

Grey and Greyish Banded Marbles from the Estremoz Anticline in Lusitania

Lapuente, Pilar; Nogales-Basarrate, Trinidad; Royo Plumed, Hernando; Brilli, Mauro; Savin, Marie-Claire

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CONTENT

PRESENTATION	15
NECROLOGY: NORMAN HERZ (1923-2013) by Susan Kane	17
1. APPLICATIONS TO SPECIFIC ARCHEOLOGICAL QUESTIONS – USE OF MARBLE	
Hermaphrodites and Sleeping or Reclining Maenads: Production Centres and Quarry Marks <i>Patrizio Pensabene</i>	25
First Remarks about the Pavement of the Newly Discovered Mithraeum of the Colored Marbles at Ostia and New Investigations on Roman and Late Roman White and Colored Marbles from Insula IV, IX <i>Massimiliano David, Stefano Succi and Marcello Turci</i>	33
Alabaster. Quarrying and Trade in the Roman World: Evidence from Pompeii and Herculaneum <i>Simon J. Barker and Simona Perna</i>	45
Recent Work on the Stone at the Villa Arianna and the Villa San Marco (Castellammare di Stabia) and Their Context within the Vesuvian Area <i>Simon J. Barker and J. Clayton Fant</i>	65
Marble Wall Decorations from the Imperial Mausoleum (4 th C.) and the Basilica of San Lorenzo (5 th C.) in Milan: an Update on Colored Marbles in Late Antique Milan <i>Elisabetta Neri, Roberto Bugini and Silvia Gazzoli</i>	79
Sarcophagus Lids Sawn from their Chests <i>Dorothy H. Abramitis and John J. Herrmann</i>	89
The Re-Use of Monolithic Columns in the Invention and Persistence of Roman Architecture <i>Peter D. De Staebler</i>	95
The Trade in Small-Size Statues in the Roman Mediterranean: a Case Study from Alexandria <i>Patrizio Pensabene and Eleonora Gasparini</i>	101
The Marble Dedication of Komon, Son of Asklepiades, from Egypt: Material, Provenance, and Reinforcement of Meaning <i>Patricia A. Butz</i>	109
Multiple Reuse of Imported Marble Pedestals at Caesarea Maritima in Israel <i>Barbara Burrell</i>	117
Iasos and Iasian Marble between the Late Antique and Early Byzantine Eras <i>Diego Peirano</i>	123

Thassos, Known Inscriptions with New Data <i>Tony Kozelj and Manuela Wurch-Kozelj</i>	131
The Value of Marble in Roman <i>Hispalis</i> : Contextual, Typological and Lithological Analysis of an Assemblage of Large Architectural Elements Recovered at N° 17 Goyeneta Street (Seville, Spain) <i>Ruth Taylor, Oliva Rodríguez, Esther Ontiveros, María Luisa Loza, José Beltrán and Araceli Rodríguez</i>	143
<i>Giallo Antico</i> in Context. Distribution, Use and Commercial Actors According to New Stratigraphic Data from the Western Mediterranean (2 nd C. Bc – Late 1 st C. Ad) <i>Stefan Ardeleanu</i>	155
<i>Amethystus</i> : Ancient Properties and Iconographic Selection <i>Luigi Pedroni</i>	167
2. PROVENANCE IDENTIFICATION I: (MARBLE)	
Unraveling the Carrara – Göktepe Entanglement <i>Walter Prochaska, Donato Attanasio and Matthias Bruno</i>	175
The Marble of Roman Imperial Portraits <i>Donato Attanasio, Matthias Bruno, Walter Prochaska and Ali Bahadır Yavuz</i>	185
Tracing Alabaster (Gypsum or Anhydrite) Artwork Using Trace Element Analysis and a Multi-Isotope Approach (Sr, S, O) <i>Lise Leroux, Wolfram Kloppmann, Philippe Bromblet, Catherine Guerrot, Anthony H. Cooper, Pierre-Yves Le Pogam, Dominique Vingtain and Noel Worley</i>	195
Roman Monolithic Fountains and Thasian Marble <i>Annewies van den Hoek, Donato Attanasio and John J. Herrmann</i>	207
Archaeometric Analysis of the Alabaster Thresholds of Villa A, Oplontis (Torre Annunziata, Italy) and New Sr and Pb Isotopic Data for <i>Alabastro Ghiaccione del Circeo</i> <i>Simon J. Barker, Simona Perna, J. Clayton Fant, Lorenzo Lazzarini and Igor M. Villa</i>	215
Roman Villas of Lake Garda and the Occurrence of Coloured Marbles in the Western Part of “Regio X Venetia et Histria” (Northern Italy) <i>Roberto Bugini, Luisa Folli and Elisabetta Roffia</i>	231
Calcitic Marble from Thasos in the North Adriatic Basin: Ravenna, Aquileia, and Milan <i>John J. Herrmann, Robert H. Tykot and Annewies van den Hoek</i>	239
Characterisation of White Marble Objects from the Temple of Apollo and the House of Augustus (Palatine Hill, Rome) <i>Francesca Giustini, Mauro Brilli, Enrico Gallochio and Patrizio Pensabene</i>	247
Study and Archeometric Analysis of the Marble Elements Found in the Roman Theater at Aeclanum (Mirabella Eclano, Avellino - Italy) <i>Antonio Mesisca, Lorenzo Lazzarini, Stefano Cancelliere and Monica Salvadori</i>	255

