini et al. (1997), (5) Pentia et al. (2002), (6) Herz & Dean (1986), (7) Herz (1987), (8), Gärtner et al. (2011).

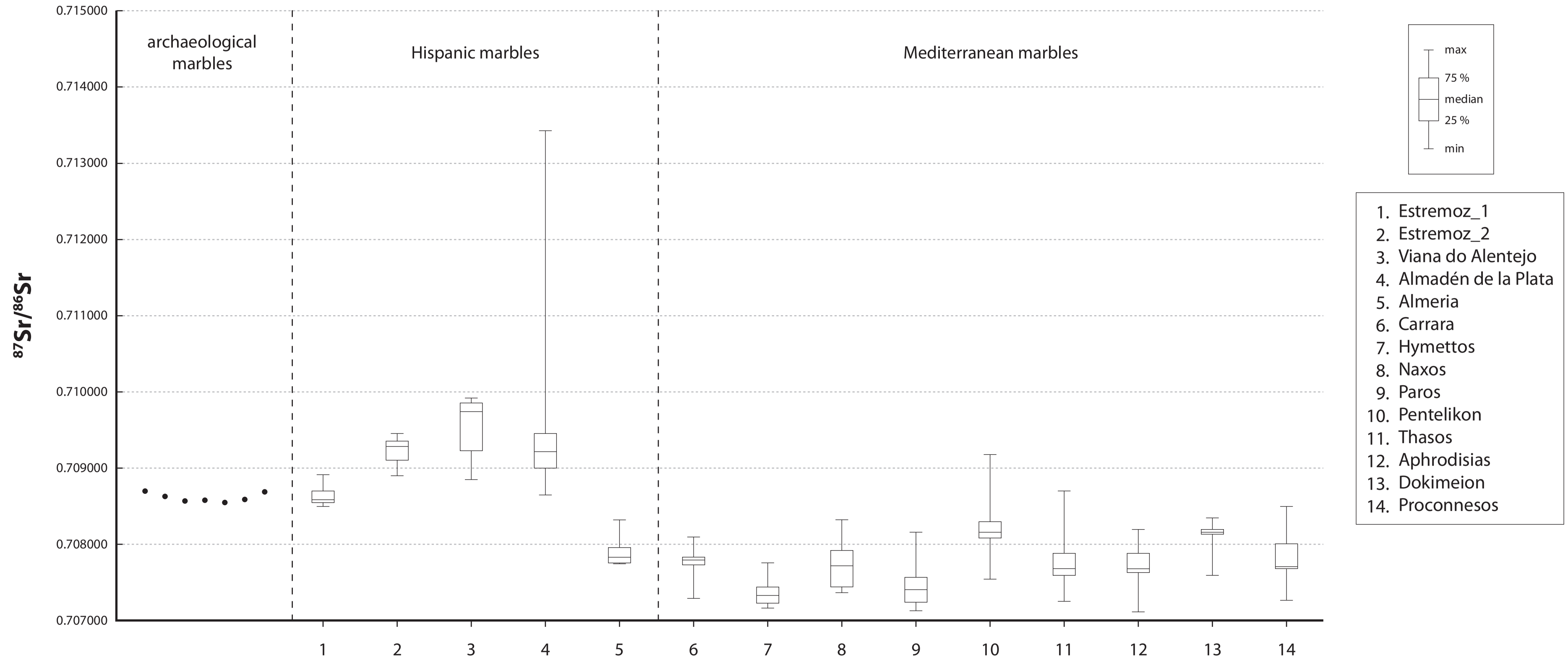

Figure 9.17 Comparison of the $^{87}Sr/^{86}Sr$ isotope ratios values of the archaeological samples with the $^{87}Sr/^{86}Sr$ isotope ratio fields of the main Hispanic and Mediterranean marbles

For Sr isotopic analysis, the importance of the sample dissolution technique for comparing results from unrelated studies is already mentioned. Reporting Rb/Sr ratios for the analysed samples is essential to assess whether any radiogenic Sr was leached from the silicate fraction of the rock samples. In the case of the marbles from *Ammaia*, the different dissolution procedures present no problem for comparing the values of the archaeological samples with the values obtained in the literature for the Mediterranean marbles, because if any radiogenic Sr from the silicate fraction influenced the $^{87}Sr/^{86}Sr$ values of the Mediterranean samples, the actual values for the calcite fraction can only be lower than the ones presented (Veizer, 1989). This may also explain the higher values of Morbidelli et al. (2007) for the Estremoz marbles in comparison with our results. Sr isotopes were, therefore, only used for the Mediterranean marbles and not for the Paleozoic Hispanic marbles. Finally, despite the overlapping Sr isotope field of the Pentelic marble and the archaeological samples, a Pentelic source is less likely as the values for the *Ammaia* samples correspond to the uppermost part of the Pentelikon Sr isotope ratio range, without accounting for the effect of the different leaching/dissolution procedures.

The petrographic and geochemical data discussed above eliminate most Mediterranean and Hispanic sources for the marble from *Ammaia*. Because of similar petrographic properties and Sr isotope ratio values for Estremoz, Almadén de la Plata and Pentelic marble, a conclusive attribution of the archaeological marbles remains problematic. However, the results of the petrographic and Sr isotopic analysis correspond the best with the data of the Estremoz marbles. Only samples DT10_AMM_ARCH_036 and 37 show a geochemical characteristic that has not been observed for the natural marbles, and that pertains to their very high Sr concentrations. The size of the Sr ion makes it a fairly poor fit in the lattice of calcite, and recrystallisation may therefore cause the expulsion of Sr from the calcite lattice, and perhaps the formation of strongly Sr-enriched domains elsewhere. Alternatively, if the precursor of the marble was an aragonitic, rather than calcitic limestone, the inherently higher Sr concentration in aragonite (e.g. Coggon et al., 2004) may have been inherited from this protolith. Marbles with similarly high Sr concentrations are known from

Macael, Spain (Morbidelli et al., 2007), but these have significantly lower $^{87}Sr/^{86}Sr$ ratios (0.707740–708320) than the two Sr-rich archaeological samples, which are indistinguishable from the more Sr-poor samples, and the geological samples from Estremoz.

Notwithstanding the limitations of the analytical procedure, it is proven that the marble originates either from the Estremoz Anticline (Portugal), Almadén de la Plata (Spain) or Pentelikon (Greece), with strong evidence suggesting the Estremoz quarries as the most likely source. This hypothesis is further enforced by the geographical proximity of the Estremoz district (only 70 km to the south) (Figure 9.1) and the expensive overland transport that the other marbles require to reach *Ammaia*. Moreover, the high quality of the Estremoz marble, especially the variety found around Borba that can compete with the Carrara marble (Lapuente, 1999), and the available exploitation and administration system for the extraction of the marble for *Emerita Augusta* (Cisneros Cunchillos, 2010) undoubtedly appealed the citizens of *Ammaia* and explains its popularity in the town. A Pentelic source can, however, not be excluded for the more prestigious embellishment projects of the town. For example, the Pentelic marble was very popular in Roman times for sculptural purposes.

Finally, although the proposed multimethod approach delivered very promising results in the provenance determination of the *Ammaia* white marbles, further archaeometric analysis, such as quantitative analysis of mineralogical composition, cathodoluminescence microscopy and stable isotopic analysis, can contribute to confirm Estremoz as the source. However, the heterogeneous nature of the white marbles from *Ammaia* and the very small sample volumes of the museum pieces are likely to bias any quantitative mineralogical as the small sample volumes are probably are not representative for the entire marble from which the object was carved. The predominance of carbon and oxygen in the calcite fraction makes stable isotopic analysis a more promising avenue. Similarly, recent cathodoluminescence studies have proven extremely valuable for distinguishing Estremoz marbles from Mediterranean sources like Pentelikon, Naxos and some Dokimeion marbles (Cisneros Cunchillos et al., 2010-2011; Lapuente et al., 1999; Lapuente et al., 2000).

