STONE QUARRYING ON THE FINAL STRETCH OF THE EBRO (SPAIN)

M. Genera and A. Àlvarez

Abstract
As a result of the exceptional discovery of Roman funerary stele, part of a wine press, and a large block of broccatello, we decided to study the quarries on the lower reaches of the Ebro River. The aim is to draw up an inventory of all the quarries, to identify possible ancient workings and to gain an accurate knowledge of the uses to which the quarried material was put. In general, the location and characteristics of the different deposits greatly facilitated their exploitation. Moreover, their proximity to the Ebro River made transportation very cheap. In the case of broccatello, shipment by sea was made easier by the proximity of the port of Tortosa.

Keywords
Local stone, Boca Bovera quarries, La Teuleria quarries, Flix Meander, broccatello, Tortosa.

Introduction

Following the exceptional find of a Roman funeral stele carved from sandstone, reused as part of a wine press, and a large block of reused broccatello at Fontjoana, Vinebre, on the banks of the River Ebro, we decided to include the quarries on the lower reaches of the Ebro in our research on *The Final Stretch of the Ebro, Transport Route and a Means of Exploiting Natural Resources in Ancient Times.*

On this occasion, our aim is to study these quarries in greater depth, in an attempt to inventory them all, to identify any items from ancient times and to determine more accurately what the materials found were used for.

The main extraction points identified at the area (not necessarily quarries) are in three areas of the river (Genera and Àlvarez 2009) (Fig. 1):

– Flix Meander: Castellons, Boca Bovera (zones A, B, C, F, G) and Teuleria (zones D, E) (Fig. 4, A)

– Around Ascó: Castle zone and Andisc

– Tortosa: La Cinta and Els Valencians quarries[1].

In the first two points, the same type of stone crops out (Oligocene calcareous sandstone), while at Tortosa the well-known broccatello (Upper Jurassic- Lower Cretaceous fossiliferous limestone) was extracted.

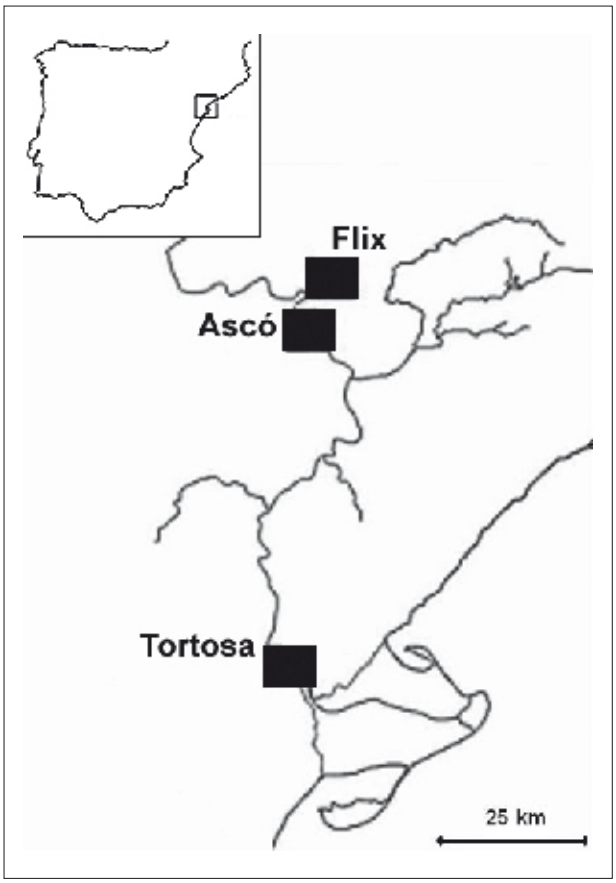

Fig. 1. Location of the areas mentioned in the text.

Geological considerations

The quarried rock was ochre-coloured sandstone-like, with salmon tonalities from the Middle to Upper Oligocene geological formations (IGME 1979) that predominate in the area. These deposits are interpreted as the middle to distal facies of alluvial fans from the southern fringe of the Ebro basin that was active during the Upper Priabonian and the Lower Oligocene (Folch 1992).

