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Minero-petrographic approaches for epigraphy: some public inscriptions from Hellenistic Syracuse

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Abstract

The present contribution aims at exploring the potentialities of incorporating a detailed minero-petrographic methodology into the study of ancient Sicilian inscriptions. More specifically, a set of three public inscriptions dated to the III c. BCE from Syracuse were tested with a fully non-invasive archaeometrical approach, and the results compared with the literature describing their materiality. This confirmed on an analytical basis that the rock used for two monumental pieces, ISic000823 and ISic003331, comes from Taormina, while for the third one, ISic000827, it was possible to correct a series of misunderstandings as to its possibly exotic origin. Nevertheless, its provenance is still unclear and will require a laboratory-based approach. The geological results are in agreement with the historical sources, regarding both the extent of the kingdom and contemporary stone quarrying.

Keywords: archaeometry, provenance of raw materials, Taormina limestone, Taormina marble

Introduction

The study presented here is part of the European ERC project CROSSREADS "Text, materiality and multiculturalism at the crossroads of the ancient Mediterranean" (2020-2026)[1]. The project is directed by Prof. Jonathan Prag of the Faculty of Classics of the University of Oxford (UK), in partnership with the Earth Sciences Section (Department of Biological, Geological and Environmental Sciences) of the University of Catania and the King's Digital lab of King's College London, with the support of the Sicilian Region. The project aims to investigate the epigraphic heritage of ancient Sicily by applying a multi-disciplinary approach, combining traditional epigraphic and historical study with systematic analysis of linguistics, palaeography and petrography. The work is underpinned by the digitization of the inscriptions of ancient Sicily within the I.Sicily

[1] This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 885040).

project, online since 2017 and directed by Prof. J. Prag[2]. A new interface is currently under construction in collaboration with King's College London, intended to make the data acquired during the Crossreads project more fully accessible.

The activities of the I.Sicily and Crossreads projects require close collaboration with the museums and superintendencies of the Sicilian Region, where the field research is carried out: this collaboration has been underpinned since 2022 by a formal convention with the Assessorato dei beni culturali e dell'identità siciliana. The epigraphic collection preserved at the Regional Archaeological Museum "Paolo Orsi" is undoubtedly the most substantial in Sicily, and a formal collaboration between the University of Oxford and the Parco archeologico e paesaggistico di Siracusa, Eloro, Villa del Tellaro e Akrai (and its predecessors) has been in place since 2014 (last renewed in 2025), with work having begun in 2006. Study of the epigraphic collection has been continuously facilitated by the availability and support of the museum staff, presently coordinated by Dr. Lanteri and with the continuous and irreplaceable presence of Dr. Manenti from the first work in 2006.

Petrographic analysis involves the characterization of the stone supports of the inscriptions in order to identify the origin of the lithotypes used, whether local (Sicilian) or imported from across the Mediterranean, as in the case of true marbles. In epigraphy, it is precisely the durability of the stone support that allows the preservation and reading of the text written on it, hundreds or thousands of years later: an advantage for historians and archaeologists, but also a fundamental motivation in its original choice by those commissioning the original monument[3]. While this monumental aspect has been an increasing focus of historical research, the stone support itself, can reveal a great deal also. Correct identification can contribute to our knowledge of the materials available in a particular place and time, and in turn to our understanding of trade routes, of the preferences of the client and his/her economic possibilities, of the presence of craftsmen, transfer of knowledge, and much else[4]. Nonetheless, in-depth study of the materials and their provenance has so far been largely ignored in epigraphic research, while the application of archaeometric methods in the ongoing research on the architectural and sculptural heritage of ancient Sicily, although limited, has already allowed further steps forward in the understanding of the commercial and cultural connections at the centre of the Mediterranean[5]. It is one of the aims of this part of the Crossreads project to integrate epigraphic research into this growing awareness of the

[2] For an overview, see PRAG 2021. I.Sicily is online at http://sicily.classics.ox.ac.uk/.
[3] See e.g. ECK, FUNKE 2014, SEARS, KEEGAN, LAURENCE 2013, WOOLF 1996.
[4] See e.g. RUSSELL 2013 on the Roman stone trade, TAELMAN 2022 on marble distribution and selective use.
[5] See for example BASILE, LAZZARINI 2012 and LAZZARINI, MARCONI 2021.

importance of materials analysis, and to contribute to the development of data for such study in ancient Sicily and the wider ancient Mediterranean.

