LOCAL STONE USED ON THE ROMAN BRIDGE OF MARTORELL (BARCELONA, SPAIN)

A. Àlvarez and À. Pitarch

Abstract
This work deals with the characterization of the materials used for the construction of the Roman bridge known as the Pont del Diable[1] in Martorell-Castellbisbal (Catalonia, Spain). The Romans used the most easily available materials they could find close to the bridge site. Four different lithological types were identified in the material used to build the Roman part of the bridge: the red and white Buntsandstein sandstones of the Triassic formation from the Deveses stream (between Martorell and Castellví de Rosanes), the yellow bioclastic calcarenites from the Miocene formation located in Can Raimundet (Sant Llorenç d'Hortons) and the grey limestone from the Miocene formation in Costa Blanca (Castellbisbal). The first three were used for the construction of the bridge itself and the last was used not only to cut some ashlars of the honorific arch, but also to make the lime used for the mortar.

Keywords
Local stone, building stone, quarries, Roman bridge of Martorell, *Ad Fines*, petrography.

Introduction

On the Via Augusta*,* the Martorell gorge was the most important route towards the rich lands of the interior as it passed near Barcino on the way to Tarraco. The bridge was sited at a point where the river was narrow enough for it to be built.

The Roman bridge of Martorell-Castellbisbal, on the Via Augusta where it crossed the Llobregat River (ancient *Rubricatus*), was built following the end the second phase of the Cantabrian Wars (19 BC). Its construction, using military manpower, was part of the extensive programme for remodelling the northern area of the Iberian Peninsula in Augustan times. It was at that time, for example, that the colonies of Caesar Augusta and Barcino were founded and the road that linked Rome to Gades (modern Cadiz) was rebuilt and renamed after the emperor (Fabre, Mayer and Rodà 1984; Gurt and Rodà 2005).

Currently known as the Pont del Diable, the bridge is a complex monument due to the several renovations and rebuilding phases it has undergone over the centuries. The chronology of these successive modifications has been studied by Clopas (1963), Bonnassie (1981), Farreny *et al.* (1994) and Izquierdo (1997), among others.

Within the framework of a joint project between CETEC-Patrimoni (Universitat Autònoma de Barcelona) and the Catalan Autonomous Government Department of Cultural Heritage (Departament de Cultura, Generalitat de Catalunya) for the possible restoration of the bridge, an extensive and detailed characterisation of the building materials was carried out (Prada *et al.* 2006). The main problem for the conservation of the monument is its current location in the middle of a busy road network and close to seriously polluting industries.

In order to gain knowledge of the materials used in the construction of the bridge during Roman times (which could be of vital importance when taking decisions about restoration work), this paper presents a systematic polarised optical microscopy (POM) study of the materials (the characterisation of the stone and its possible sources) used for the construction of the Roman part of the bridge. Furthermore, as some of the same stone used to build the Roman bridge was also widely used in the construction of other ancient buildings near Martorell (*Recull del patrimoni arquitectònic de Martorell*

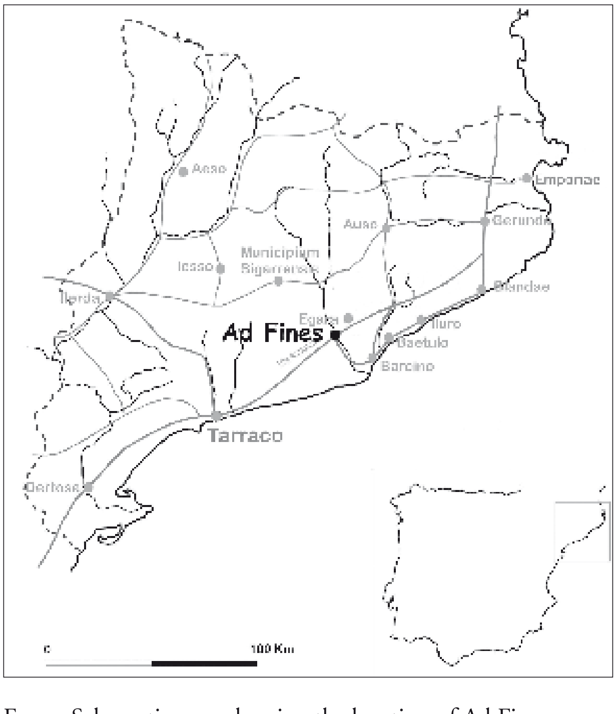

Fig. 1. Schematic map showing the location of Ad Fines (modern-day Martorell area) and other Roman towns in the northeast of the Iberian Peninsula (after Carreté *et al.* 1995, 8, fig.1.1).