The stratigraphic series is made up of alternating sandstone and lutite of decimetric thickness. The sandstone is massive with grooved bases and grey, ochre and salmon colouring. The lutite is massive with ochre and reddish salmon colouring, often with levels of fibrous white gypsum. These alternating stones become conglomeratic sandstone and conglomerates. The conglomeratic sandstone is grey and has a crossed stratification.

1. Although up to nine extraction points have been identifed nearby (Àlvarez *et al.* 2003; Gutiérrez Garcia-M. 2009, 238-245, fig. 262), these two are the most important quarries.

The conglomerates are massive, clast-supported, very homometric and strongly cemented. The matrix is sandstone-like, grey in colour and with a grain size ranging from medium to fine sand. The clasts are rounded and composed mainly of Mesozoic carbonates and, in lower relative proportions, chert (flint), Triassic sandstone and rounded quartz. The conglomerates are some 4 m thick and pass vertically 20 cm from salmon-coloured lutite above which 40 or 50 cm of calcareous lithoarenite is deposited. This material is massive and has an ochre salmon colouring. It belongs to Oligocence period and the direction of the pitch measured above it is 342º/5º (ICC 1999) (Fig. 2).

The Flix Meander

The rock used here comes from both sides of the river, specifically the area crossed by the meander in the Ebro as it flows past Flix, partly within a stratigraphic series of alternating ochre- and salmon-coloured calcareous lithoarenite and lutite layers dated to the Mid to Late Oligocene (IGME 1979).

Els Castellons

This location is home to a major group of archaeological finds that tells us there was human settlement here between the Late Bronze Age and the middle to late 1st century BC (Genera 1979; Genera *et al.* 2006). So far two inhabited areas and two necropolises have been documented. In the highest part several signs of ancient workings have been noted in the sandstone materials (three long parallel trenches) (Fig. 3, B). There is no evidence of discarded stone materials such as ashlars or blocks (Genera *et al.* 2005b).

Geologically speaking this meander is partially inserted into a stratigraphic series consisting mainly of alternating ochre- and salmon-coloured calcareous lithoarenite and lutite from the Oligocene. Throughout this area carved out by the Ebro River it is possible to observe the scars of gravitational landslips of various sizes on alternations of calcareous lithoarenite and lutite. To the south there are Quaternary deposits of gravel, sand and stones with a sandy matrix crowned by sandy silts interpreted as Terrace 3 (Qt_3) of the Ebro. These belong to the Upper Pleistocene (ICC 1999).

The conglomerates make up a positive relief that stands out with respect to the other rocks in their surroundings. Shallow caves have been formed below the conglomerates that crown the hill on which the archaeological site of Els Castellons stands. These caves are the result of the differential erosion between the hardest levels (conglomerates) and the softer ones (alternations of calcareous lithoarenite and lutite) (Àlvarez 2007) (Fig. 3, A and C).

A sample was taken of the stone (Cast-1)[2] located a couple of metres from the traces of the ancient workings. Observation of the thin section under the polarised light microscope shows that it is a calcodoloarenite. In other words, it is sandstone formed by calcite and dolomite crystals with a granular sparitic texture. The presence is observed of grains of a similar size to those of the carbonate crystals (calcite-dolomite) that are probably of authigenous origin. The dolomite crystals have the typical rhombohedral shape with a characteristic zoning (the nucleus of the crystal usually appears darker than the edges), while the calcite crystals present the typical