Two Imperial Monuments in Puteoli: Use of Proconnesian Marble in the Domitianic and Trajanic Periods in Campania <i>Irene Bald Romano, Hans Rupprecht Goette, Donato Attanasio and Walter Prochaska</i>	267
Coloured Marbles in the Neapolitan Pavements (16 th And 17 th Centuries): the Church of <i>Santi Severino e Sossio</i> <i>Roberto Bugini, Luisa Folli and Martino Solito</i>	275
Roman and Early Byzantine Sarcophagi of Calcitic Marble from Thasos in Italy: Ostia and Siracusa <i>Donato Attanasio, John J. Herrmann, Robert H. Tykot and Annewies van den Hoek</i>	281
Revisiting the Origin and Destination of the Late Antique Marzamemi 'Church Wreck' Cargo <i>Justin Leidwanger, Scott H. Pike and Andrew Donnelly</i>	291
The Marbles of the Sculptures of Felix Romuliana in Serbia <i>Walter Prochaska and Maja Živić</i>	301
Calcitic Marble from Thasos and Proconnesos in Nea Anchialos (Thessaly) and Thessaloniki (Macedonia) <i>Vincent Barbin, John J. Herrmann, Aristotle Mentzos and Annewies van den Hoek</i>	311
Architectural Decoration of the Imperial Agora's Porticoes at Iasos <i>Fulvia Bianchi, Donato Attanasio and Walter Prochaska</i>	321
The Winged Victory of Samothrace - New Data on the Different Marbles Used for the Monument from the Sanctuary of the Great Gods <i>Annie Blanc, Philippe Blanc and Ludovic Laugier</i>	331
Polychrome Marbles from the Theatre of the Sanctuary of Apollo Pythios in Gortyna (Crete) <i>Jacopo Bonetto, Nicolò Mareso and Michele Bueno</i>	337
Paul the Silentary, Hagia Sophia, Onyx, Lydia, and Breccia Corallina <i>John J. Herrmann and Annewies van den Hoek</i>	345
Incrustations from Colonia Ulpia Traiana (Near Modern Xanten, Germany) <i>Vilma Ruppiniè and Ulrich Schüssler</i>	351
Stone Objects from Vindobona (Austria) – Petrological Characterization and Provenance of Local Stone in a Historico-Economical Setting <i>Andreas Rohatsch, Michaela Kronberger, Sophie Insulander, Martin Mosser and Barbara Hodits</i>	363
Marbles Discovered on the Site of the Forum of Vaison-la-Romaine (Vaucluse, France): Preliminary Results <i>Elsa Roux, Jean-Marc Mignon, Philippe Blanc and Annie Blanc</i>	373
Updated Characterisation of White Saint-Béat Marble. Discrimination Parameters from Classical Marbles <i>Hernando Royo Plumed, Pilar Lapeunte, José Antonio Cuchí, Mauro Brillì and Marie-Claire Savin</i>	379

Grey and Greyish Banded Marbles from the Estremoz Anticline in Lusitania <i>Pilar Lapuente, Trinidad Nogales-Basarrate, Hernando Royo Plumed, Mauro Brilli and Marie-Claire Savin</i>	391
New Data on Spanish Marbles: the Case of <i>Gallaecia</i> (NW Spain) <i>Anna Gutiérrez García-M., Hernando Royo Plumed and Silvia González Soutelo</i>	401
A New Roman Imperial Relief Said to Be from Southern Spain: Problems of Style, Iconography, and Marble Type in Determining Provenance <i>John Pollini, Pilar Lapuente, Trinidad Nogales-Basarrate and Jerry Podany</i>	413
Reuse of the <i>Marmorata</i> from the Late Roman Palatial Building at Carranque (Toledo, Spain) in the Visigothic Necropolis <i>Virginia García-Entero, Anna Gutiérrez García-M. and Sergio Vidal Álvarez</i>	427
Imperial Porphyry in Roman Britain <i>David F. Williams</i>	435
Recycling of Marble: Apollonia/Sozousa/Arsuf (Israel) as a Case Study <i>Moshe Fischer, Dimitris Tambakopoulos and Yannis Maniatis</i>	443
Thasian Connections Overseas: Sculpture in the Cyrene Museum (Libya) Made of Dolomitic Marble from Thasos <i>John J. Herrmann and Donato Attanasio</i>	457
Marble on Rome's Southwestern Frontier: Thamugadi and Lambaesis <i>Robert H. Tykot, Ouahiba Bouzidi, John J. Herrmann and Annewies van den Hoek</i>	467
Marble and Sculpture at Lepcis Magna (Tripolitania, Libya): a Preliminary Study Concerning Origin and Workshops <i>Luisa Musso, Laura Buccino, Matthias Bruno, Donato Attanasio and Walter Prochaska</i>	481
The Pentelic Marble in the Carnegie Museum of Art Hall of Sculpture, Pittsburgh, Pennsylvania <i>Albert D. Kollar</i>	491
Analysis of Classical Marble Sculptures in the Michael C. Carlos Museum, Emory University, Atlanta <i>Robert H. Tykot, John J. Herrmann, Renée Stein, Jasper Gaunt, Susan Blevins and Anne R. Skinner</i>	501
3. PROVENANCE IDENTIFICATION II: (OTHER STONES)	
Aphrodisias and the Regional Marble Trade. The <i>Scaenae Frons</i> of the Theatre at Nysa <i>Natalia Toma</i>	513
The Stones of Felix Romuliana (Gamzigrad, Serbia) <i>Bojan Djurić, Divna Jovanović, Stefan Pop Lazić and Walter Prochaska</i>	523
Aspects of Characterisation of Stone Monuments from Southern Pannonia <i>Branka Migotti</i>	537

The Budakalász Travertine Production <i>Bojan Djurić, Sándor Kele and Igor Rižnar</i>	545
Stone Monuments from Carnuntum and Surrounding Areas (Austria) – Petrological Characterization and Quarry Location in a Historical Context <i>Gabrielle Kremer, Isabella Kitz, Beatrix Moshhammer, Maria Heinrich and Erich Draganits</i>	557
Espejón Limestone and Conglomerate (Soria, Spain): Archaeometric Characterization, Quarrying and Use in Roman Times <i>Virginia García-Entero, Anna Gutiérrez García-M, Sergio Vidal Álvarez, María J. Peréx Agorreta and Eva Zarco Martínez</i>	567
The Use of Alcover Stone in Roman Times (<i>Tarraco, Hispania Citerior</i>). Contributions to the <i>Officina Lapidaria Tarraconensis</i> <i>Diana Gorostidi Pi, Jordi López Vilar and Anna Gutiérrez García-M.</i>	577
4. ADVANCES IN PROVENANCE TECHNIQUES, METHODOLOGIES AND DATABASES	
Grainautline – a Supervised Grain Boundary Extraction Tool Supported by Image Processing and Pattern Recognition <i>Kristóf Csorba, Lilla Barancsuk, Balázs Székely and Judit Zöldföldi</i>	587
A Database and GIS Project about Quarrying, Circulation and Use of Stone During the Roman Age in <i>Regio X - Venetia et Histria</i> . The Case Study of the Euganean Trachyte <i>Caterine Previato and Arturo Zara</i>	597
5. QUARRIES AND GEOLOGY	
The Distribution of Troad Granite Columns as Evidence for Reconstructing the Management of Their Production <i>Patrizio Pensabene, Javier Á. Domingo and Isabel Rodà</i>	613
Ancient Quarries and Stonemasonry in Northern Choria Considiana <i>Hale Güney</i>	621
Polychromy in Larisaeon Quarries and its Relation to Architectural Conception <i>Gizem Mater and Ertunç Denктаş</i>	633
Euromos of Caria: the Origin of an Hitherto Unknown Grey Veined Stepped Marble of Roman Antiquity <i>Matthias Bruno, Donato Attanasio, Walter Prochaska and Ali Bahadır Yavuz</i>	639
Unknown Painted Quarry Inscriptions from Bacakale at <i>Docimium</i> (Turkey) <i>Matthias Bruno</i>	651
The Green Schist Marble Stone of Jebel El Hairech (North West of Tunisia): a Multi-Analytical Approach and its Uses in Antiquity <i>Ameur Younès, Mohamed Gaied and Wissem Gallala</i>	659
Building Materials and the Ancient Quarries at <i>Thamugadi</i> (East of Algeria), Case Study: Sandstone and Limestone <i>Younès Rezkallah and Ramdane Marmi</i>	673