Chapter 10
Provenance of the coloured ornamental stones

Contrary to white marbles from different quarry areas that show very little macroscopic and petrographic variation, coloured ornamental stones can often be distinguished on the basis of a simple visual inspection or mineralogical–petrographic observations under the polarising microscope.
Using macroscopic and thin section microscopic observations, the coloured ornamental stones were first classified macroscopically in view of the rock type, structure, colour, patterning, veining, texture and the presence of fossils or other distinctive features. Other properties observed for the samples are foremost the overall grain or crystal size, grain size distribution, main mineralogy and hardness of the rock.

10.1 Pink limestone

10.1.1 Stone characterisation

The pink limestone from *Ammaia* is a fine-grained limestone with a micritic texture and a heterogeneous macroscopic appearance. No fossils or bioclasts have been observed.

The dominant colour is pink with frequent white streaks and dark-coloured, carbon stylolites. Tests using dilute 10 % hydrochloric acid and a staining technique for the thin sections using alizarin red S revealed calcite as the dominant carbonate mineral. Quartz occurs as accessory mineral. Secondary calcite veins have been observed (Figure 10.1).

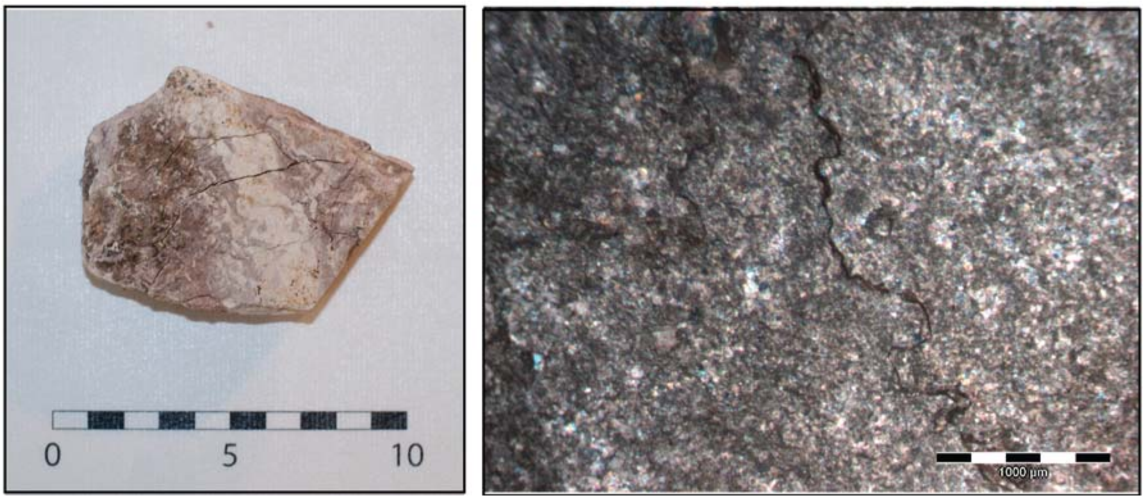

Figure 10.1 Macroscopic photograph and microphotograph of two pink limestone samples from *Ammaia*.

10.1.2 Provenance determination

Two formations of pink limestone, one near Sintra (Portugal) and one near Alconera (Spain), crop out in the western part of the Iberian Peninsula.

The **Sintra limestone** can be found in the municipalities of Sintra and Loures (district of Lisbon), about 20 km northwest of the present-day capital of Portugal. The limestone belongs to a vast platform of the Belasian Formation of Cretaceous age with limestone and marl deposits. The Sintra limestone is microcrystalline limestone that is characterised by a pink–purple, orange or yellow colour with abundant fossils and bioclasts (Coelho, 2009; Fusco and Manãs Romero, 2006; Manãs Romero and Fusco, 2009) (Figure 10.2).

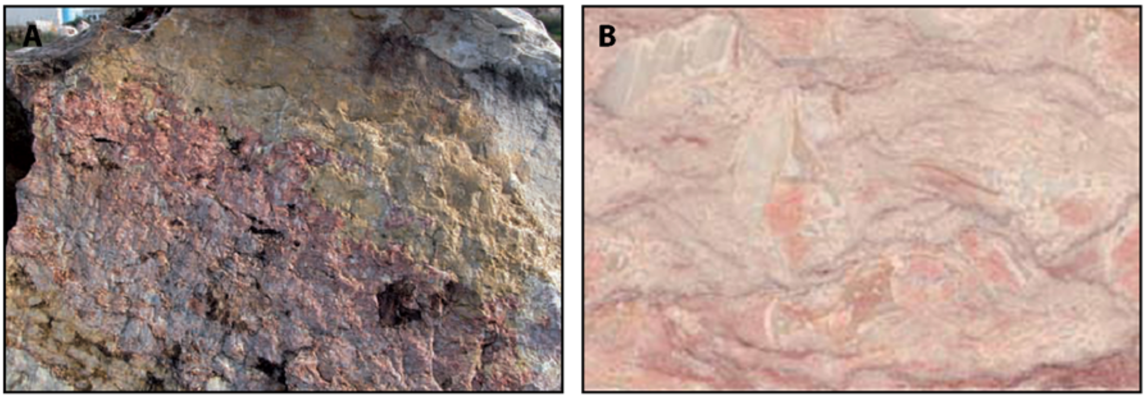

Figure 10.2 Pink limestone from Sintra: (A) limestone outcrop showing a pink and yellow–beige variety (Manãs Romero, 2011); (B) pink variety, commercially known as *Lioz rosa* (Fusco and Manãs Romero, 2006).

Traces of Roman quarrying were recently detected in Colaride and include wedge holes and negative traces extracted blocks (Coelho, 2002; 2009). In Roman times, the pink limestone from Sintra was used mainly for the production of wall and floor veneer, and for votive and funerary monuments such as *stelae* and altars (Fusco and Manãs Romero, 2006; Manãs Romero and Fusco, 2009; Nogales Basarrate et al., 2009). It has been used essentially in *Olisipo*; for example, for the *opus sectile* flooring of the *orchestra* in the Roman theatre (Coelho, 2009; Nogales Basarrate et al., 2009). Other Roman towns were the use of the limestone was observed are *Hispalis*, *Italica* and *Ilipa* (Alcalá del Rio, Spain) (Amores Carredano et al., 2009; Coelho, 2009; Manãs Romero and Fusco, 2009).

The second outcrop area of pink limestone in the western part of the Iberian Peninsula is located near **Alconera–Zafra**, in the ancient province of *Baetica*, just south of the border with *Lusitania*. The limestones are part of the Alconera Formation of the OMZ that crops out along the *Sierra Gorda*. The rocks are of Lower Cambrian age (early–middle Georgian) (Cisneros Cunchillos, 1988; Vennin et al., 2001). Ornamental stones found in the Alconera Formation are a white marble with greyish and greenish spots, a grey–white marble, a grey–black marble, a pink–purple limestone, a red–white breccia and a red dolomite (Canto, 1977-1978; Cisneros Cunchillos, 1997; Fusco and Manãs Romero, 2006; Lapuente, 1995). The pink–purple variety, the only one exploited in Roman times, is a fine-grained limestone with a heterogeneous and irregular colour pattern. Both intense and dull pink–purple varieties occur, frequently with light–

coloured veins. The presence of recrystallised calcite and slate is not uncommon (Fusco and Manãs Romero, 2006) (Figure 10.3).