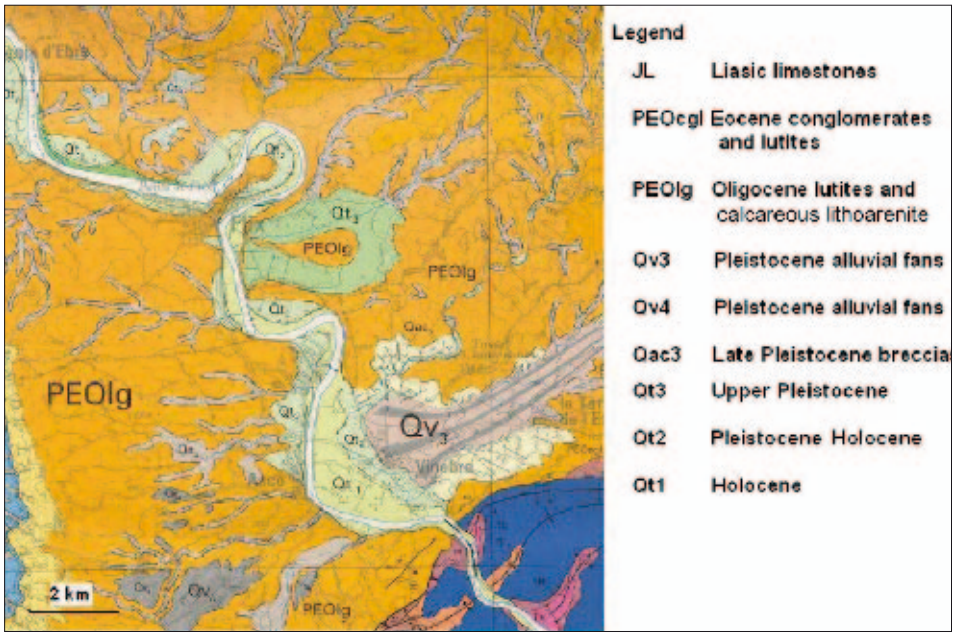

Fig. 2. General geological map of the area of Flix and Ascó (ICC 1999).

2. All samples were studied and petrographically described by using a NIKON Eclipse 50iPOL polarised light microscopy equipped with a Nikon Coolpix 5400 camera.

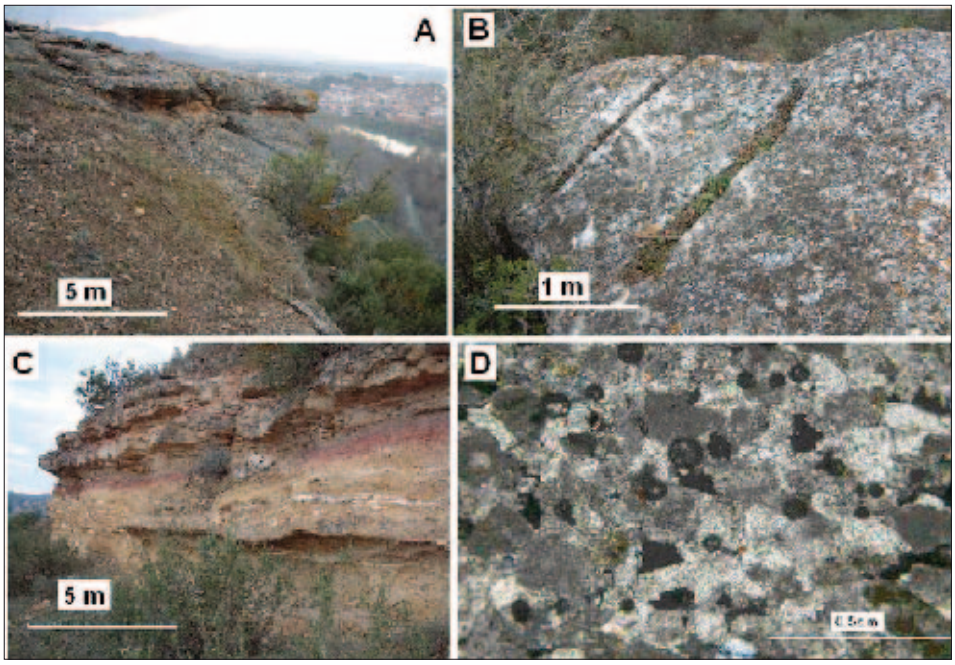

Fig. 3. Els Castellons: A) Relief originated by the Oligocene conglomerates; B)Traces of quarrying; C) Stratigraphic series showing the conglomerates, lutites and calcareous lithoarenite alternance; D) Microphotograph of sample Cast-1(crossed polars).

polysynthetic macles. The cement is basically calcareous and formed by small calcite and/or dolomite crystals (micrite). The porosity is a little high and could be originated by natural moulds, caused by the dissolution of calcite and/or dolomite crystals. As is common in dolomitic rocks (dolomitic limestones) it is difficult to find fossils of organisms, given that the tendency of dolomite to recrystallize eradicates all types of pre-existing forms. This sample, unlike the two from Boca Bovera area, has a slightly larger quantity of quartz grains (Fig. 3, D).