The Local Quarries of the Ancient Roman City of <i>Valeria</i> (Cuenca, Spain) <i>Javier Atienza Fuente</i>	683
The Stone and Ancient Quarries of Montjuïc Mountain (Barcelona, Spain) <i>Aureli Álvarez</i>	693
<i>Notae Lapidinarum</i> : Preliminary Considerations about the Quarry Marks from the Provincial Forum of <i>Tarraco</i> <i>Maria Serena Vinci</i>	699
The Different Steps of the Rough-Hewing on a Monumental Sculpture at the Greek Archaic Period: the Unfinished Kouros of Thasos <i>Danièle Braunstein</i>	711
A Review of Copying Techniques in Greco-Roman Sculpture <i>Séverine Moureaud</i>	717
Labour Forces at Imperial Quarries <i>Ben Russell</i>	733
Social Position of Craftsmen inside the Stone and Marble Processing Trades in the Light of Diocletian's Edict on Prices <i>Krešimir Bosnić and Branko Matulić</i>	741
6. STONE PROPERTIES, WEATHERING EFFECTS AND RESTORATION, AS RELATED TO DIAGNOSIS PROBLEMS, MATCHING OF STONE FRAGMENTS AND AUTHENTICITY	
Methods of Consolidation and Protection of Pentelic Marble <i>Maria Apostolopoulou, Elissavet Drakopoulou, Maria Karoglou and Asterios Bakolas</i>	749
7. PIGMENTS AND PAINTINGS ON MARBLE	
Painting and Sculpture Conservation in Two Gallo-Roman Temples in Picardy (France): Champlieu and Pont-Sainte-Maxence <i>Véronique Brunet-Gaston and Christophe Gaston</i>	763
The Use of Colour on Roman Marble Sarcophagi <i>Eliana Siotto</i>	773
New Evidence for Ancient Gilding and Historic Restorations on a Portrait of Antinous in the San Antonio Museum of Art <i>Jessica Powers, Mark Abbe, Michelle Bushey and Scott H. Pike</i>	783
Schists and Pigments from Ancient Swat (Khyber Pukhtunkhwa, Pakistan) <i>Francesco Mariottini, Gianluca Vignaroli, Maurizio Mariottini and Mauro Roma</i>	793
8. SPECIAL THEME SESSION: „THE USE OF MARBLE AND LIMESTONE IN THE ADRIATIC BASIN IN ANTIQUITY”	
Marble Sarcophagi of Roman Dalmatia Material – Provenance – Workmanship <i>Guntram Koch</i>	809

Funerary Monuments and Quarry Management in Middle Dalmatia <i>Nenad Cambi</i>	827
Marble Revetments of Diocletian's Palace <i>Katja Marasović and Vinka Marinković</i>	839
The Use of Limestones as Construction Materials for the Mosaics of Diocletian's Palace <i>Branko Matulić, Domagoj Mudronja and Krešimir Bosnić</i>	855
Restoration of the Peristyle of Diocletian's Palace in Split <i>Goran Nikšić</i>	863
Marble Slabs Used at the Archaeological Site of Sorna near Poreč Istria – Croatia <i>Đeni Gobić-Bravar</i>	871
Ancient Marbles from the Villa in Verige Bay, Brijuni Island, Croatia <i>Mira Pavletić and Đeni Gobić-Bravar</i>	879
Notes on Early Christian Ambos and Altars in the Light of some Fragments from the Islands of Pag and Rab <i>Mirja Jarak</i>	887
The Marbles in the Chapel of the Blessed John of Trogir in the Cathedral of St. Lawrence at Trogir <i>Đeni Gobić-Bravar and Daniela Matetić Poljak</i>	899
The Use of Limestone in the Roman Province of Dalmatia <i>Edisa Lozić and Igor Rižnar</i>	915
The Extraction and Use of Limestone in Istria in Antiquity <i>Klara Buršić-Matijašić and Robert Matijašić</i>	925
Aurisina Limestone in the Roman Age: from Karst Quarries to the Cities of the Adriatic Basin <i>Caterina Previato</i>	933
The Remains of Infrastructural Facilities of the Ancient Quarries on Zadar Islands (Croatia) <i>Mate Parica</i>	941
The Impact of Local Geomorphological and Geological Features of the Area for the Construction of the Burnum Amphitheatre <i>Miroslav Glavičić and Uroš Stepišnik</i>	951
Roman Quarry Klis Kosa near Salona <i>Ivan Alduk</i>	957
Marmore Lavdata Brattia <i>Miona Miliša and Vinka Marinković</i>	963
Quarries of the Lumbarda Archipelago <i>Ivka Lipanović and Vinka Marinković</i>	979

Island of Korčula – Importer and Exporter of Stone in Antiquity <i>Mate Parica and Igor Borzić</i>	985
Faux Marbling Motifs in Early Christian Frescoes in Central and South Dalmatia: Preliminary Report <i>Tonči Borovac, Antonija Gluhan and Nikola Radošević</i>	995
INDEX OF AUTHORS	1009

GREY AND GREYISH BANDED MARBLES FROM THE ESTREMOZ ANTICLINE IN LUSITANIA

Pilar Lapuente^{1,3}, Trinidad Nogales-Basarrate², Hernando Royo Plumed^{1,3}, Mauro Brilli⁴ and Marie-Claire Savin^{1,5}

¹ Petrology and Geochemistry, Earth Sciences Department, Zaragoza University, Zaragoza, Spain (plapuent@unizar.es; hroyo@icac.cat; marie-claire.savin@u-bordeaux-montaigne.fr)

² National Museum of Roman Art, Mérida, Spain (trinidad.nogales@mecd.es)

³ Institut Català d'Arqueologia Clàssica (ICAC), Tarragona, Spain (plapuent@unizar.es; hroyo@icac.cat)

⁴ Istituto di Geologia Ambientale e Geoingegneria, CNR, Area della Ricerca Roma1, Rome, Italy (mauro.brilli@igag.cnr.it)

⁵ Institut de recherche sur les Archéomatériaux – Centre de Recherche en Physique Appliquée à l'Archéologie (IRAMAT-CRP2A), Université de Bordeaux Montaigne, Bordeaux, France (marie-claire.savin@u-bordeaux-montaigne.fr)

Abstract

This contribution addresses the characterization study of grey and greyish banded marbles from the Estremoz Anticline (EA) marble district in Portugal. During Roman times, the whole of *Lusitania*, including its capital *Augusta Emerita*, was supplied with white and coloured marbles from this district. Grey varieties were used mainly in architectural and epigraphic elements, funerary *stelae* and *arae*. The interest in the EA marbles focuses here on the grey types as they could have been used for trading beyond their provincial administrative domains, as was the case with the white marbles, in competition with other Iberian and classical materials, creating an increasing need to know how to identify them. A multi-method approach combining visual examination, spectrophotometry to quantify the greyscale tones, optical microscopy (OM), cathodoluminescence (CL) and stable C and O isotope analysis was applied to 25 quarry samples, which were collected from the south-eastern part of the EA structure.