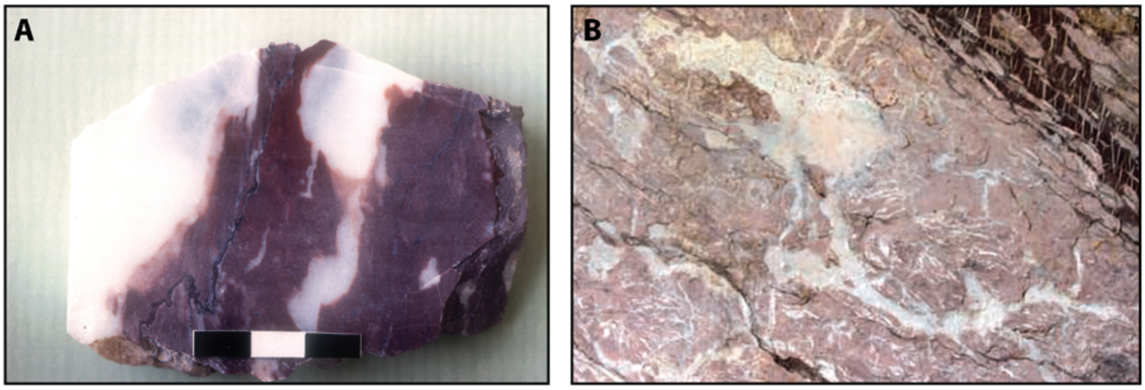

Figure 10.3 Pink limestone from Alconera: (A) Dark purple variety with white streaks (photo by M. Cisneros); (B) Light purple variety with with streaks (Manãs Romero, 2011).

Remains of ancient quarrying are limited to a roughed-out column. So far ancient quarries have not been detected yet (Fusco and Manãs Romero, 2006; Manãs Romero and Fusco, 2009). Pink limestone from Alconera has been attested essentially for column shafts, wall and floor veneer panels, and occasionally for funerary monuments (Manãs Romero and Fusco, 2009; Padilla Monge, 1999). Distribution of the stone was mainly in the western part of *Baetica* and in *Lusitania*, along the *Via de la Plata*. For example, it was imported in *Emerita Augusta* for veneering the aedicules and niches of the *Portico del Foro*, and in *Regina Turdulorum* for columns of the *frons scaenae* of the theatre. Other towns were the Alconera pink limestone was found are *Hispalis*, *Italica* and *Adra* (near Almeria, Spain) (Cisneros Cunchillos, 1988; 1989-1990; Fusco and Manãs Romero, 2006).

Considering its appearance, the pink limestone from Alconera might have been used as a substitute stone for the more expensive *Portasanta* (*marmor Chium*) from Chios, Greece that was very popular in Rome in the Trajan–Hadrian period but that could not easily reach the inland and remote sites of the Iberian Peninsula (Amores Carredano et al., 2009; Cisneros Cunchillos, 1997; Fusco and Manãs Romero, 2006; Gnolli et al., 2004).

On the basis of the petrographic observations of the archaeological samples and the available descriptions of the pink limestones from Sintra and Alconera, it is clear that the pink limestone archaeological artefacts from *Ammaia* originate from the Alconera

Formation in Spain. The abundant bioclasts and fossil remains in the Sintra limestones rule out this limestone formation as a possible source.

10.2 Grey–white marble

10.2.1 Stone description

The grey–white marble used for wall and floor veneer panels essentially in the forum temple of *Ammaia* is characterised by abundant (dark) grey veins or streaks alternating with white-coloured zones, giving the stone a distinctive colour palette. The marble is medium-grained. Tests with dilute 10 % hydrochloric acid (HCl) revealed calcite as the dominant carbonate mineral. Regarding structure and texture, the grey–white marble is very similar to the white marble found in *Ammaia*. Both types differ mainly in the overall grey aspect of the rock and the density of grey veining pattern.

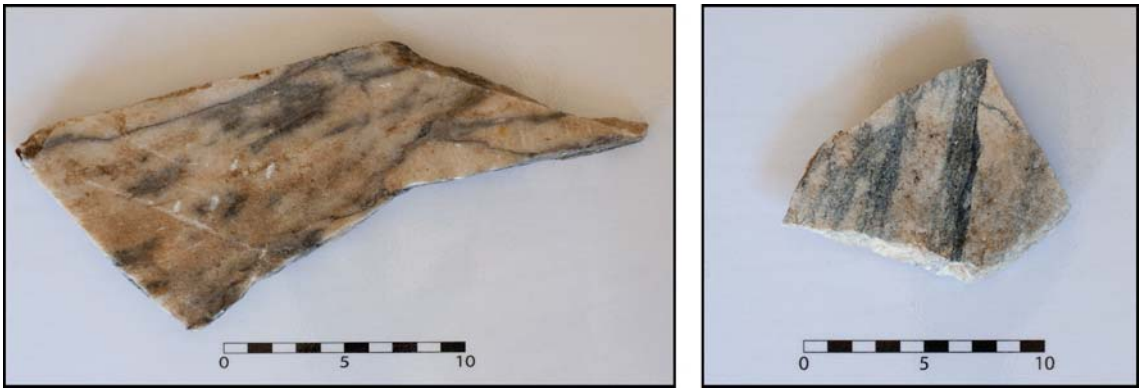

Figure 10.4 Macroscopic photograph of two veneer panels in grey–white marble from *Ammaia*.

10.2.2 Source determination

The nearest outcrops of grey–white marble to *Ammaia* can be found in the Estremoz Anticline, about 70 km south of the Roman site. Comparison of the mineralogical–

petrographic features of the archaeological samples with samples of grey–white marble taken from the outcrops – see Chapter 9 – revealed a high degree of resemblance, suggesting the Estremoz Anticline as the source for the grey–white marble from *Ammaia*.

Grey– white and dark grey marbles from the Estremoz Anticline, commercially known as *Azul Lagoa* and *Ruivina* (Casal Moura and Carvalho, 2007), are part of the upper deposits of the Volcano–Sedimentary Carbonate Complex of the Estremoz Anticline and occur as intercalations in the white marble deposits. In comparison with the high-quality white marbles, these dark varieties are found only in limited quantities around the villages of Pardais and Rio de Moinhos, mainly in the southeastern part of the anticline and along its flanks (Henriques et al., 2006; Lamberto and Sá Caetano, 2009; Lopes, 2003).

The marbles are fine- to medium-grained, calcitic and have a heteroblastic texture. Dolomite and quartz are common accessory minerals. Opaque minerals and muscovite are sometimes observed. In the dark grey marbles, carbonaceous material is sometimes present in low concentrations. Some dark grey marbles quarried near Vigária-B are almost pure dolomitic (Figure 9.14, Table 9.1 and Table 9.2). A detailed discussion of the geology and geomorphology of the Estremoz Anticline and of the petrographic observations of the grey–white and dark grey marbles can be found in Chapter 9.

In Roman times, this variety of the Estremoz marbles was mainly used for producing veneer panels and columns (Àlvarez Pérez et al., 2009b; Cisneros Cunchillos, 1988; Fusco and Manãs Romero, 2006). Some rare cases of epigraphic monuments are known as well (Manãs Romero and Fusco, 2009). Its distribution was rather limited; so far, it has been attested only in *Emerita Augusta*, *Conimbriga*, *Regina Turdulorum* and Carranque (Alarcão and Etienne, 1977; Cisneros Cunchillos, 1988; García-Entero et al., 2009). In *Emerita Augusta*, the marble was used together with pink–yellow Sintra limestone for floor veneer of the *orchestra* of the theatre to create a polychrome effect. The *frons scaenae* of the theatre was also embellished with white marble, purple limestone from Alconera and grey marble columns from the Estremoz area (Fusco and Manãs Romero, 2006; Nogales Basarrate et al., 2009) (Figure 10.5).