Boca Bovera

Boca Bovera area is barely 5 km north-west of Els Castsellons, on the left and right banks of the Cana River where it flows into the Ebro River[3]. Five extraction points have been identified on this stretch (A, B, C, F, G) (Fig. 4, A). They contain many marks of possible ancient workings and several blocks (ashlars), some broken and others abandoned (Genera *et al.* 2005b; Gutierrez Garcia-M. 2009, 247-249). However, the most important are A and C, which is why they have been sampled.

The stone quarried here was an ochre-coloured calcareous lithoarenite with salmon tonalities from the Middle to Upper Oligocene (IGME 1979). These deposits are interpreted as the middle to distal facies of alluvial fans from the southern edge of the Ebro basin.

The stone is stratified with levels of decimetric thickness and a more or less tabular morphology. There are occasional levels of centimetric thickness. They are ochre in colour with salmon tonalities and normally massive, although in some cases crossed stratifications and the presence of soft clasts can be observed. The bases are flat or furrowed. The sandstone with levels of centimetric thickness is fine-grained and has parallel, wavy laminations. The lutite is ochre and reddish salmon in colour. The measured direction of the pitch is 300º/08º.

There are marks showing the use of wedges of around 20 cm on the surface. These could indicate possible ancient workings (Fig. 4, C) but it cannot be confirmed as the use of wedges was also widespread in medieval and modern times. Of particular interest is the large amount of discarded material that can be seen at this point, including ashlars and probable architectural elements (Fig. 4, B).

Under the polarised light microscope samples A and C match those from the Els Castellons area. This is a calcodoloarenite consisting of calcite and dolomite crystals with a granular sparite texture. Grains of a similar size to the calcite and dolomite crystals, possibly autogenous in origin, can be seen. The dolomite crystals have the rhombohedral shapes typical of marked zoning. The calcite crystals show typical polysynthetic twins and calcareous cement resulting from the dissolution of small calcite and dolomite crystals. Fossilised remains are difficult to identify. There are some quartz crystals in a very low proportion to the rock as a whole (Fig. 4, D).

La Teuleria

La Teuleria is next to Boca Bovera, on the left bank of the River Ebro. Apart from the alternating sandstone and lutite layers mentioned above, Quaternary deposits consisting of Terraces 1 and 2 of the River Ebro can also be seen. Two quarrying areas have been identified (D and E) (Fig. 4, A) with similar characteristics to those of Boca Bovera. They were revealed when the left bank of the river was cleared (Genera and Àlvarez 2009).

3. This site is also known as "Pedrera de Flix" or "de Riu de la Cana" (i.e. Flix or Riu de la Cana quarry) (IPAC 2003; Gutiérrez Garcia-M. 2012, Fig. 1).