One reason for the lack of attention to such approaches in epigraphic studies is that it requires specialist knowledge and specialist techniques. The correct description of rocks requires the application of geological methodologies and knowledge. But these stone objects are also unique cultural heritage objects whose understanding must be enhanced, through scientific research, but whose integrity must be preserved, as prescribed in the Italian legislation[6]. The archaeometric approach adopted within Crossreads takes these two needs into account and combines on the one hand a systematic acquisition of data in a completely non-invasive way, and on the other the collection of micro-samples for a detailed characterization, in the laboratory. In this paper we therefore aim at an interdisciplinary approach that combines preliminary geological investigations with the historical evidence, to provide new data and interpretations on key examples of Sicilian epigraphy. Further interdisciplinary discussion within a fully integrated study of language, palaeography and epigraphic practice is forthcoming.

The inscriptions and their stone supports

The three inscriptions presented here can legitimately be considered a coherent group, and are commonly associated in the modern literature. All three stones were found in the area of central Syracuse, and each carries a Greek inscription. Two of the three are large stone statue bases, honouring respectively Hieron II, king of Syracuse between c.269 and 215 BCE, and his son, Gelon, co-regent between c.241 BCE and 216 BCE. The third is a fragment of a stone stele, recording at least one public text, generally attributed to the reign of Hieron II. All three stones are currently held in the Regional Archaeological Museum "Paolo Orsi" in Syracuse, with only the third being on display.

ISic000823 (inv. 6489), is a large quadrangular stone base (H = 49 cm; W = 99 cm; D = 84 cm) preserving parts of two footholes for a statue on the upper surface[7]. The stone is damaged upper front right and upper rear left, with loss of the end of line one of the text,

[6] See: Codice dei beni culturali e del paesaggio (Decreto Legislativo 22 Gennaio 2004, n. 42), regulating both "Tutela" in Titolo I (which includes « Protezione e conservazione », artt. 20-28) and « Fruizione e valorizzazione » (Titolo II). In the same Decreto, Articles 118 and 119 regulate research and outreach activities, respectively.

[7] See http://sicily.classics.ox.ac.uk/inscription/ISic000823 for full edition and further bibliography.

which runs for three lines across the upper half of the front face (letters of 40-48 mm height). The stone was found in 1734 in the area of Achradina, likely in the vicinity of the ancient agora or the temple of Zeus Olympios built by Hieron II. The text records a dedication in honour of King Hieron son of Hierokles, by the Syracusans. The exact date of creation cannot be fixed, but it is usually placed near the start of Hieron II's rule (usually placed in 269 BCE, following Polybius' claim (*Histories* 7.8.2) that Hieron reigned as king for 54 years). Formally, the date could be anywhere between 269 and his death in 215 (Livy, *Histories* 24.4).

ISic003331 (inv.16109) is a large quadrangular block (H = 24 cm; W = 96 cm; D = 65 cm), smooth on all sides but rough below and broken to the rear[8]. There is some damage to the top left corner, the rear right corner, and across the rear of the block. At a later date, the lower part of the front face has been roughly cut away, across the third line of text, leaving only the tops of the letters visible, and the upper front edge has suffered from abrasion and chipping resulting in some loss of letters (26-33 mm high). Clamp holes are visible on the upper side edges, indicating the block was part of a larger monument, most likely a base for the dedication, most likely a statue. The block was found in late 1895 on the island of Ortygia, close to the entrance from the mainland. The text records a dedication by the people of Syracuse in honour of King Gelon, son of Hieron. Gelon's co-regency is not securely dated, but usually thought to begin between 241 BCE and 227 BC (based on Polybius, *Histories* 5.88); Gelon died in late 216 / early 215. Consequently, the inscription probably dates between c.241 and 215 BCE.

ISic000827 (inv. 4) is a fragment of a stone slab, broken on all sides, rough and uneven behind (H = 13 cm; W = 42 cm; D = 8 cm)[9]. The front face preserves parts of two columns of text with a blank space of variable width (>2 cm) in between, and letters of 8-9 mm. The stone was found in 1749 in the lower part of Achradina and so presumably in the vicinity of the ancient agora (similarly to ISic000823). The text contains part of an oath sworn by the council and other institutions of the Syracusans (although formally that attribution is a restoration), as well as part of what is probably a letter, which makes reference to kings. This combination, together with the palaeography of the inscription, has led almost all scholars to attribute the text to the reign of Hieron.

All three, therefore, are monumental public texts from the reign of Hieron II, a long-lived monarch, who maintained a rich and prosperous Hellenistic kingdom in eastern Sicily, centred on Syracuse, allied to the rising power of the Roman Republic and with relationships across the Mediterranean (e.g. with the island state of Rhodes and the

[8] See http://sicily.classics.ox.ac.uk/inscription/ISic003331 for full edition and further bibliography.
[9] See http://sicily.classics.ox.ac.uk/inscription/ISic000827 for full edition and further bibliography.