Figure 10.5 Grey–white marble columns in the *frons scaenae* of the theatre of *Emerita Augusta*.

10.3 Marble breccia

10.3.1 Stone description

The final ornamental stone used for the architectural decoration of *Ammaia* is a monomict, matrix-supported breccia with poorly sorted clasts of white marble, sometimes with a light pink–red shine. The clasts have a maximum size between 0.4 cm and 8 cm, are angular and have sharp and clear boundaries. The matrix is compact, fine-grained and dark brown to grey (Figure 10.6).

Figure 10.6 Macroscopic photograph of the marble breccia from *Ammaia*.

10.3.2 Source determination

Many varieties of marble breccia similar to the one found in *Ammaia* were quarried throughout the Mediterranean in Roman times. They are frequently found as minor outcrops in outcrops of white marble. Marble breccias were very popular in Roman times, especially since the late Republican or early Imperial period. The most famous are the so-called *Africano* or *marmor Luculleum* from Kara Gölu, near ancient Teos in Turkey, *Pavonazzetto* or *marmor Phrygium*, *marmor Synnadicum* or *marmor Docimium* from Ischehisar in Turkey, and *Breccia di Sciro*, *Breccia di Settebasi* or *marmor Scyrium* from the island Skyros in Greece. Similar breccias are also found in minor quantities in the quarries of Carrara (*Breccia di Carrara*, sometimes also called *Pavonazzetto* from Carrara) and Serravezza (*Breccia di Serravezza* and *Breccia Medicea*, sometimes also called *Africano* from Serravezza), both in Italy (Price, 2012). In Portugal, a similar marble breccia can be found in the Estremoz Anticline, near Pardais (Henriques et al., 2006).

All the above-referred marble breccias bear strong resemblances with each other and generally show only small colouration or patterning differences, making the provenance determination often very difficult. This is further complicated by the heterogeneous appearance of the stones.
Despite these drawbacks, some hypotheses can be presented for the provenance of the marble breccia from *Ammaia*. A Serravezza source can be excluded, as these quarries were largely unexploited in Roman times. Large-scale exploitation of the marbles from Serravezza started not earlier than the 13th century CE, with a notable increase from the 16th century CE onwards (Attanasio et al., 2006). Likewise, the use of marble breccia from Carrara, *Breccia di Carrara* or *Pavonazzetto* from Carrara, has not yet been attested in Roman times. A local Estremoz source also seems unlikely as outcrops of the Pardais marble breccia from the Estremoz Anticline in Portugal are very scarce and no signs of its exploitation have been attested yet (L. Lopes pers. comm.).
The remaining sources, *Africano* from Teos, *Pavonazzetto* from Ischehisar and *Breccia di Sciro* from Skyros, were all imperial marbles and were the most widespread marble breccias in Roman times. *Africano* or *marmor Luculleum* is a collective name for a group of Cretaceous tectonic breccias displaying a wide range of colours. The rock is composed of white crystalline limestone clasts with sometimes a pink, grey–blue, red or yellow shine. Clasts are calcitic and micritic. Clasts are poorly sorted and embedded in a brown, dark grey to black micritic matrix. Quartz and sericite can occur in the matrix. A variety with a distinct dark green colour has chlorite in the matrix (Lazzarini, 2010; Price, 2012; Ward-Perkins, 1992). *Pavonazzetto* is a breccia–conglomerate of medium-grained white marble clasts in a purple to red hematite-rich matrix. Marble clasts are generally coarse-grained and have a sugarish texture. Distinctive are the very diffuse clast boundaries (Gnolli et al., 2004; Price, 2012). Finally, *Breccia di Sciro* is characterised by fine-grained, white marble clasts, sometimes with a pronounced

pinkish tone. Red and yellow markings are not infrequent. The matrix is dark purple. Characteristic for *Breccia di Sciro* is the elongated shape and variable dimensions of the white marble clasts (Gnolli et al., 2004; Price, 2012).
From the above descriptions, an identification of the marble breccia from *Ammaia* as *Africano* from Teos in Turkey can be suggested.

Africano stone was one of the most renowned and most expensive ornamental stones in Antiquity. In the edict of Diocletian, it was listed as the third most expensive ornamental stone (Gnolli et al., 2004). The famous *Africano* was quarried mainly in Kara Gölu, Turgut and Küçukkaya, near the ancient city of Teos, about 45 km southwest of Izmir, in modern-day Turkey (Ballance, 1966; Bruno et al., 2012).
Africano is believed to be one of the earliest ornamental stones used in Rome (74 BCE), where its popularity mainly spanned from the Augustan to Antonine period (Dworakowska, 1990; Gnolli et al., 2004). The ornamental stone was mainly used for columns, veneer and *opus sectile* flooring. It was very popular in Rome and Italy. In lower quantities, it was also detected in towns in Turkey (e.g. Ephesos, Sardes and Pergamum) and France (e.g. Arles and Orange) (Gnolli et al., 2004; Türk et al., 1988). On the Iberian Peninsula, *Africano* has been documented as veneer and *opus sectile* flooring in *Bilbilis* (Calatayud, Spain), *Colonia Lepida Celsa* (Velila de Ebro, Spain), *Tarraco*, *Caesaraugusta*, *Singilia Barba* (El Castillón, Spain), *Colonia Patricia* and *Carthago Nova* (Cartagena, Spain), Carranque (Spain), *Malaca* (Malaga, Spain), *Hispalis* and *Emerita Augusta*, but generally only in limited quantities (Àlvarez Pérez et al., 2009c; Àlvarez Pérez et al., 2012; Beltrán Fortes et al., 2012; Beltrán Lloris, 1990; Cisneros Cunchillos, 1997; 2000; Cisneros Cunchillos and Martín-Bueno, 2006; Gutiérrez Deza, 2002-2003; Gutiérrez Garcia-Moreno and López Vilar, 2012; Soler Huertas, 2003; 2012). In *Emerita Augusta*, it was used as veneer for the *Portico del Foro* (Amores Carredano et al., 2009; Cisneros Cunchillos, 2002; García-Entero et al., 2009; García-Entero and Vidal Álvarez, 2007; Nogales Basarrate et al., 2009). Interesting to note is the use of a local/regional imitation of *Africano* in *Bilbilis* (Cisneros Cunchillos, 2002).

Chapter 11
Organisation of the ornamental stone supply

The quantitative overview of the ornamental stones used in *Ammaia* (see Chapter 6) revealed that a white marble with occasional coloured veins was the principal ornamental stone for embellishing the town and its prestigious architecture. Besides the general predominance of the white marble, it outranks by far the other ornamental stones in all object categories and in all excavated sectors. On the basis of the petrographic and archaeometric data, it was proven that the white marble from *Ammaia* originates from either the Estremoz Anticline (Portugal), Almadén de la Plata (Spain) or Pentelikon (Greece), with the Estremoz quarries as the most likely source (see Chapter 9). A Pentelic source for the more prestigious decorative programmes such as, for example, Imperial sculpture cannot be fully excluded given that marbles from main Mediterranean quarries were often imported as a symbol of prestige and that the raw material from which the object was carved added to the message conveyed (Pensabene, 2004).

In addition to the white marble from Estremoz, a pink limestone, a grey–white marble and a marble breccia have been documented. Detailed observations of the macroscopic and petrographic features of these coloured ornamental stones permitted to trace back their geological origin to the Alconera Formation (Spain), the Estremoz Anticline (Portugal) and the Imperial *Africano* quarries near Teos (Turkey) respectively.