Keywords

Estremoz Anticline quarries, Lusitanian grey marbles, provenance study

Introduction and aims

With few exceptions, when scholars talk about the use of the noble Roman material par excellence, they are referring to white statuary marble. However, in recent years, grey marbles used in antiquity have begun to attract great interest among the scientific community (LAZZARINI *et al.* 1999; LAZZARINI 2013) especially after the discovery of ancient quarries found in Asia Minor (ATTANASIO *et al.* 2009; BRUNO *et al.* 2012; YAVUZ *et al.* 2011, 2012). Several noble varieties also include those referred to as *bigio morato*

and *bigio antico* in traditional literature, which have been scientifically studied in different archaeological papers (ATTANASIO *et al.* 2013; BRUNO *et al.* 2015). After comparisons with reference materials, there is a better perspective regarding the identification of their quarry sources (ATTANASIO *et al.* 2015, BRILLI *et al.* 2015; 2018). Additionally, banded or listed black and white varieties, and in particular the so-called *greco scritto* marbles, have been studied and their original sources have been redefined, either to the quarries near Ephesus, or those in North Africa (ANTONELLI *et al.* 2009; ATTANASIO *et al.* 2012; HERRMANN *et al.* 2012).

The perception of the use of grey materials in the Western Roman provinces is not comparable with the important role that they played in Rome or in other ancient locations related to the Aphrodisias workshops. However, in *Hispania*, grey marbles of different quality and features were extensively exploited and used for different purposes. In the majority of the Iberian marble districts, both white and coloured marbles were jointly extracted. But, it is clear that the workshops selected the materials according to their intended purpose. White marble was a preferable choice, not only for sculpture, as Pliny noted, but also for architectural elements using the polychrome types as part of the decorative programmes (FUSCO, MAÑAS 2006; NOGALES, GONÇALVES, LAPUENTE 2008; Taelman *et al.* 2013a). Most of these grey marbles could be classified, according to the traditional nomenclature, as *bigio antico*, as they vary from light to dark grey, almost black. But also the repertory includes marble banded in black and white or in patches which remind us of those of the *greco scritto* types. Here reference is made to grey and greyish banded marbles. Roman Lusitanian architectural ornamentation (columns, pavements and wall veneer slabs), funerary *stelae* and *arae*, *lapidae* and epigraphic elements are documented in different qualities of this material. Visigothic elements were also carved in white and grey veined marbles and in dark to very dark grey, many of them reused from Roman artefacts (VILLALÓN 2015).



Fig. 1a. One of the active quarries in the south of the EA district. b. Detail of the foliation developed on a grey marble outcrop

When grey marble pieces appear on an Iberian archaeological site, they are usually assigned to a local provenance if some supply quarry is relatively close. The problem arises when the location of the site is sufficiently far away from whatever area of regional supply, as imported materials were also brought into the Western provinces. It is in a case like this that archaeometric studies must distinguish local-regional or imported marble source.

In recent years, knowledge of the marbles used in antiquity in Hispania has made great progress, but much work still remains to be done. The situation regarding the use of each marble quarry is almost complete in some districts, while in others, several lithotypes are still waiting to be described and discriminated. With regards to the Lusitanian marbles of the EA, varieties of statuary quality have been defined, and their discrimination from other Hispanic marbles of wide use in other Roman provinces, such as the Almadén de la Plata marbles, has progressed thanks to the CL features. The updated analytical database of white marble has helped us better to recognize the white statuary marble of the EA used in artefacts found in *Augusta Emerita*, modern Mérida, the capital of Roman Lusitania. (LAPUENTE *et al.* 2014; NOGALES *et al.* 2015).

Once the updated database was put into implementation with relative success, the recognition of white statuary marble of the EA found in other Roman provinces advanced. Recently a white marble head (possibly of Tiberius) found in *Caesar Augusta* was identified as EA marble. This site located more than 700 km from the marble district of Estremoz and is currently the north-easternmost place from which this Portuguese material has been located (NOGALES *et al.* 2017; LAPUENTE *et al.* 2016).

In this context, this paper aims at highlighting the identifying characteristics of grey and banded marbles of

the EA, combining visual examination, spectrophotometry to quantify the greyscale tones, OM, CL and stable C and O. A wider study with additional Iberian grey varieties, is being carried out, in which archaeological samples are also being analysed to check the consistency of the analytic quarry marble database generated.

Geological setting

The EA is one of the Variscan macrostructures in the Ossa Morena Zone, a major geological unit of the Iberian Massif in the SW of *Hispania*. During the Hercynian orogeny, this Zone underwent a complex structural-metamorphic evolution, governed mainly by transpressional tectonics with progressive and continuous deformation associated with regional metamorphism, generally of low grade (greenschists) but high temperature-low pressure thermal domes developed locally.

The EA, located in the Alto Alentejo province of Portugal, is an elongated NW-SE geological structure approximately 40 km long by 5-7 km wide. The stratigraphic sequence of the EA structure consists of a Precambrian detrital basement, a Lower Cambrian “Estremoz Dolomitic Formation”, a Cambrian-Ordovician carbonate sequence referred to as the “Estremoz volcano-sedimentary carbonate Complex” (OLIVEIRA *et al.* 1991) and Silurian detrital deposits. According to CARVALHO *et al.* (2008), three main Variscan tectonic phases are usually distinguished. The D_1 episode produced isoclinal recumbent westward-verging folds with N-S oriented axes, schistosity with bedding transposition and low-grade regional metamorphism. With progressive deformation, the D_2 episode assigned to the Late Carboniferous age developed NW-SE trending fold axes and left-lateral shear zones, with discrete occurrence, showing deformation stages from ductile to brittle. Finally,