1. "Devil's Bridge" in Catalan.

2006), the systematic study presented in this work might also be applied to those monuments.

Location and history

The bridge stands 58 m above sea level, at the junction between the Autovía del Nordeste motorway (A-2) and the C-243c local road to Terrassa (ancient Egara), between the modern towns of Martorell and Castellbisbal. In Roman times, the area of present-day Martorell was known as Ad Fines as it was the frontier between the *territoria* of Tarraco and Barcino (Gurt and Rodà 2005) (Fig. 1). It was, thus, a territorial arch that indicated the limit on the left bank of the Llobregat River (Fig. 2).

The Roman part of the bridge is 130 m long and the river is 75 m wide at the crossing point. It was built on Upper Ordovician–Silurian phyllites that form a small gorge through which the Llobregat River runs on its way to the sea.

The first reports of the construction of the Gothic part of the bridge date to 26 May 1283 in a document issued by the Catalan King Peter III. It seems that by 1286 the work was nearly finished, although in 1295 it still had to be completed as the king was asking for money to pay for this (Pedemonte 1929).

The current bridge was rebuilt in 1963 after the original had been destroyed during the Civil War (1939). It maintains the structure of the Gothic rebuilding, with a central arch having a double angle 21 m high and a span of 43 m. Figure 3 shows the superposition of the Gothic part of the building and the possible Roman one.

Materials and Methods

For the accurate characterisation of the materials used in the construction of the Roman bridge, samples from the areas that may have been used as quarries and that provide stone similar to that used in the bridge were studied. The latter were used as reference materials for the final identification of the archaeological materials.

The petrographic characterisation was obtained by using a commercial petrographic microscope (NIKON Eclipse 50iPol) at the Unit for Archaeometric Studies the Catalan Institute of Classical Archaeology (Unitat d'Estudis Arqueomètrics, Institut Català d'Arqueologia Clàssica). All the microphotographs were taken with polarised light and crossed polarisers.

Provenance of the building materials

Four lithological types have been identified: (1) a red sandstone mainly used for the blocks of the bridge, (2) a white sandstone used for the blocks of the bridge, (3) a yellow bioclastic calcarenite used on the arch and (4) a grey limestone used to carve some blocks and to make the lime used for the mortar (Margarit 2000; Prada *et al.* 2006; Àlvarez *et al.* 2007).

All these materials are well represented in the surroundings of the bridge and have been extensively studied (Àlvarez and Galindo 1997, 1999; Àlvarez *et al.* 2000, 2007; Prada *et al.* 2006; Àlvarez 2008). It seems that the Romans used the most easily available materials they could find close to the bridge site (Fig. 4).

Today it is difficult to identify ancient quarries as the evidence may have been destroyed by recent working. However, within the context of the exploitation of geological resources in Roman times, we have identified at least 3 different provenances (Fig. 5):

– The Deveses stream (Castellví de Rosanes). The Buntsandstein sandstones (from the lower Triassic) are well represented in the area, although it is in the surroundings of the Deveses stream where, despite the fact that the main walls have been heavily weathered, it was possible to find some evidence of quarrying (Àlvarez and Galindo 1997; Àlvarez *et al.* 1999, 2007; Mauri *et al.* 1999; Prada *et al.* 2006).

– Can Raimundet/La Rierussa (Sant Llorenç d'Hortons). The bioclastic sandstones of this area are from the Miocene (Serravallian-Tortonian, middle/upper Miocene) (Mauri *et al.* 1999). The site is an opencast quarry and stretches along the left bank of the La Rierussa stream. In fact, the quarry takes advantage of a natural front formed by the waters of the Rierussa, where it is possible to see multiple wedge marks and block delimitation grooves (Gutiérrez Garcia-M. 2009a). It is well preserved, although only scattered parts are visible due to the high bushes that cover most of the walls. The lack of written evidence of mediaeval and post-mediaeval quarrying suggests that this site was used in Roman times (Mauri *et al.* 1999; Carbonell and Adseiras 2002; IPAC 2003; Sendra 2003; Gutiérrez Garcia-M. 2009a, 2009b).