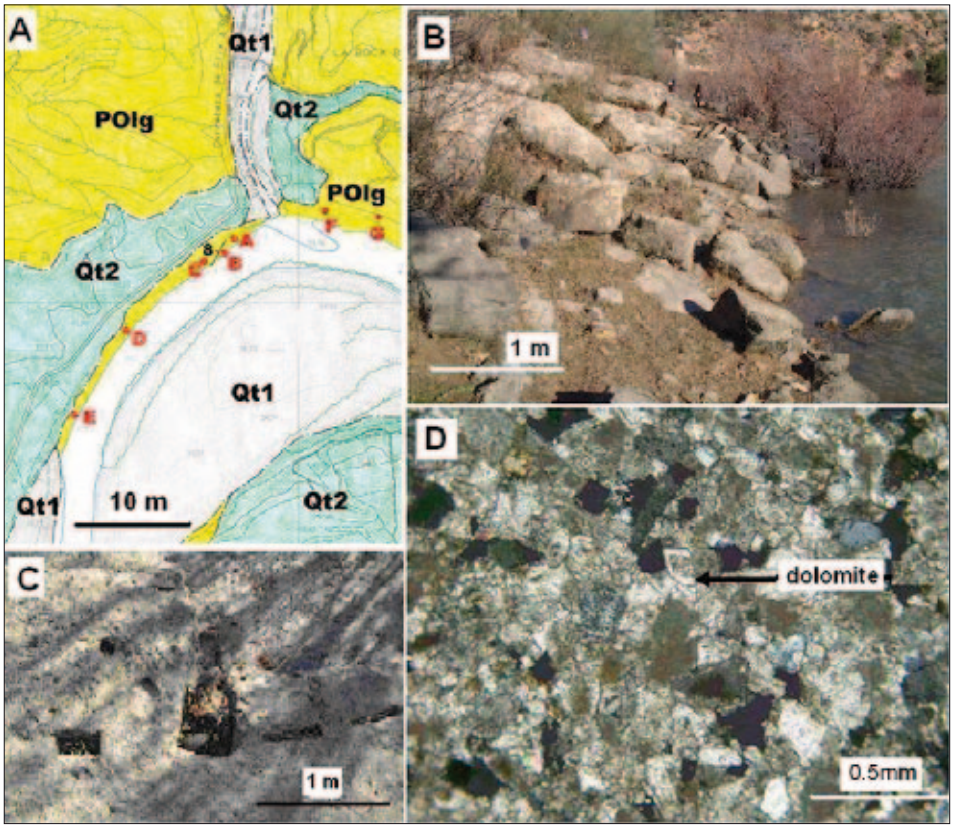

Fig 4. La Teuleria and Boca Bovera: A) Geological map of Flix meander (see legend in Figure 2); B) Abandoned blocks at zone C; C) Wedge holes at zone C; D) Microphotograph of sample C (crossed polars) showing the presence of dolomite.

The quarries have been recorded but no petrographic study has yet been made of the rock, as it is a natural stratigraphic continuation of those studied at Boca Bovera; thus, the petrographic characteristics are most likely to be similar.

Around Ascó

The most imposing monument in the area, the castle, stands on a base which has provided stone for centuries. There is evidence of extraction, although the gradual expansion of the settlement has led to the disappearance of possible ancient traces. This stone was used to build the castle itself (Fig. 5, C). Despite remains of the ancient quarries have not been preserved, we can confirm that this stone belongs to the same facies that the stone we find in the Iberian remains in Ascó (Genera 1979, 107-157) (Fig. 5, A and B).

Tortosa

In the area known as "Raval de la Llet", near Tortosa, the Romans quarried a large number of the fossiliferous limestone deposits for ornamental purposes. These materials form the highest part of the local geographic relief. Recent extraction has partially destroyed evidence of Roman quarrying, making it thus difficult to give us an idea of the work carried out during that period. Yet this can be overcame by the abundant archaeological evidence of its Roman use.

The material extracted here is the renowned broccatello, whose name recalls its resemblance to the ancient brocades woven with gold thread[4]. However, it is locally known as jaspi de la Cinta, "jaspi" because of its resemblance to jasper and "La Cinta" because this stone was used to decorate the chapel dedicated to the patron saint of the town, "Nostra Senyora de la Cinta", in Tortosa cathedral (Muñoz 2005; Àlvarez *et al.* 2011).