In Chapter 3, it was mentioned that three main Roman roads connected *Emerita Augusta* with *Olisipo*. Two of these roads crossed the territory of *Ammaia*, and one passed the quarry district of Estremoz (Almeida et al., 2011; Carneiro, 2009) (Figure 11.1). In addition, a network of secondary roads ensured the communication between the towns and between the towns and their territory. Through this dense network of roads, the white and grey–white marble from Estremoz could reach *Ammaia* relatively easy after approximately 80 km. It remains, however, uncertain whether the marble was exported directly from the quarries to *Ammaia* or whether the marble objects were first brought to *Emerita Augusta* from where they were subsequently distributed to other towns. Even though there is no explicit evidence as for the legal status of the Estremoz quarries, the location of the quarries in *the ager Emeritensis* and the importance of the marble for *Emerita Augusta* seem to suggest that the quarries were municipal property. In this case, the town would not only have been the main consumer for the Estremoz marble, but it might also have functioned as a stockpiling and distribution centre (Cisneros Cunchillos, 2010). The presence of many roughed-out and semi-worked blocks, column shafts, sarcophagi and statuary illustrate that the marble objects left the quarries in an unfinished state (Fusco and Manãs Romero, 2006; Nogales Basarrate et al., 2009). Because of the high demand for sculptural and architectural marble decoration for the monumental architecture of the town, many skilled sculptors and workshops (e.g. C. Aulus and Demetrios) settled in *Emerita Augusta* that might also have worked as itinerant sculptors or workshops that accompanied the blocks of marble that left the Estremoz quarries (Cisneros Cunchillos, 1988; Creus Luque, 2002; De la Barrera, 2000; Fusco and Manãs Romero, 2006; Nogales Basarrate et al., 2009).

Like for the Estremoz marble, the limestone from Alconera had to be transported overland. The first part of the trajectory would have taken place over the so-called *Via de la Plata* as far as *Emerita Augusta*, after approximately 55 km. Transport continued along the northern route between *Emerita Augusta* and *Olisipo* as far as *Butua* or as far as the crossroad with the road coming from the Estremoz quarries, somewhere between Crato and Assumar, where a secondary road diverted in the direction of

Ammaia (see Chapter 3). The total length of the route amounted to c. 175 km or 205 km, depending on the trajectory chosen (*Butua* or Crato–Assumar).

For the *Africano*, it remains unclear whether the stone reached *Ammaia* directly from the quarries or whether it was purchased and shipped from the stockpile yards in Rome. Based on inscriptions found on quarried blocks, J.C. Fant (1989; 1993) suggests a distinction between the trade in coloured ornamental stones and white marbles. While inscriptions on blocks of white marble (e.g. marble from Carrara, Proconessos, Thasos, Carystian and Dokimeion) were related to the internal functioning of the quarry, the inscriptions on blocks in coloured ornamental stones (e.g. *Africano*, *Portasanta*, Parian marble, *Giallo Antico*, *Pavonazzetto*, *Alabastro cotognino* and *Cipollino*) generally have a purpose for the administration outside of the quarry. Based on these observations, it is suggested that the exploitation of the coloured ornamental stones, which were highly valued in Roman times, was fully organised and monopolised by the Roman state and that the material was brought to Rome after extraction from where it was subsequently shipped to the rest of the Roman world. P. Pensabene (2004), however, states that the mode of distribution depends on the historical period, whether the stone is for a public or private building, whether the state was involved in the construction or embellishment of the building or not, and on the role of the local elite. Regardless of the mode of distribution for the *Africano* stone, it is certain that the material was transported overseas to the harbour city of *Olisipo*. In *Olisipo*, the stone was transferred onto river vessels for transport up the Tagus River probably as far as *Scallabis* (Fabião, 2009). From here, the transport continued over one of the roads between *Olisipo* and *Emerita Augusta* and a secondary road towards *Ammaia* for about 150 km. The low amount of *Africano* might suggest that the material was part of a larger shipment for a nearby town like *Emerita Augusta* where the material has been attested for the embellishment of, for example, the *Portico del Foro* of the municipal forum (Amores Carredano et al., 2009; Cisneros Cunchillos, 2002; García-Entero et al., 2009; García-Entero and Vidal Álvarez, 2007; Nogales Basarrate et al., 2009).

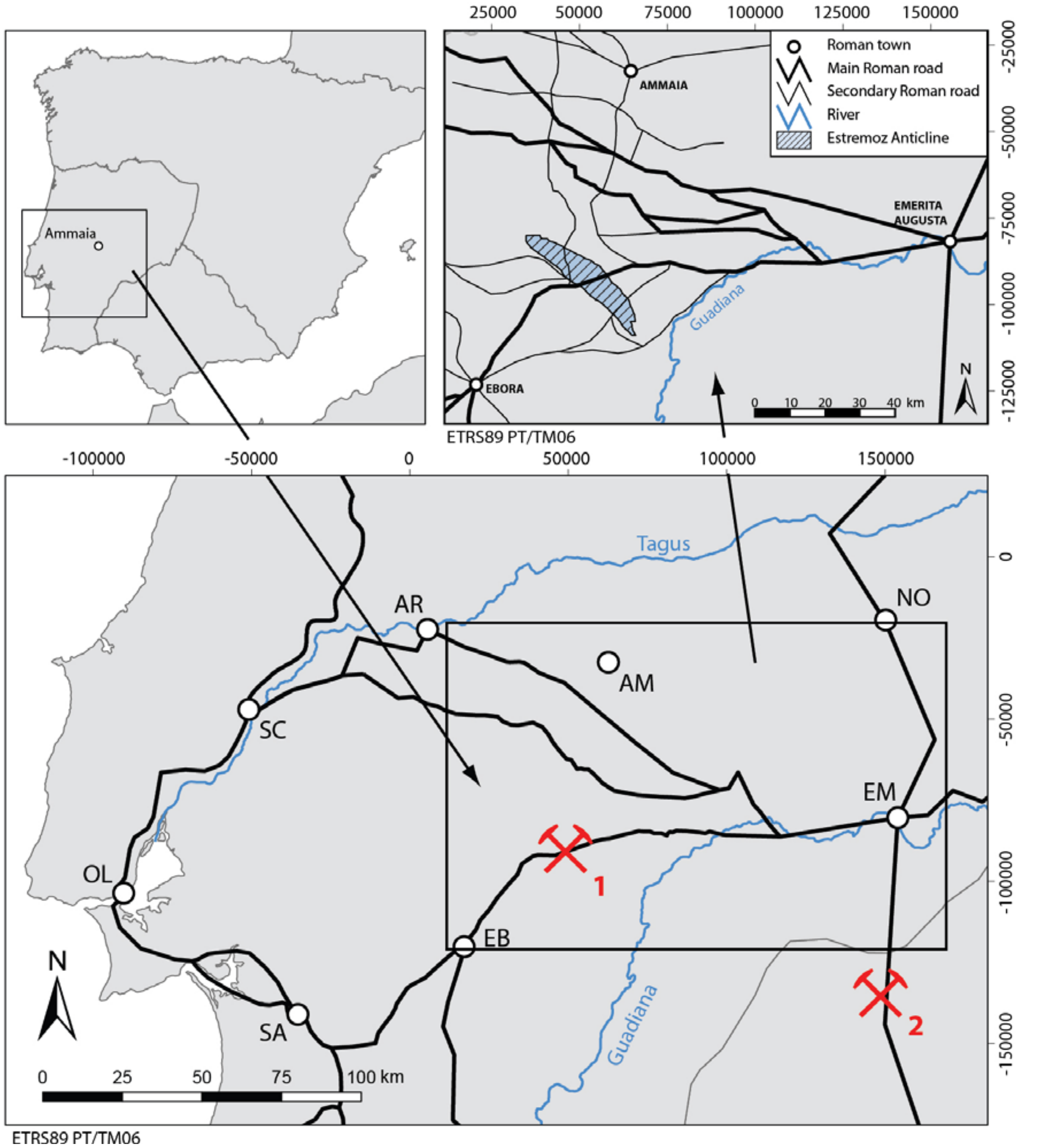

Figure 11.1 Location of the Estremoz (1) and Alconera (2) quarries in relation to *Ammaia* and the regional road network. AM: *Ammaia*, AR: *Aritium Vetus*, EB: *Ebora*, EM: *Emerita Augusta*, NO: *Norba Caesarina*, OL: *Olisipo*, SA: *Salacia*, SC: *Scallabis*.