– Costa Blanca (Castellbisbal). From this area comes a bulk light-grey limestone from the Burdigalian-Serravallian (lower/middle Miocene), that was used to carve some of the blocks and to make the lime used as a filler for the *opus caementicium* (Àlvarez and Galindo 1997; Margarit 2000; Prada *et al.* 2006; Àlvarez *et al.* 2007). Nevertheless, we cannot locate exactly where the quarrying took place in Roman times as the area is much affected by road infrastructure that has led to the destruction of the evidence of earlier quarrying.

Buntsandstein sandstone

As already pointed out, in Roman times this sandstone was quarried around the Deveses stream, between Martorell and Castellví de Rosanes (Àlvarez *et al.* 2000). Although the red variety is the predominant lithological type of Buntsandstein sandstone, another variety –the white one– was used in the construction of the bridge.

Buntsandstein sandstone is a lower Triassic terrigenous clastic rock widely represented throughout the

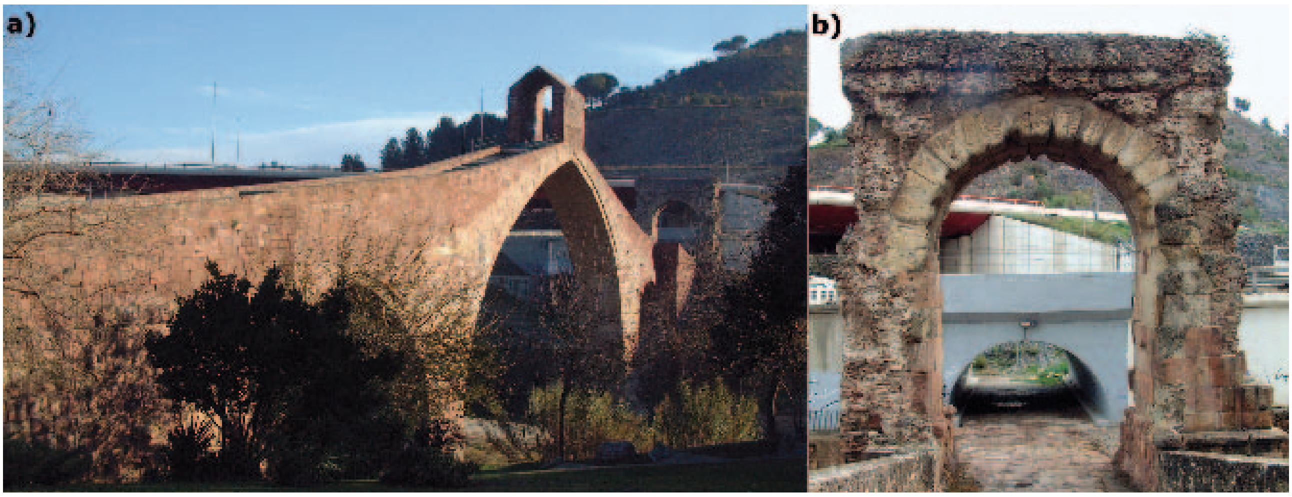

FIG. 2. A) Present view of the Roman bridge and B) view of the territorial arch.