The two most important ancient quarries are known as La Cinta (Fig 6, A and B) and Els Valencians (Fig 6, C and D) (Àlvarez 1992, 2009; Àlvarez *et al.* 2003, 2011; Genera *et al.* 2005a, 2006; Gutiérrez Garcia-M. 2009, 238-245). From them, Aptian limestone was extracted and used for ornamental purposes. None of these quarries is currently in use

In the Jurassic Period the limestone was deformed by a series of tectonic faults and movements during the Alpine phases. They were later compacted by a colour matrix with obvious signs of karstic activity, which resulted in an opening that in turn underwent

4. It was already mentioned by F. Corsi (1828) and after its inclusion in R. Gnoli's *Marmora Romana* (1971, 1988) this stone has been studied and mentioned in several works by both Spanish and foreign scholars (see Àlvarez 1984, 2009; Àlvarez and Mayer 1992; Àlvarez *et al.* 2003, 2009, 2011; Antonelli 2002; Borghini 1998; Braemer 1984, 1986, 1992; Falcone and Lazzarini 1998; Gutiérrez Garcia-M. 2009, 2012; Lazzarini 2004, Mannonni and Mannonni 1978; Mayer 1992; Mayer and Rodà 1985, 1998, 1999; Mielsch 1985; Rodà 1998, 2004, 2005).

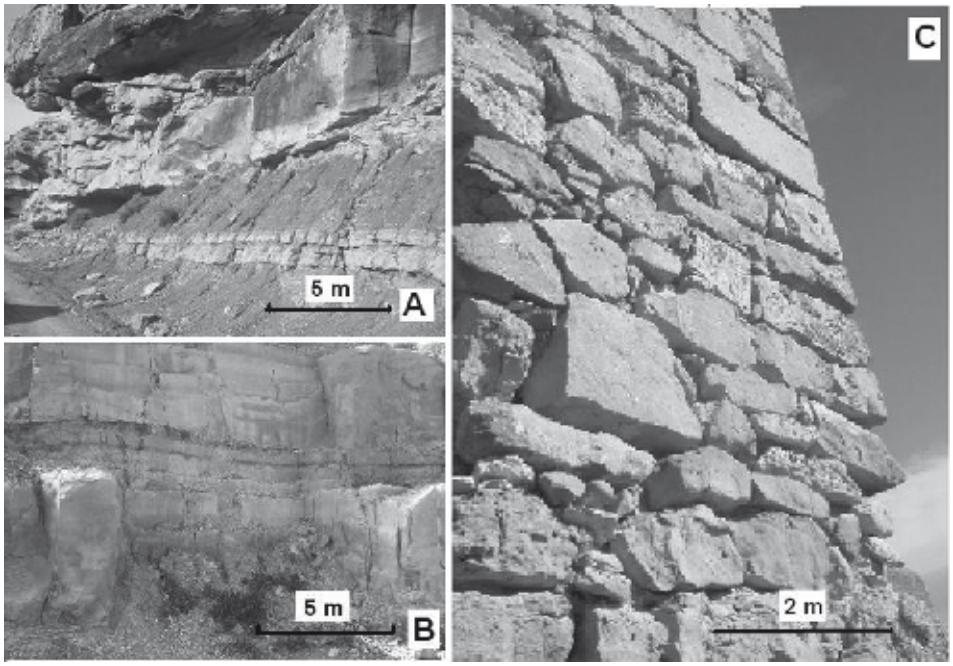

Fig. 5. Ascó:
A) Conglomerates, lutites and calcareous lithoarenite alternance at the base of the castle; B) Current exploitation area; C) Castle wall where these stones (calcareous lithoarenite) is employed.