Overall, the ornamental stone decoration of the architecture in *Ammaia* was based mainly on regionally available stones: white and grey–white marble from Estremoz and pink limestone from Alconera. The forum temple is the only building excavated so far where imported stones from the Mediterranean area have been documented, namely *Africano* from Teos.

Despite the use of predominantly regional stones, the large volume of stone material and its presence in both public and private contexts (see Chapter 4 and Chapter 6) is an index of the town's prosperity and wealth. Local elite families undoubtedly played an important role in the embellishment of the town. Donating marble decoration was a common form of private benefaction in Roman society, and was used for propaganda reasons by wealthy individuals to increase their social and political prestige in the local community (Cisneros Cunchillos, 1997; Fant, 1988; Pensabene, 2004; Zuiderhoek, 2009). While the presence of a considerable amount of ornamental stone suggests that the town and its inhabitants were relatively well off, the low volume and limited range of imported stone is striking and can be explained by the fact that the import of ornamental stones in *Ammaia* was not primarily determined by the economic power of its inhabitants but, rather, by the remote geographical location of the town and the financial burden related to the long-distance overland transport that was required to reach *Ammaia*. The importance of transport also explains the popularity of veneer in *Ammaia*. While fragile and bulky goods, such as columns and statuary, involve great technological and practical difficulties for transporting, veneer could be brought to the town as standardised blocks that were sawn up on the construction site (Dodge, 1991; Ward-Perkins, 1951). Moreover, ornamental stone veneer does a great job in economically embellishing a building with 'noble' material.

A similar situation with mainly regional ornamental stones is observed for *Emerita Augusta* where the Estremoz quarries provided the bulk of the white marbles. For example, the so-called *Temple of Diana*, the *Portico del Foro* of the municipal forum and the theatre were embellished with Estremoz marble. To a lesser extent, also white marbles from Almadén de la Plata and Macael, and coloured ornamental stones from the Imperial quarries in the Mediterranean were used (Ayerbe Vélez et al., 2009; Cisneros Cunchillos, 1988; 2002; De la Barrera, 2000; Fusco and Manãs Romero, 2006; Manãs Romero and Fusco, 2009; Nogales Basarrate et al., 1999; Nogales Basarrate et al., 2009). It needs to be noted, however, the most provenance data for the architectural marbles from these buildings is derived through petrographic observations only. Whereas provenance determination of the architectural white marbles is still preliminary, sculptural white marbles have already been studied in more detail. Most private portraiture was carved in Estremoz marble. For the more important sculptural programmes, such as the Imperial statuary, Carrara marble was imported (Fusco and Manãs Romero, 2006; Lapuente et al., 1999; Lapuente et al., 2000).

The decorative programme at *Ammaia* was rather sober with generally only white marble. Only at the forum complex, a polychromatic effect was created by applying white marble in combination with pink limestone, grey–white marble and marble breccia veneer. To a lesser extent, the same applies for the monumental complex of the South Gate where white marble was combined with pink limestone.

The polychromatic effect created by applying these different types of coloured ornamental stones in combination with white marble can be considered a local, more sober imitation of the polychromatic veneer decoration observed in many monumental, public buildings in towns in the western and southern part of the Iberian Peninsula. For example, a similar polychromatic effect was created in the theatre and the *Portico del Foro* of the municipal forum of *Emerita Augusta* where white marble capitals and grey–white and grey column shafts from the Estremoz Anticline with wall and floor veneer in pink–red limestone from Alconera, *Africano*, *Giallo Antico*, *Cipollino*, *Portasanta* and possibly also *Pavonazzetto*. The *Portico del Foro* of the municipal forum was also adorned with Imperial portraits carved in white marble from Carrara (Ayerbe Vélez et al., 2009; De la Barrera, 2000; Fusco and Manãs Romero, 2006; Lapuente et al., 1999; Nogales Basarrate et al., 2009). In addition, some of the white marble cornices of the *Portico del Foro* of the municipal forum were painted red to imitate *Rosso Antico* or *marmor taenarium* and to further enhance the polychromatic effect. Similar red-painted white marble cornices have been found in *Bilbilis*, *Saguntum* and *Carthago Nova* (Cisneros Cunchillos, 2002; Cisneros Cunchillos and Martín-Bueno, 2006; Nogales Basarrate et al., 2009). A similar red-painted cornice in white marble has been found at *Ammaia*, but unfortunately the archaeological provenance of the piece is unknown.

In several towns in the Iberian Peninsula (e.g. *Emerita Augusta*, *Bilbilis*, *Colonia Patricia*, *Caesaraugusta*, and *Italica*), a decorative programme with a mixture of white marble and coloured ornamental stone was used for the embellishment of the main public buildings (especially fora and theatres). Besides the general purpose of architectural embellishment, the use of this particular scheme of decoration conveyed a propagandistic message for the Imperial cult of the Julio–Claudian emperors (e.g. the theatre of *Carthago Nova* and in the theatre and *Portico del Foro* of the municipal forum in *Emerita Augusta*). These buildings imitated the decoration of buildings constructed in Rome such as the forum of the Emperor Augustus (Cisneros Cunchillos, 2002; Cisneros Cunchillos et al., 2010-2011). Even though more sober, the decorative programme for the forum temple of *Ammaia* probably propagates a similar message promoting the cult of the Julio–Claudian family. The togate statue of the young prince Nero that was found in *Ammaia* could be part of a statuary group representing the *Gens Augusta* that possibly adorned the forum square and added to the propaganda of the Imperial cult.

The nature and provenance of these ornamental stones depends primarily on the geographical location and accessibility of the different towns. Like in *Ammaia*, only a reduced quantity of coloured ornamental stone from the Mediterranean area has been observed in towns such as *Emerita Augusta*, *Asturica Augusta* and *Munigua* that are characterised by a remote, inland location far from any sea port or navigable rivers. The difficult accessibility of these sites promotes the exploitation of local and regional sources (Cisneros Cunchillos, 1997; 2002; Cisneros Cunchillos et al., 2010-2011; Fusco and Manãs Romero, 2006; Nogales Basarrate et al., 2009; Pensabene, 2004; Schattner and Ovejero Zappino, 2009). The situation in *Ammaia* with only little import stone material and a predominant use of regional ornamental stones needs to be seen in the same light. Unlike the towns situated in the inner parts of the Iberian Peninsula, the towns near the Mediterranean coast or close to navigable rivers such as the Guadalquivir or the Ebro have a much wider range of imported ornamental stones (Cisneros Cunchillos, 2001; 2004; Nogales Basarrate et al., 2009) (Table 11.1).

Table 11.1 Distribution of coloured ornamental stones from the Mediterranean in the Iberian Peninsula (after Aguilar and Raluy, 2004; Amores Carredano et al., 2009; Arola et al., 2012; Ayerbe Vélez et al., 2009; Beltrán Lloris, 1990; Cisneros Cunchillos, 1997; 2000; Cisneros Cunchillos, 2001; Cisneros Cunchillos et al., 2010-2011; Cisneros Cunchillos and Martín-Bueno, 2006; De la Barrera, 2000; Gutiérrez Deza, 2002-2003; Gutiérrez Garcia-Morena and López Vilar, 2012; Mayer and Rodà, 1998; Rodríguez Gutiérrez, 2009; Schattner and Ovejero Zappino, 2009; Soler Huertas, 2003; 2009).