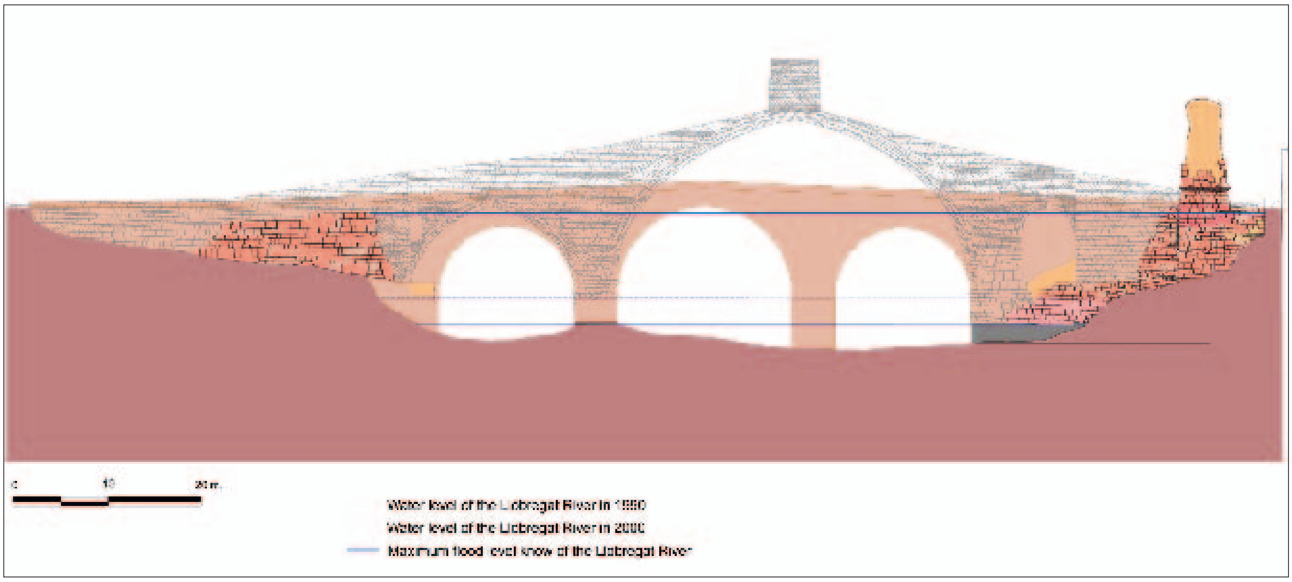

FIG. 3. Superposition of the Gothic part of the bridge and the possible Roman one (according to A. Mauri, in Farreny *et al.* 1994).

Catalan Coastal Range (Serralada Litoral) (*Atles Geològic de Catalunya* 2010). This formation has been extensively studied by Gómez-Gras (1993) and is mainly composed of a sand-sized grained framework. According to Folk (1954), it can be classified as a siliceous sandstone or a quartzarenite (Pettijohn *et al.* 1972).

The red variety

The grain size ranges from very coarse to fine sand. In some of the ashlars we can clearly see remaining sedimentary structures, such as stratification and cross bedding.

Observed under the polarised microscope, the red variety cement is formed by silica and iron minerals that surround the quartz grains of detrital origin. Feldspar grains and thin muscovite/biotite plates were also identified. Furthermore, a different grain size was detected in this variety (Fig. 6).

The white variety

In this variety, the ferruginous cement of the sandstone has been replaced by new barite ($BaSO^4$) cement due to a late hydrothermal fluid intrusion that generated the presence of sulphur compounds in the area (such as galena or sphalerite) (Varela 2010).

Observed under the microscope (Fig. 7), we can clearly identify this barite cement, as well as the presence of coarse quartz and feldspar grains and thin muscovite/biotite plates dispersed in the matrix.

Costa Blanca limestone

This grey Miocene limestone was quarried in the area known as Costa Blanca, near the town of Castellbisbal. It was occasionally used in the construction of the bridge and the honorific arch, but was mainly a constituent of mortars.

Fig. 4. Geological map of the area showing the location of the bridge and the nearby localities (ICC 2002, scale: 1.250.000). Key: N1: Lower Miocene; N2: Middle/Upper Miocene; N3: Upper Miocene; T1: Lower Triassic; T2/T3: Middle/Upper Triassic.

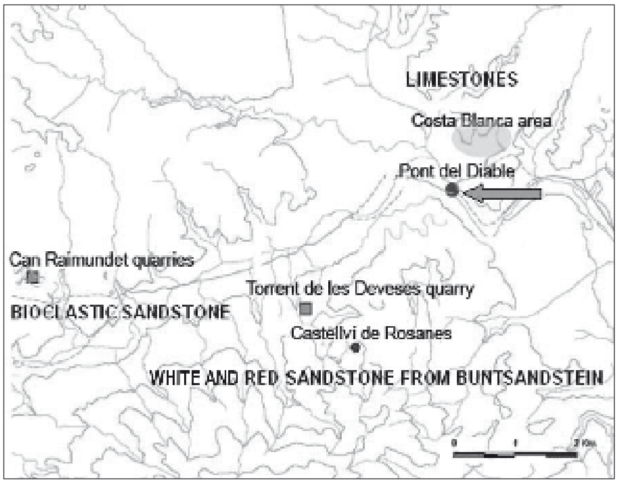

Fig. 5. Location-sources of the different materials used on the Pont del Diable.