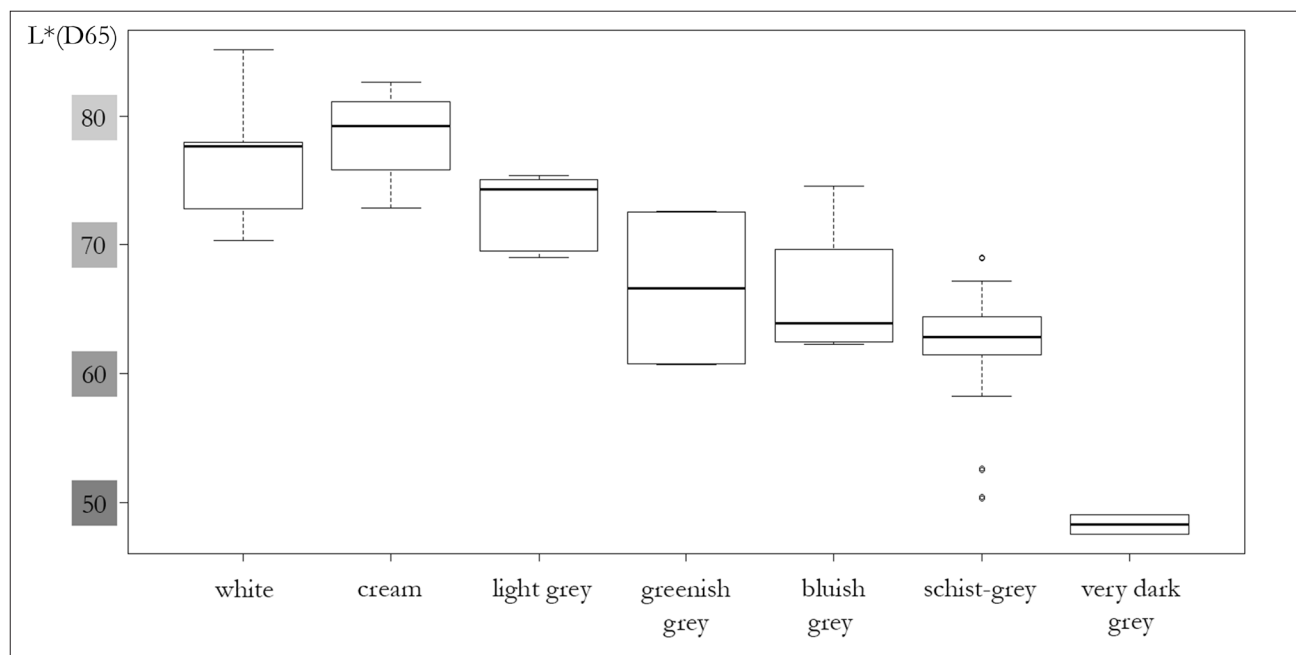


Fig. 2. Visual categories of grey (light, intermediate -greenish and bluish-, and dark to very dark grey according to the $L^*(65)$ parameter

during a late Variscan event, the EA was segmented by a network of NE-SW trending fractures, some associated with dolerite dikes.

The marbles form part of the Cambrian-Ordovician carbonate sequence whose age is still under discussion due to the lack of biostratigraphic and geochronological data. The metamorphic complex comprises a 300 m thick sequence of marbles and calc-schists with lenticular bodies of acid metavolcanites and metadolomites (CARVALHO *et al.* 2008; LAMBERTO, SÁ CAETANO, 2008). The light-coloured varieties, namely the white and cream coloured marbles, are found throughout the entire complex. The pink marbles, currently the most commercial materials, are associated with veined varieties inter-layered with green metavolcanic rocks (TAELMAN *et al.* 2013b). Grey and dark grey marbles occur either in continuous levels at the top of the sequence or as lenses in the light-coloured unit showing alternating bands in white and grey (Figs. 1a, 1b). The current 400 marble quarries are concentrated next to the locations of Estremoz, Vila Viçosa and Borba, and particularly in the South, close to Pardais. For this study, 25 grey marbles were collected preferentially in the southern half of the EA structure.

Macroscopic description: Colour measurements and patterns

One of the macroscopic features is the colour, which was measured using a MINOLTA CM-2600d portable spectrophotometer whose SpectraMagic NX 2.5 software obtains different parameters. The instrument provides a

direct display of CIE colour coordinates (X, Y, Z) along with CIELAB values (L^* , a^* and b^*). In addition, the Whiteness index (WI) was calculated according to both CIE 1982 and the norm E313-96. Each test specimen was prepared with a flat unpolished surface, at least 2cm thick, to avoid any rough irregularity, and on which three small circles were drawn for each visual colour category (white, cream, light grey, greenish grey, bluish grey, dark schistose-grey and very dark grey). Three automatic measurements were taken in each of the small circles, using a window of 3 mm diameter. Other standard specifications were the D65 illuminant, and the 10° observer. Both modes, the specular reflectance excluded (SCE) and included (SCI), were simultaneously measured. In the SCE mode, only the diffuse reflectance is measured, producing a colour evaluation that correlates with the way the observer sees the colour of the specimen. When using the SCI mode, both the specular and the diffuse reflectance are taken into account during the measurement process, whose evaluation provides the total appearance independent of surface conditions.

In Fig. 2, the visual categories of grey are shown attending the L^* parameter of Luminescence, which in most of the cases ranges from 60 to 75, excluding the very dark grey with values below 50. Light grey is well defined between 69 and 75. Intermediate grey tones (mostly in white/grey alternations) include some greenish grey ($60 < L^* < 73$), whose negative a^* -axis represents the green shares of the spectrum, and bluish grey ($62 < L^* < 75$), whose negative b^* -axis characterizes the blue portions. Many of the measured samples have a negative value of parameter b^* , especially the dark greys, which determines