	AFR	ALP	ALF	BNT	BRC	BRA	BRS	CIP	CM	ALE	FP	GAB	GIA	GRS	ON	LUM	MOC	MOP	OCP	PAV	POR	POV	PSA	ROA	VEA	Total
Ammaia	x																									1
Asturica Augusta	x								x				x					x				x				5
Bilbilis	x		x		x	x	x	x					x							x			x	x	x	11
Caesaraugusta	x						x	x					x		x			x		x		x	x		x	10
Carthago Nova	x		x		x		x	x	x		x		x	x	x					x	x	x	x	x	x	16
Colonia Lepida Celsa	x		x			x	x	x	x			x	x		x					x			x	x		12
Colonia Patricia	x	x		x	x		x	x		x			x	x	x	x	x	x		x	x	x	x	x	x	19
Hispalis	x							x					x							x		x		x		6
Italica	x						x	x					x	x			x		x	x	x	x	x	x	x	13
Emerita Augusta	x							x					x							x			x			5
Munigua								x						x						x						3
Rubí *(near Barcelona, Spain)*	x							x												x		x				4
Singilia Barba	x												x	x						x		x			x	6
Tarraco	x				x		x	x				x	x	x	x				x	x	x	x	x	x	x	15
Turiaso (Moncayo, Spain)													x					x				x	x		x	5

AFR = *Africano*, ALP = *Alabastro a Pecoralla*, ALF = *Alabastro Fiorito*, BNT : *Bianco e Nero Tigrato*, BRC = *Breccia Coralina*, BRA = *Breccia di Aleppo*,BRS = *Breccia di Settebasi*, CIP = *Cipollino*, CM = *Cipollino Mandolato*, ALE = yellow alabaster from Egypt, FP = *Fior di Pesco*, GAB = Gabbro, GIA = *Giallo Antico*, GRS = *Greco Scritto*, ON = *Lapis Onyx*, LUM = *Lumachella Carnina*, MOC = granite from *Mons Claudianus*, MOP = granite from *Mons Porphyrites*, OCP = *Occhio di Pavone*, PAV = *Pavonazzetto*, POR = *Porfido Rosso*, POV = *Porfido Verde*, PSA = *Portasanta*, ROA = *Rosso Antico*, VEA = *Verde Antico di Grecia*.

Final conclusions

The *ex novo* foundation of *Ammaia* at the latest in the Claudian period resulted in intensive construction works in the town. A proper urbanisation programme according to Roman principles has led to an orthogonal town plan with typical Roman buildings such as a forum, bathhouse, temples and Roman funerary monuments. In addition to the necessary public buildings, many private buildings had to be erected. The burst of building activity around the middle of the 1st century CE involved an enormous demand of building and ornamental stones. The building activity that started in the first half of the 1st century CE experienced a peak in the Flavian–Trajan period when several existing buildings were replaced by monumental, public complexes (e.g. the forum bathhouse and the South Gate). Architectural modifications were frequent throughout the period between the middle of the 2nd century CE and the beginning of the 5th century CE and have been attested in most buildings.

In a region where a proper pre-Roman stone architecture was practically inexistent, the foundation of a new town inevitably implied the development of a well-organised building industry and stone supply system. The adoption of a Roman lifestyle in *Ammaia* is visible not only from the typical Roman buildings in the town, but also from the introduction of Roman construction techniques such as mortared rubblework masonry, ashlar masonry, *opus africanum*, stucco and the use of ornamental stones. Other typically Roman elements are the columnar architecture and epigraphy.

A pale brown, medium-grained, two-mica granite was the most popular building stone from the town's early years onwards. Granite was used as facing stones for the rubblework masonry, for ashlars and for the columnar architecture. In addition, it was also employed for the production of millstones and epigraphic monuments. Quartzite and sandstone gravelstones from the riverbeds of the Sever River and the *Ribeira do Porto da Espada* (with an average size of 10 cm to 40 cm across) were used mainly for wall cores and foundations and, in some cases, also as raw material for the walls of private buildings. A brown–yellow and a grey–black shale was used exclusively in the shape of thin slabs (less than 10 cm thick) for creating horizontal courses in the rubblework masonry and as cover stones for drain channels. It was sometimes used in wall foundations and in the *opus caementicium* core of the rubblework masonry. Finally, a uniform, fine-grained and well-cemented sandstone with an overall red–brown colour due to a high concentration of iron oxides was used mainly for wall cores and wall foundations.

Macroscopic and petrographic observations in combination with a geoarchaeological study of the hinterland of *Ammaia* have illustrated that these four types of stone were obtained either on-site (less than 100 m) or in the immediate surroundings of the town (less than 10 km).

While gravelstones were collected from the riverbed of the Sever River and the *Ribeira do Porto Espada* that flow only 50–60 m from the town, shale and sandstone form the geological substratum of the valley bottom in which the town is located. Shale was obtained from outcrops in the riverbed of the Sever River and became progressively available during the excavation of the foundation trenches of the buildings in the easternmost part of the town. Sandstone outcrops are found on the flanks of the Malhadais hill that form the westernmost part of the town. The remains of a semicircular hillside quarry for sandstone were observed c. 50 m northwest the town.

Unlike gravelstones, shale and sandstone that could be obtained locally, granite had to be procured from more distant sources. The closest outcrops occur in the Nisa–Alburquerque Batholith, at c. 2.5 km from *Ammaia*. Field surveys in the Nisa–Alburquerque Batholith, within a 10-km radius of *Ammaia*, located four potentially

Roman granite quarries that could have supplied *Ammaia,* Marvão, Lajes, Santo António das Areias and Pitaranha. The large-scale extractive activities at Pitaranha, the petrographic resemblance of the Pitaranha and *Ammaia* granite and the few chronological indications available for the extraction have proven that the Pitaranha quarry was the main granite supplier for the town. Cost surface analysis to determine the accessibility of granite quarries has illustrated that, surprisingly, the three smaller quarries were significantly easier to reach than the Pitaranha quarry. The local geological and geomorphological properties of the Pitaranha granite were among the main reasons why this quarry was preferred and not more accessible sites. In addition to the geological and geomorphological advantages, the joint occurrence of granite with quartz and rock crystal was certainly a major asset for the exploitation at Pitaranha. An in-depth survey of the quarry, for which a cost-efficient and rapid mapping method was developed using an unmanned low-altitude aerial photography system and recent advances in computer vision-based methods, allowed a better understanding the complex organisation and methodology involved in the extractive activities.

As a result of the larger distance of the granite sources and the difficult overland transport, the costs for obtaining granite must have been considerably higher than that of the other types of stone used in *Ammaia*. That the extra effort and cost was spent to obtain granite can be explained by the excellent physical properties of the stone for building purposes (i.e. mechanically tough, durable and massive). In *Ammaia*, granite can therefore be considered as a superior building stone.

Proximity, accessibility and straightforward transportation appear to have been the keywords in the supply of building stones at Roman *Ammaia*. The importance of transportation is illustrated, for example, by the predominant use of rubblework masonry (*opus incertum* and *opus caementicium*) with stones that could be handled and transported easily. As the quarrying, transport and lifting (on the building site) of ashlars is technologically difficult and labour-intensive, ashlar masonry was limited to buildings of great (communal) importance (e.g. the forum temple and the South Gate), to buildings that express the grandeur of the elite families in the town (e.g. the mausoleum monument east of the town), and to places where absolutely necessary to ensure structural stability (e.g. wall corners and intersections).