Observed under a polarised light microscope, it can be classified as a layered micro-biosparite limestone (Folk 1959, 1962) and can be considered a mudstone (Dunham 1962). There is a presence of micro foraminifera and organic components. Detrital quartz grains have also been identified (Fig. 8).

Bioclastic sandstone

This Miocene material, mainly used in the honorific arch, comes from the quarry of Can Raimundet, in Sant Llorenç d'Hortons (Àlvarez *et al.* 1999, 2007; Carbonell and Adseiras 2002; IPAC 2003; Prada *et al.* 2006; Gutiérrez Garcia-M. 2009a). The geological formation has been extensively studied by Navas *et al.* (1994). The stone, of a yellowish colour, can be classified as a bioclastic calcarenite (Folk 1962) or a packstone (according Dunham 1962). It has a variable percentage of incorporate fauna and detrital particles (lithic fragments and quartz grains). An intense bioturbation hinders seeing the sedimentary structures. The grain size ranges from coarse to very coarse.

Observed under a microscope, this limestone is mainly composed of an accumulation of small foraminifera, echinoderm, gastropod and algal fragments with quartz, feldspars and plagioclase grains and thin muscovite/biotite plates. Granite fragments and some glauconite grains have also been identified. We should emphasise the presence of *Ditrupa sp.* (Fig. 9).

Conclusions

A building project the size of the Pont del Diable would not have remained outside the general standards used by the Romans to rationalise to the maximum the resources needed for its construction. This involved seeking out and quarrying the most suitable stone as close as possible to the site chosen for the bridge.

A brief look at the local geology shows us outcrops of various types of rock from diverse geological periods. The foundations of the Pont del Diable were built on Upper Ordovician-Silurian phyllites. However, it was the red stone from the Triassic era (Buntsandstein) that the Romans mainly used to build all the facings of the bridge. This was quarried in an area between La Roca Dreta and El Torrent de les Deveses near Castellví de Rosanes. The bioclastic sandstones used on the foundations and the arch, as well as on the western buttress, came from the Can Raimundet quarry in Sant Llorenç d'Hortons. From the area known as Costa Blanca, near the eastern buttress of the bridge (Castellbisbal), came the compact light grey limestone used mainly for cutting ashlars and making lime for the mortar.

Acknowledgements

This study is part of a joint project between the Universitat Autònoma de Barcelona (UAB) and the Catalan Government Department of Cultural Heritage. À. Pitarch received a grant (ref. AP2006-4591) from the Spanish Ministry of Education. This work has been done within the framework of the Geology PhD Programme of the Autonomous University of Barcelona.

References

Àlvarez, A. 2008: "Alterations on Roman mortars. A case study: the Roman bridge of Martorell (Spain)" –conference in *Traimonhere: Valorisation of Monumental Heritage through Higher Education and Professional Training. Socioeconomic study and analysis of National Policies on EU-MED-DEV countries and EC Directives*" (project financed by the European Union; ref. num: FP6-2002-INCO-COMultilatRTD/SSA-5), Split (Croacia) 29th September to 3rd October 2008.

Àlvarez, A; Galindo, J. 1997: *Pont del diable. Caracterització i procedència dels materials constructius*