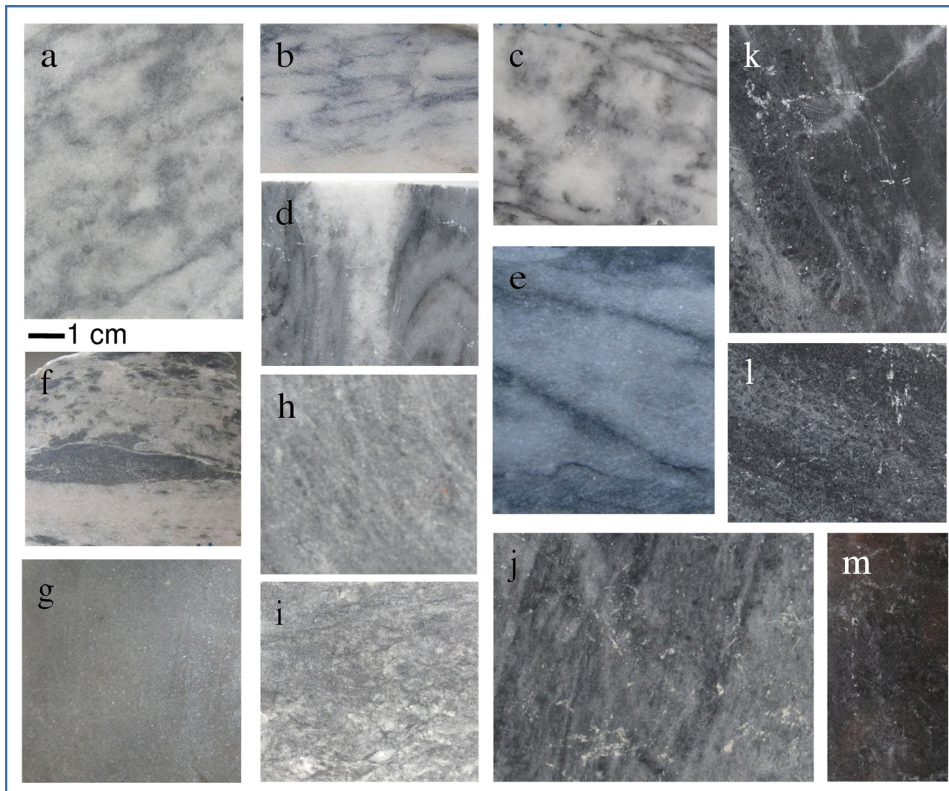


Fig. 3. Different patterns on grey and greyish banded marbles. All on the same scale

a bluish tone not always visually evident. The L^* measurements made in the schistose dark grey show a high range of values, the majority between 62 and 65, but with outliers at 50 and 69, due to the fine millimetre coloration, which is difficult to adjust to the size of the window. The L^* parameter is quite well associated with the WI (ranging from 23 to 62; with values below 10 for the very dark grey).

The defined grey categories are differently combined, giving a high diversity of patterns with several visual aspects (Fig. 3). Three are the most common: -1) a diverse combination of white and grey in bands or in veins (Figs. 3 a, b, c, d, e, f), which show different grey tones, as sheath microfolds in dark grey (Fig. 3d), or lenticular greenish grey (Fig. 3f). They may all sometimes show differences in the width of bands and streaks; -2) homogeneous light grey or spotted in white (Figs. 3 g, h, i); and -3) dark to very dark grey (Figs. 3 j, k, l, m).

Mineralogical-petrographical and CL features

Several analytical techniques (XRD, OM, CL) were applied to characterize the mineralogical-petrographical and CL features. Experimental procedures were carried out according the methodology described elsewhere (LAPUENTE *et al.* 2014). Taking into account that foliated marbles were used by Romans in two orientations, thin-sections were prepared taken from 2 or 3 different sub-perpendicular alignments. This is particularly useful for the white and grey layered, veined and

streaked samples, in which the foliation provides a different pattern with a white background crossed by spotted and irregular grey stripes, which in some cases could look like the so-called *greco scritto* marble.

XRD confirms calcite as the principal mineral in all the grey categories. Dolomite is present as an accessory mineral, always in aggregates of microcrystals. Quartz is relatively frequent, mono and polycrystalline, small granular but also in poikilitic and reabsorbed forms. K-feldspar, muscovite and chlorite are rare, while phlogopite appears quite often, especially in the greenish grey bands and occasionally in the dark grey samples, where graphite and Fe-bearing opaques are very common. One significant feature is the variation of the Maximum Grain Size (MGS) in the same sample depending on the thin-section orientation, which in many cases differs by 0.2-0.4 mm, though occasionally is in the order of 1 mm. However, the Most Frequent Size (MFS) is very fine in all samples, regardless of the orientation of the samples (Fig. 4). In most of the analyzed specimens, MGS is in the fine grain category (less than 2 mm long). When this parameter is in the coarse to very coarse grain, the texture is extremely heteroblastic, with a few isolated porphyroclasts in a very fine grain texture.

One of the most characteristic features of the EA marbles is the great variety of textures observed in the same thin-section. Depending on the orientation, the microstructural variation is even more evident, as Fig. 5 shows, where two sub-perpendicular thin-sections were taken from the same sample (on the left), or on the right,

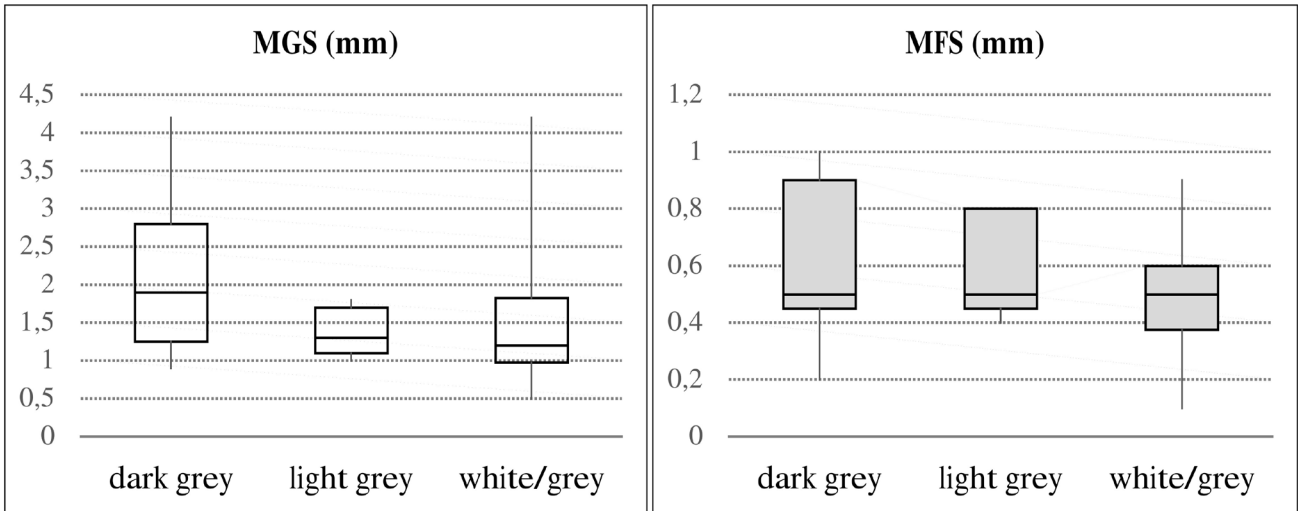


Fig. 4. Maximum grain size (MGS) and most frequent size (MFS) in the three categories of grey and greyish banded marbles from the EA, measured in 45 thin-sections. Quartiles and median are indicated in each box