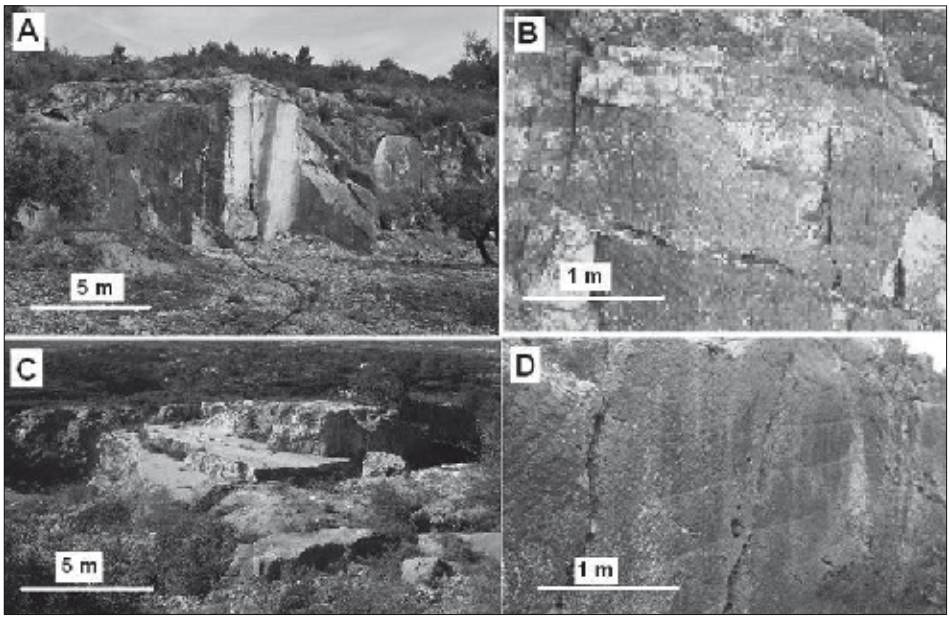

Fig. 6. Tortosa: La Cinta quarry: A) General view; B) Extraction front. Els Valencians quarry:
C) General view;
D) Extraction front.

one last process of dolomite formation. The result was an opening with badly damaged fossilised remains that are difficult to identify and that range in colour from vivid red to violet and pale yellow (Fig. 7 A, B) (Àlvarez 1992).

When viewed under a polarised light microscope it is rich in fossils with a calcareous composition and has a micritic matrix with abundant clay minerals and iron oxides. It contains many bioclasts that vary widely in size and has numerous, highly heterogranular recrystallised calcite nuclei. The grain size forming the matrix ranges from 1/16 to 1/125 mm. There are mineralised stylolites with ferrous minerals. The bioclasts are difficult to identify (Àlvarez *et al.* 2009, 2011) (Fig. 7, C and D).

Comments

The conglomerate blocks of metric thickness at the eastern entrance of Els Castellons archaeological site are probably from gravitational falls. These falls would have been caused by the effect of being very close to an unstable slope and the action of differential erosion on considerably contrasting materials such as well-cemented conglomerates and the calcareous lithoarenite and lutite alternations.

The conglomerates constitute a positive relief that stands out with respect to the other rocks in the surroundings. Caves have been formed below the conglomerates that crown the hill of Els Castellons archaeological site. These caves are the result of differential erosion

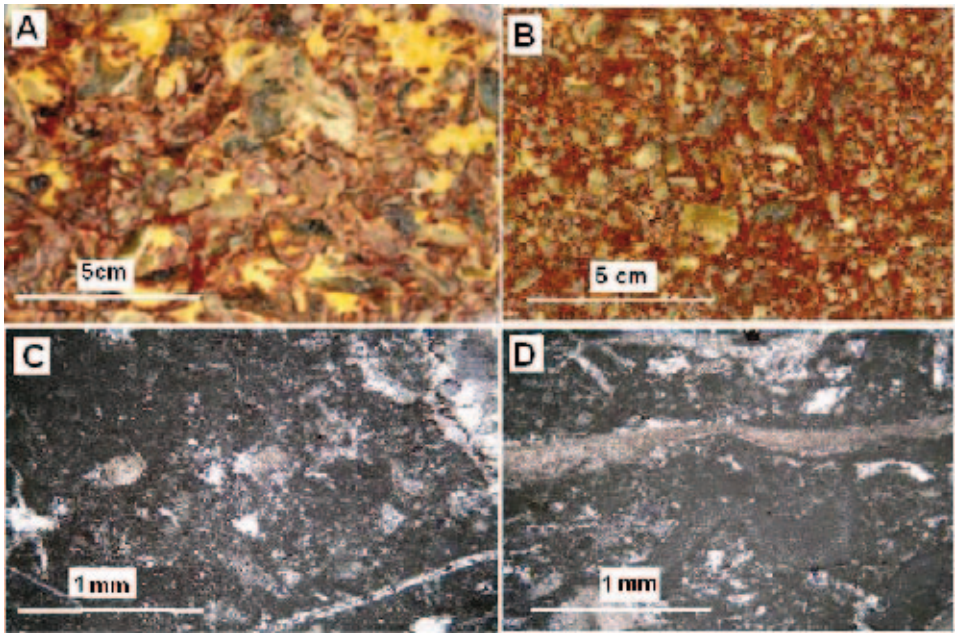

Fig. 7. Broccatello: A and B, macroscopic appearance; C and D, microphotograph (crossed polars).

between the hardest levels (conglomerates) and the softer ones (calcareous lithoarenite and lutite alternations).