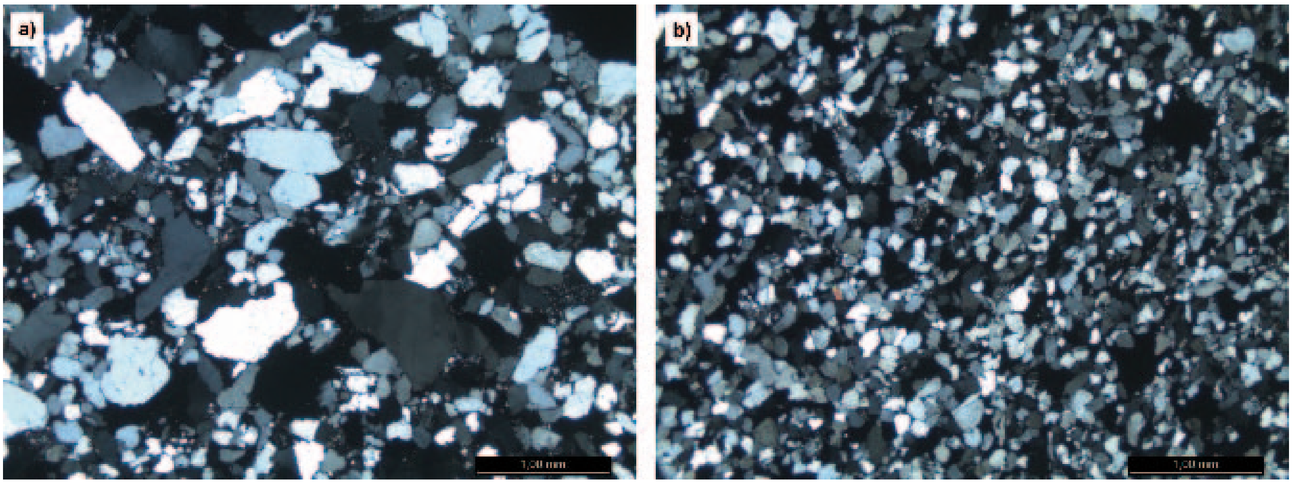

FIG. 6. Examples of the microscopic appearance of: a) the red Buntsandstein coarse grained variety (sample PD-1) and b) the red Buntsandstein fine-grained sandstone variety (the siliceous cement is clearly observed) (sample PD-3).

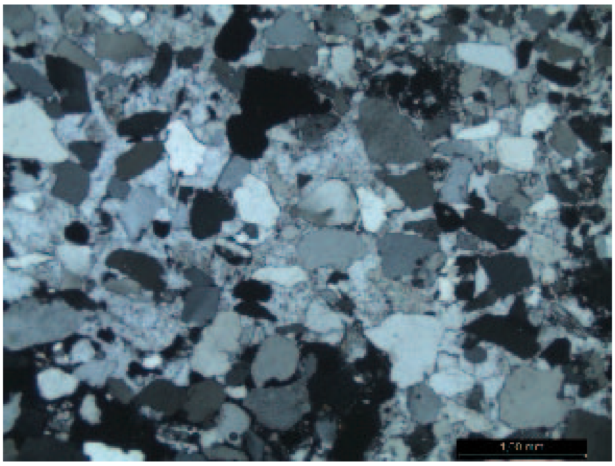

FIG. 7. Example of the microscopic appearance of the white Buntsandstein variety in which we can clearly see the barite cement (sample PD-5).

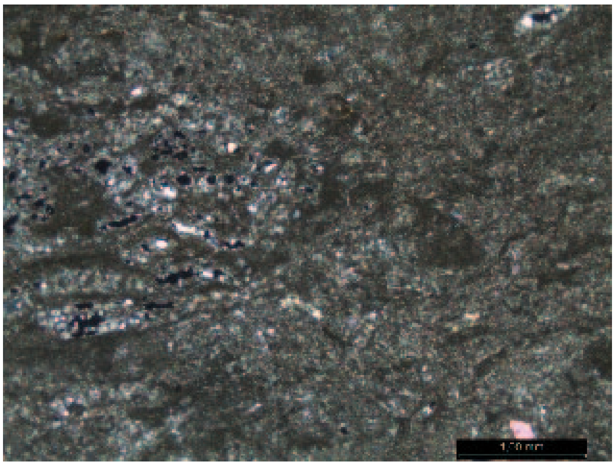

FIG. 8. Example of the appearance of the Costa Blanca limestone viewed under the microscope. A clear stratification and abundant presence of micro fossils are observed (sample PD-4).

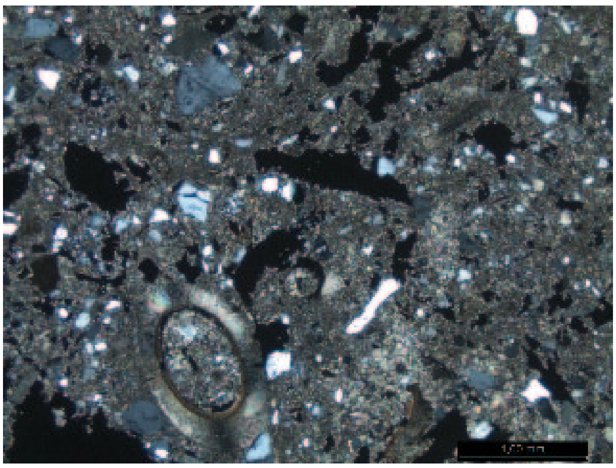

FIG. 9. Microphotograph of the Can Raimundet stone (sample PD-6) showing *Ditrupa sp.* specimens.