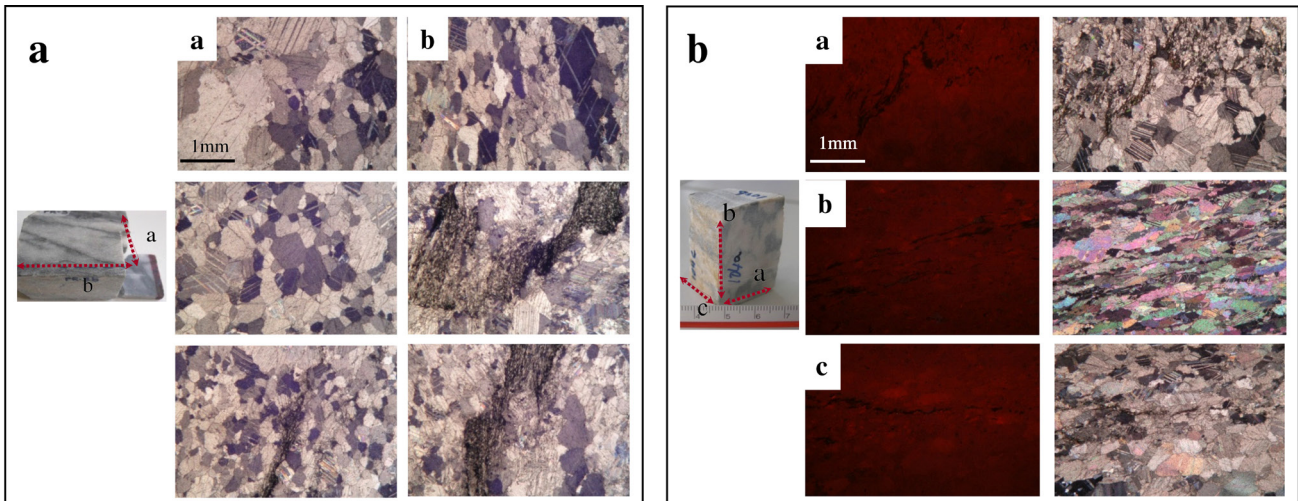


Fig. 5a. Three different microphotographs in each (a) and (b) thin sections of the same sample, where the variation is evident in texture (homeo/heteroblastic), fabric (iso-anisotropic), MGS and distribution of accessories. b. CL and petrographic microphotographs of three sub-perpendicular (a), (b) and (c) thin sections of the same sample

where both fabric and texture are quite different in view of three sub-perpendicular orientations. However, CL features are not affected by the thin-section orientation.

In the dark to very dark grey marbles (Figs. 6 a, b, c, d) it is common to find, in the same sample, a great variation of grain size combining zones with apparent isotropic and clearly anisotropic foliation. MGS ranges from 1 to 4.2 mm, but the MFS varies from 0/2 to 1 mm. (Fig. 4). High strained textures are frequent and signs of intracrystalline deformation are evident on the coarser grains of calcite (Fig. 6b). Lenticular and elongated aggregates of microdolomite with graphite are very common (Figs. 6a, 6d), but the carbonaceous matter is also dispersed in the dark grey type. Quartz, mono and polycrystalline, are frequent, especially in association with

small white patches and very small white veins (Fig. 6c). Regarding CL, very dark grey marbles show medium luminescence in reddish orange calcite, which occasionally exhibits an intracrystalline zoned CL of stronger intensity, with dispersed microdolomite, as shown in Fig. 6 d but also very faint to faint intensities are possible.

In the spotted light grey varieties (Figs. 6 e, f), microdolomite is dispersed (Fig. 6e), while the homogeneous light grey shows higher uniform CL intensity (Fig. 6f). Both subtypes of light grey are quite homeoblastic, as shown in Fig. 4 where the median of the MGS is 1.25 mm and the MFS is below 0.8 mm, with a median of 0.5 mm.

With the white and grey banded marbles (Figs. 6 g, h, i, j), two types have been distinguished; one is homeoblastic and extremely fine grained, with a heterogeneous

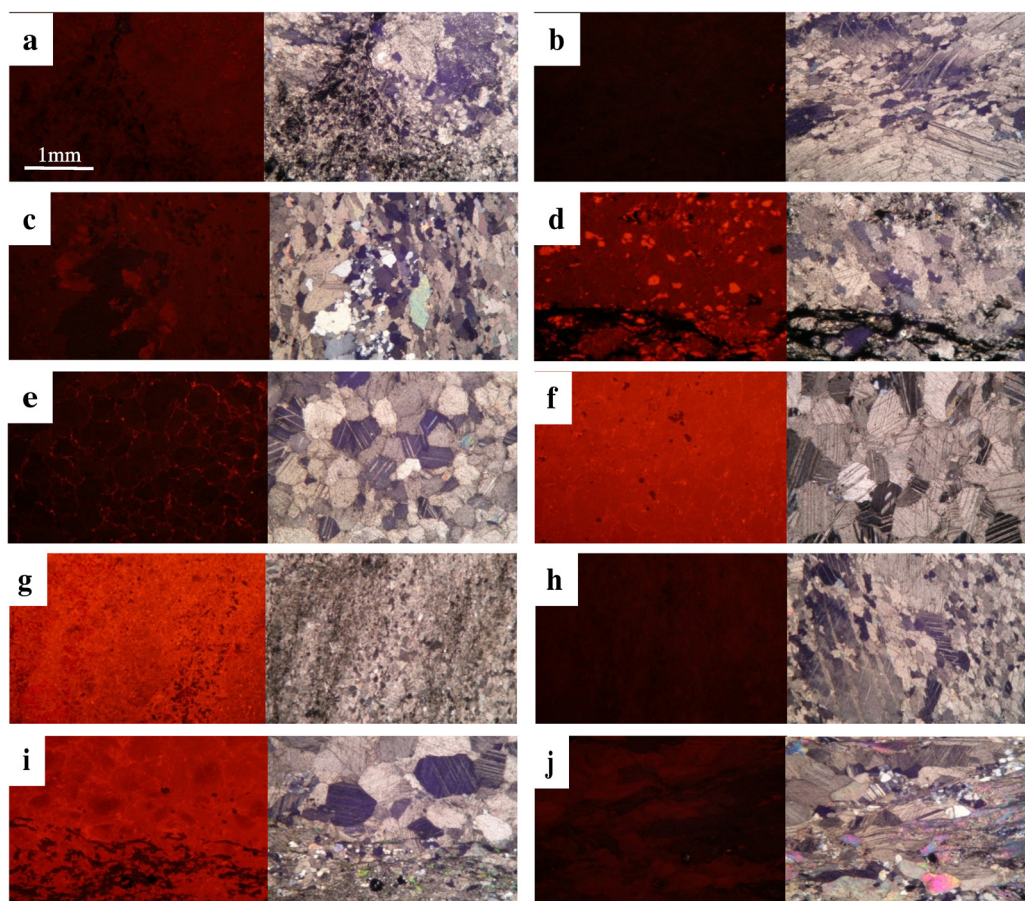


Fig. 6. Selection of CL images and photomicrographs in crossed polarized light. Dark to very dark grey samples (a, b, c, d); light grey samples (e, f); white / grey samples (g, h); white / greenish grey samples (i, j)

distribution of CL in medium-high to high intensities (Fig. 6g), and a second heteroblastic with MGS ranging from fine to medium-coarse grained, in faint CL intensity (Fig. 6h). When the grey bands are schistose-greenish grey in white, phlogopite in lepidoblastic texture is developed and another two varieties have been differentiated. In the first, schistosity is defined by an alignment of platy small flakes (Fig. 6i) and in the second, by bands of massive phlogopite (Fig. 6j). CL shows heterogeneous distribution with medium to moderately strong intensities with intracrystalline zoning in the first, and faint intensity CL in the second.