Notwithstanding that *Ammaia* was well provisioned with good-quality building stones in its immediate surroundings, it lacked any outcrops of ornamental stone. Hence, ornamental stone had to be imported. Four different types of ornamental stone were used to embellish the architecture at *Ammaia* from the Claudian period onwards. A white marble variety with occasional coloured veins clearly formed the most important ornamental stone, followed by a pink limestone. A grey–white marble and a marble breccia were imported only in marginal quantities. Overall, the decorative programme at *Ammaia* was rather sober with generally only white marble. Only at the forum complex and, to a lesser extent, at the South Gate, a polychromatic effect was created by applying different types of ornamental stones.

Macroscopic, petrographic and geochemical analyses have illustrated that most ornamental stones used for embellishing the architecture in *Ammaia* were obtained from formations in the western part of the Iberian Peninsula. White and grey–white marble were quarried in the Estremoz Anticline (Portugal), located about 70 km to the south (as the crow flies). The pink limestone originates from the Alconera quarries (Spain), located about 55 km south of *Emerita Augusta* (as the crow flies), in the ancient Roman province of *Baetica*. The only imported stone from the Mediterranean area thus far observed was *Africano* from Teos in Turkey. For more prestigious white marble objects, such as statuary, a Pentelic source cannot be fully excluded on the basis of the analytical results.

Despite the predominance of regional ornamental stones, the ubiquitous use and the presence in both public and private contexts illustrates the prosperity and wealth of the town and its inhabitants. While the presence of a considerable amount of ornamental stone suggests that the town and its inhabitant were relatively well off, the low volume and limited range of imported stone is striking and can be explained by the fact that the import of ornamental stones in *Ammaia* was not primarily determined by the economic power of its inhabitants but, rather, by the remote geographical location of the town and the financial burden related to the long-distance overland transport that was required to reach *Ammaia*. The location of the town in the centre of *Lusitania*, remote from any sea port or river transport – the rivers Tagus and Guadiana were largely unnavigable in Roman times – meant that it was very expensive to import stone material. The importance of transport also explains the popularity of veneer. While fragile and bulky goods, such as columns and statuary, involve great technological and practical difficulties for transporting, veneer could be brought to the town as standardised blocks that were sawn up on the construction site (Dodge, 1991; Ward-Perkins, 1951). As a result, veneer does a great job in economically embellishing a building with 'noble' material. The transport difficulties related to the import of ornamental stones also explain why the local granite remained the preferred raw material for certain objects with a decorative purpose such as columns and capitals. Importing marble for these heavy and bulky goods must have been a too large financial burden. That white marble was more highly regarded than granite can be observed in the epigraphic monuments as well. While all religious monuments are carved in the local Pitaranha granite, the two commemorative inscriptions dedicated to the Roman Emperor are in a high-quality white marble from the Estremoz Anticline. Funerary inscriptions occur on both granite and marble, but white marble from Estremoz was preferred for members of the elite families.

Concluding, the architectural and archaeological record at *Ammaia* clearly illustrates a provincial architecture that mixed elements of a local, indigenous culture with typical Roman elements. In a region with no proper pre-Roman stone architecture, the Roman conquest triggered the development of an urban culture in northeastern Alentejo and western Extremadura region. Typically Roman buildings and techniques were introduced on the Iberian Peninsula through the major towns that had direct contact with the models in Rome. Roman colonists that had settled in the main urban centres undoubtedly introduced many Roman innovations that gradually spread to smaller towns on the Iberian Peninsula. This is certainly valid for towns like *Ammaia* that were located in remote parts of the Iberian Peninsula where the influence of the more developed pre-Roman urban cultures, such as the Tartessian, Phoenician, Greek and Carthaginian, was less profound than in the southern part of the Iberian Peninsula.

For *Ammaia*, the role of *Emerita Augusta*, the nearby capital of *Lusitania*, as an architectural model is without a doubt. Numerous examples permit to identify an architectural connection between the two towns. These include the use of similar construction techniques such as the combination of granite ashlars rubblework masonry (see the Flavian–Early Antonine South Gate in *Ammaia* and the Augustan–Tiberian temple of the provincial forum in *Emerita Augusta*), the *opus africanum* technique (see the southeastern outer wall of the forum baths in *Ammaia* and the retaining wall of the Guadiana River in *Emerita Augusta*), the *opus mixtum* technique (see the Flavian–Early Antonine South Gate in *Ammaia* and the so-called *Temple of Diana* on the colonial forum and the *Portico del Foro* of the municipal forum in in *Emerita Augusta*), and the use of large square granite blocks for monumental paving (see the monumental square of the South Gate in *Ammaia* and the paving of the colonial forum in *Emerita Augusta*).

The link between *Ammaia* and *Emerita Augusta* is also reflected in the architectural embellishment. The Tuscan and plain Ionic capitals with Tuscan influence characterised by a sober execution were introduced in *Emerita Augusta* in the Early Imperial period and served as a model for the capitals used in towns like *Ammaia*, Bobadela and *Civitas Igaeditanorum*, located in the centre and the north of *Lusitania*. A second example of the imitation of architectural decoration is the polychromatic decorative programme of the forum temple in *Ammaia* with essentially ornamental stones from regional sources. A similar polychromatic decoration can be observed for the embellishment of the main public buildings in many towns of the Iberian Peninsula. For example, the *Temple of Diana*, the *Portico del Foro* of the municipal forum and the theatre in *Emerita Augusta* were adorned with a similar polychromatic decoration that was mainly based on regionally available ornamental stones. Even though the general nature of the polychromatic decoration is comparable to that of other towns on the Iberian Peninsula, the range of imported stones in *Ammaia* is far more reduced with only low quantities of *Africano* as Mediterranean import. This low quantity might suggest that the stone arrived in *Ammaia* as part of a larger shipment for a nearby town such as

Emerita Augusta. Finally, the presence of a cornice in white marble that was painted red to imitate *Rosso Antico* from Greece enhanced the polychromatic effect. Similar red-painted cornices have been found in *Bilbilis*, *Saguntum*, *Carthago Nova* and *Emerita Augusta*.

Noteworthy are also the funerary monuments. The imposing altar mausoleum constructed in *opus quadratum* has, for example, parallels in *Emerita Augusta* and near the *Quinta da Fórnea* in Belmonte, about 100 km north of *Ammaia*. This type of funerary monument developed on the Italic Peninsula around the end of the 2nd century BCE and was introduced in *Lusitania* in the Julio–Claudian period (Beltrán Fortes, 2004; Carvalho dos Santos and Carvalho, 2008; Gros, 2001). Other funerary monuments are the simple, elongated granite *stelae* with rounded tops or triangular pediments that have many parallels in Roman *Hispania* and in late Republican and Early Imperial Rome (Edmondson, 2001; 2002; 2007). This type of *stelae* with rounded tops and a rosette decoration are typically found in indigenous contexts in *Emerita Augusta* and north of the Tagus River in central *Lusitania* (Edmondson, 2002; 2007; Márquez Pérez et al., 2008).

This intensive link between *Ammaia* and *Emerita Augusta* is not only clear from the architectural developments, but can also be observed in the fine-ware ceramic trade. Soon after its foundation in the late Julio–Claudian period, *Ammaia* appears to have been part of the economic sphere of *Emerita Augusta*. For example, the capital town probably acted as a distribution centre for Hispanic *terra sigillata* from La Rioja from the second half of the 1st century CE onwards. In addition, a large amount of lamps and thin walled ware from *Emerita Augusta* is found in *Ammaia* (Quaresma, 2010-2011).

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