(pedres i morters). Project granted by Direcció General de Patrimoni Cultural - Generalitat de Catalunya, Barcelona. [Unpublished]

– 1999: *Informe sobre la determinación de la época de construcción de las estructuras murales (estructura rectangular y muro de contención (UE 4110)) situadas al norte del extremo oriental del Pont de Diable (Martorell-Castellbisbal)*. Project granted by Direcció General de Patrimoni Cultural - Generalitat de Catalunya, Barcelona. [Unpublished]

ÀLVAREZ, A.; GALINDO, J.; MAURI, A. 1998: *El Pont del Diable: tècniques constructives, materials i seqüència històrica*. Project granted by Direcció General de Patrimoni Cultural - Generalitat de Catalunya, Barcelona. [Unpublished]

– 2000: *El Pont del Diable: Tècniques constructives, materials i seqüència històrica*, Ajuntament de Gelida, Gelida.

Àlvarez, A.; Prada, J. L.; Pitarch, À.; Galindo, J. 2007: "El Puente Romano (Pont del Diable) de Martorell (Barcelona)", in: *Proceedings of VII Congreso Ibérico de Arqueometría* (Madrid, October 2007), Madrid, 618-627.

Bonnassie, P. 1979, 1981: *Catalunya mil anys enrera (segles X-XI).* Col·lecció estudis i documents, 31 i 32, I i II, Edicions 62, Barcelona.

Carbonell, M. C.; Adseiras, M. 2002: *Memoria de la prospección arqueológica en la línea de alta velocidad Madrid-Barcelona-Frontera francesa. Subtramo Gelida- Sant Llorenç d'Hortons (Alt Penedès)*, Barcelona. [Unpublished report]

Carreté, J.M.; Keay, S.; Millet, M. 1995: *A Roman provincial capital and its hinterland. The survey of the territory of Tarragona, Spain, 1985-1990*, Journal of Roman Archaeology Supplementary series, 15, Portsmouth.

Clopas, I. 1963: *Historia y leyenda del puente del diablo de Martorell*, Ayuntamiento de Martorell, Martorell.

Dunham, R. J. 1962: "Classification of carbonate rocks according to the depositional texture", in: Ham, W.E. (ed.), *Classification of Carbonate Rocks. American Association of Petroleum Geologists Bulletin Memoir* I, 108-121.

Fabre, G.; Mayer, M.; Rodà, I. 1984: "A propos du Pont de Martorell: La participation de l'armée a l'aménagement du réseu routier de la tarraconaise orientale sous Auguste" in: *Epigraphie Hispanique. Problèmes de Méthode et d'Édition, Actes de la table ronde internationale du C.N.R.S,* Centre Pierre Paris, París, 282-288.

Farreny, M.; Mauri, A.; Vives, M. 1994: "La seqüència històrica del Pont del Diable i el seu context territorial", in: Gómez, M.; Gutiérrez, G.; Luengo, M. (eds.), *Miscel·lània d'homenatge a Jaume Codina*, El Prat, 219-250.

Folk, R.L. 1954: "The distinction between grain size and mineral composition in sedimentary rock nomenclature", *Journal of Geology* 62, 343-359.

– 1959: "Practical Petrographic classification of limestone", *American Association of Petroleum Geologists Bulletin* 43, 1-38.

– 1962: "Spectral subdivision of limestone types", in: Ham, W.E. (ed.), *Classification of Carbonate rocks, American Association of Petroleum Geologists Bulletin Memoir* I, 62-84.

Gurt, J.M.; Rodà, I. 2005: "El Pont del Diable. El monumento romano dentro de la política augustea", *Archivo Español de Arqueología* 78, 191-192.

Gutiérrez Garcia-M., A. 2009a: *Roman Quarries in the northeast of Hispania (Modern Catalonia),* Institut Català d'Arqueología Clàssica, Tarragona.