Isotopic signature

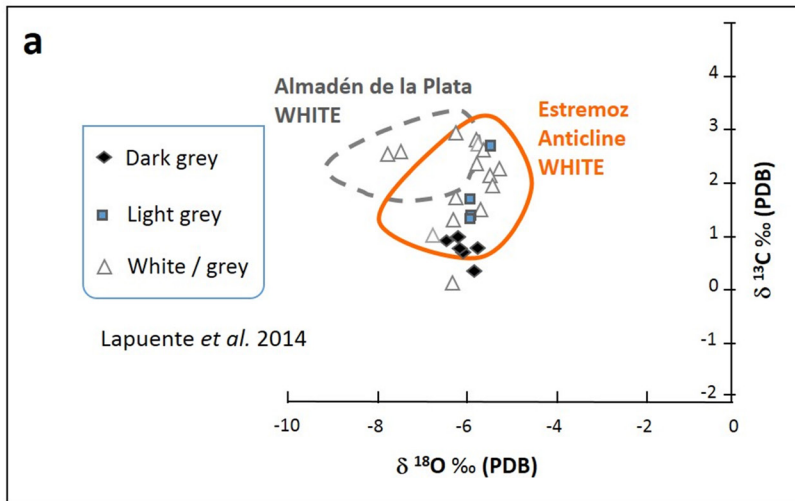
Oxygen and carbon isotopes were determined by isotope ratio mass spectrometry with Finnigan MAT 252 equipment following the standard procedures. The $d^{18}\text{O}$ and $d^{13}\text{C}$ (PDB) values are shown in Fig. 7 grouped by each lithotype. Most of them fall inside the EA isotopic field defined for the white marbles (LAPUENTE *et al.* 2014). Only 4 samples out of 25 are plotted outside. The isotopic $d^{18}\text{O}$ value is quite uniform, ranging mostly from -5.3 to -6.8‰, with two samples of lower values (close to -8‰). However, $d^{13}\text{C}$ varies from 0.3 to 3‰. The white and grey banded samples show a wide range

of $d\text{C}$ values and several samples from Pardais overlap the isotopic signature defined for the white marbles of Almadén de la Plata (AP) (Fig. 7a). Comparing the isotopic data with those from various Mediterranean sources of veined, streaked or banded, white and grey marbles, including the typical *greco scritto* from different authors (ANTONELLI *et al.* 2015, with data by ANTONELLI *et al.* 2009, 2010; ATTANASIO *et al.* 2012; HERRMANN *et al.* 2012), they fall into an area of the isotopic diagram with an extensive overlap (Fig. 7b). Therefore, the isotopes should be used in combination with other petrographic and CL parameters.

Conclusions

The differences in physical and/or compositional features of marbles collected at each quarry in the southern half of the EA district are minimal and depend largely on the specific collection of samples taken. The intra-quarry variation of features ranges from the macro to microscale. Moreover, the petrographic and CL variability found in samples from each quarry makes it difficult to highlight the marble fingerprints of each quarry. Consequently, instead of specifying characteristics of a single quarry, it is more reasonable to consider all the quarries of the EA district as one unique reference group.

With respect to Iberian white marbles



With respect to the classical white / grey streaked / spotted

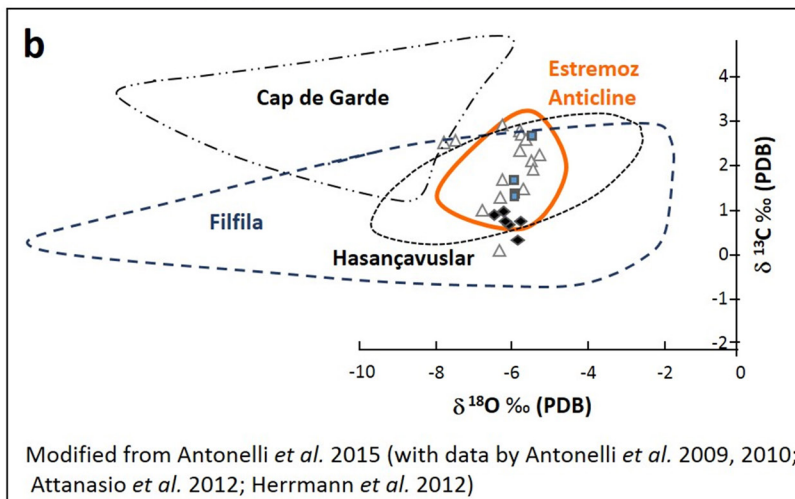


Fig. 7. Isotopic diagrams of the grey and greyish banded marbles from the Lusitanian EA district

Different lithotypes have been distinguished from the grey marbles of the EA according to the visual aspect, color, mineralogy, MGS, MFS, microstructure-texture and CL features along with the C and O isotopes. Regarding the visual appearance, three main varieties have been characterized, with subsequent subcategories:

Dark to very dark grey types ($L^* < 50$): Macroscopically homogeneous, spotted or with small veins, in white. MGS ranges from fine to very coarse grain, but mostly below 2 mm; however MFS is very fine to fine grain size, below 1 mm.

Light grey types ($69 < L^* < 75$): homogeneous or spotted in bluish dark grey, MGS ranges from 1 to 1,8 mm, while MFS is between 0,4 to 0,8 mm.

White/grey (intermediate tones, $60 < L^* < 74$) with a great diversity of patterns, either centimetric to millimetric bands in bluish grey, or in veins, spotted, sheath microfolds in dark bluish grey; or in schistose bands in greenish grey. MGS are in the fine grained range, some even in the very fine.

Petrographic features (microstructure-texture) are determined by the thin-section orientation. Signs of intracrystalline deformation are very common with occasional isotropic mosaic zones.

CL intensity varies from very faint to faint-medium intensity, but certain very fine grained samples in white/grey exhibit strong luminescence. The CL distribution is quite often homogeneous, but heterogeneous, patched and frequent zoned calcite is observed in areas of the same sample.

The isotopic signature of the grey and greyish EA marbles is quite uniform in the $d^{18}O$ value, but not in the $d^{13}C$ data. Altogether, almost all isotopic values are projected within the updated white EA isotopic field defined in LAPUENTE *et al.* 2014. Finally, extensive overlap exists with the isotopic values of the Mediterranean sources of white/grey marbles.

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