The Quaternary rocks on the Ebro River, which are to the south of the archaeological site, are part of what would have been a larger meander than the present-day Flix Meander. This meander existed during the Upper Pleistocene, as can be seen from the sediments on Terrace 3.

The calcareous lithoarenite on the roof of the previously described stratigraphic series has the following drawbacks when it comes to quarrying:

– The narrow exploitable width (50 cm) and the small amount of surface area where it crops out; below this is the level of conglomerates that is some 4 m thick, making it impossible to quarry the stone located below this level or stratum.

– Transport would have had to have been towards the south to La Valleta dels Castellons, as the steep slope and instability of the terrain (gravitational landslips) would have made it almost impossible to transport ashlars or blocks of any size north to the Ebro River.

The three trenches at Els Castellons could have been experiments or tests to evaluate the technical characteristics of the stone found in the area of Flix and maybe the starting point of a more intensive survey of the surroundings.

Despite containing a large amount of dolomite (an unstable mineral that can initiate a spontaneous process of calcium carbonate and magnesium carbonate formation), the rock shows no signs of alteration. This demonstrates it is a highly stable stone and thus that it would have been a good material to be used.

At Boca Bovera and La Teuleria, the strata quarried for ashlars were those with a more tabular morphology, fewer discontinuities (less crossed stratification and/or lamination) and a thickness of almost 50 cm. The fact that this stone is deposited alternately with lutite and that it is on the banks of the Ebro make this an optimum area for quarrying rock for building or epigraphic use.

Any dressing of the stone carried out at the points where extraction marks have been observed would have been kept to a minimum, as the location on the banks of the Ebro River would have allowed the rough-hewn pieces to be transported immediately by boat.

In this area quarrying was carried out in terraces, taking advantage of the stratigraphic structure of the rock (alternating calcareous lithoarenite and lutite in decimetric thicknesses), which crops out with no meteorisation or sedimentary material (on the or with Quaternary deposits) that cover the levels to be quarried. This means that stone could be quarried almost without prior preparation. The presence of wedge sockets in some places indicates that some of the fronts with traces of ancient quarrying have probably disappeared due to the continuity of extraction in modern times.

On the other hand, broccatello quarrying dates at least from Augustan times, as attested by the finds at Segobriga (Cebrián *et al.* 2004; Rodà 2005, 467). Yet broccatello was mostly used from mid 1st century AD, which matches the results obtained during research carried out at the site on the Costa dels Capellans in Tortosa, up to the present moment the oldest Roman remains found in the town, where some fragments of broccatello were found (Genera and Jàrrega 2009).

It was distributed throughtout the Roman Empire (Lazzarini 2004; Gutiérrez Garcia-M. 2009, 236-237; 2012) but the period of greatest use was the Renaissance and the Baroque, as its colouring (at times somewhat multi-coloured) made it highly valued at that time (Muñoz 2005).

Final Conclusions

As already mentioned, the trenches observed at the settlement of Els Castellons do not constitute the remains of ancient workings related to a quarry. These

marks are more likely to be from surveys and tests carried out to evaluate the stone resources, probably in Roman times.

At Boca Bovera, it is possible to see the remains of workings related to the exploitation of stone resources although its ancient date cannot be confirmed with the data currently available. There are outlines for the extraction of ashlars with two types of marks to insert wedges as well as several discarded blocks left on the site.

The location of the quarries on the banks of the Ebro and the almost complete absence of indications of preparations prior to quarrying make it highly likely that this area was used to supply the building and epigraphic materials for the Roman town of Dertosa, as well as for the mediaeval town, as documented in the archives of the time (Almuni 2002).

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