– 2009b: "Canteras del Noroeste de Hispania (Actual Cataluña): propuesta de cronología y consideraciones generales", in: Nogales, T.; Beltrán, J. (ed.), *Marmora Hispana: explotación y uso de los materiales pétreos en la Hispania Romana,* L'Erma di Bretschneider, Roma, 167-195.

Grahit, J. 1947: *Memoria de la labor realizada por la misma en su primer siglo de existencia (1844-1944)*, Comisión Provincial de Monumentos históricos y artísticos, Barcelona.

Hurtado, V.; Mestre, J.; Miserachs, T. 1995: *Atles d'Història de Catalunya*, Edicions 62, Barcelona.

ICC 2002: *Mapa geològic de Catalunya. Scale: 1:250000.* [Cartographic document]. Servei Geològic de Catalunya, Institut Cartogràfic de Catalunya, Second Edition, Barcelona.

IPAC 2003: "Carta arqueològica: Alt Penedès", in: *Inventari del Patrimoni Arqueològic*, Generalitat de Catalunya, Barcelona.

Izquierdo, P. 1997: *Memoria de la primera fase de intervención arqueológica del Proyecto complementario de acondicionamiento hidráulico del rio Llobregat y rieras en el entorno de la autovía del Baix Llobregat al Pont del Diable.* [Unpublished].

Margarit, J. 2000: "L'activitat dels forns de calç", in: *Programa de Festa Major de Gelida 2000*, Ajuntament de Gelida, Gelida.

Mauri, A. 1997: *Sistemes territorials i l'estudi de les traces arqueològiques medievals. Un exemple d'aplicació a l'antiga baronia de Castellvell de Rosanes (Baix Llobregat, Barcelona),* Universitat de Barcelona. [PhD Thesis]

Navas, E.; Martinell, J.; Domènech, R.; Batllori, J. 1994: "Correlación bioestratigráfica entre las sucesiones miocénicas marinas de Sant Pau d'Ordal y Sant Llorenç d'Hortons (Depresión del Vallès – Penedès, Barcelona)", *Acta Geológica Hispánica,* vol. 29, n. 2-4, 149-168.

Pagès, M. 1992: *Art romànic i feudalisme al Baix Llobregat*, Biblioteca Abat Oliva, 108, Publicacions de l'Abadia de Montserrat, Barcelona.

Palet, J. M. 1997: "Estudi territorial del Pla de Barcelona. Estructuració i evolució del territori entre l'època iberoromana i l'altmedieval (segles II-I aC i X-XI dC)", *Estudis i Memòries d'Arqueologia de Barcelona*, Institut de Cultura, Barcelona.

Pallí, F. 1985: *La Via Augusta en Cataluña,* Bellaterra.

Pedemonte, B. 1929: *Notes per a la Història de la Baronia de Castellví de Rosanes*, Barcelona.

Pettijohn, F. J.; Potter, P. E.; Siever, R. 1972: *Sand and Sandstones*, Spriger-Verlag, New York.

Prada, J. L.; Àlvarez, A.; Pitarch, À.; Badia, M. 2006: *Els materials constructius (pedres i morters) del Pont del Diable (Martorell – Castellbisbal): caracterització, alteració i estat de conservació*, Project granted by Direcció General de Patrimoni Cultural - Generalitat de Catalunya, Barcelona. [Unpublished].

Sendra, M. 2003: *Memòria control arqueològic L.A.V: Subtram XI-B Gelida-Sant Llorenç d'Hortons*, Arxiu Servei d'Arqueologia [unpublished archaeological report].

Soto, P. De 2010: *Anàlisi de la xarxa de comunicacions i del transport a la Catalunya Romana: estudis de distribució i mobilitat*, Universitat Autònoma de Barcelona, Barcelona. [PhD Thesis]

Varela, F. 2010: "Mina la Martorellense, Martorell / Castellví de Rosanes, Baix Llobregat (Barcelona), *FMF - Foro de Minerales,* http://www.foro-minerales.com [Accessed: September 2011]

Recull del patrimoni arquitectònic de Martorell in: *Auditoria Ambiental Municipal de Martorell. Document I: Memòria descriptiva*. Diputació de Barcelona, Àrea de Medi Ambient, Barcelona 2006.

Atles Geològic de Catalunya. IGC / ICC, Barcelona 2010.