Ptolemaic kingdom in Egypt)[10]. ISic000827 and ISic003331, with the exception of the texts inscribed across the *cunea* of the stone theatre in Syracuse, are the only certainly attributable public inscriptions of Hieron's reign[11]. Consequently, they offer a privileged opportunity to explore the nature of public display and commemoration in the Hellenistic kingdom of Syracuse and, in this specific case, the choices involved in the commissioning and creation of significant public monuments, apparently placed in the heart of the ancient city.

Their materiality has been described and noted since their first recording in the museum inventory, but no proper geological study seems to have been performed. In the following, the literature discussing the selected inscriptions is summarized only as far as the rock identification is concerned. This allows us to identify some challenging aspects of dealing with geomaterials in museum collections and in epigraphic research, and to emphasize the need for interdisciplinary research including geology in epigraphy.

ISic000823 is described first as « marmo compatto di Taormina » (i.e. compact marble from Taormina)[12] and then « marmo » *tout court* in the inventory compiled by Cavallari, the former identification repeated by Orsi in 1896. Libertini describes it as « pietra scura » (i.e. dark stone) in 1929[13]. Dimartino first uses « marmo » (i.e. marble) in 2006 and then « marmo o calcare » (i.e. marble or limestone) in 2017[14]. In the same year, Prag suggests a revision of Dimartino's conclusions, as they were unfortunately not supported by autopsy[15].

ISic003331 is also described as « pietra di Taormina » (i.e. stone from Taormina) in the museum inventory (compiled by Orsi), and likewise in Orsi's publication in 1896[16]. Libertini agrees with Orsi on the provenance of the stone, but instead of « pietra » uses « marmo » as a synonym[17]. In 2006, Dimartino describes the object as « base marmorea » (i.e. marble base), but then changes it in 2017 to the more generic « calcare » (i.e.

[10] On Hieron II's kingdom see now WALTHALL 2024.
[11] For an initial overview of Hieronian inscriptions, see DIMARTINO 2006.
[12] In the inventory volume compiled by Cavallari, recording acquisition in 1888; cf. ORSI 1896, p.22, where he describes ISic003331 as « un masso di pietra di Taormina » (i.e. a block of Taormina stone), and then notes that ISic000823 « ha comune anche il genere della pietra » (i.e. has in common the type of stone). Earlier antiquarian records such as Capodieci 1813, vol. 1, p.119, through to Kaibel in *IG* XIV.2, if they record the material at all, simply refer to « marmo » or « marmor ».
[13] LIBERTINI 1929, p.123.
[14] DIMARTINO 2006, p.703; DIMARTINO 2017a, p.241.
[15] PRAG 2017, p.121, note 9. I.Sicily (last visited on 30/05/2025) adopts « limestone (area of Taormina?) » as the physical description for this stone.
[16] ORSI 1896, p.22.
[17] LIBERTINI 1929, p.121.

limestone)[18]. Furthermore, Dimartino adds the adjective « locale » (i.e. local) [19], suggesting some sort of geographical proximity between Syracuse and the quarries that produced this block. Walthall refers to ISic003331 as an « inscribed marble base »[20], apparently preferring the more prestigious material over the possibility of one quarried in Taormina, and referred to by the early scholars[21].

ISic000827 is described in the inventory compiled by Sogliano in 1885 as a « marmo bigio oscuro » (i.e. dark grey marble), and then « marmo bigio » (i.e. grey marble)[22]. Capodieci in 1813 defines it as « marmo » and « marmo irregolare » (i.e. marble and marble of irregular form, respectively)[23]. Libertini, similarly to his description of ISic000823, uses « pietra nera » (i.e. black stone)[24]. Manganaro in 1965 describes it as « marmo grigio » (i.e. grey marble)[25], but in 2005 changes his opinion, proposing « pietra scura, forse granito » (i.e. dark stone, maybe granite) as an alternative to his original « marmo grigio » identification[26]. None of these identifications, however, is supported by proper geological autopsy. Nevertheless, a straightforward link with economic history is proposed, albeit with reference to the Roman imperial period, highlighting the Mons Claudianus quarries[27]. Manganaro furthermore comments on the unusual material, preferring Egypt to Greece as the provenance for the block. He has however no reasonable hypothesis on the reasons for this choice by the Syracusans[28]. After this claim was published in 2005,

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[18] Dimartino 2006, p.705, Dimartino 2017b, p.175.
[19] Dimartino 2017b, p.177. Taormina is approximately 90 km (ca. 55 miles) as the crow flies from Syracuse.
[20] Walthall 2024, p.67.
[21] Orsi 1896, p. 22 and Libertini 1929, p.121; as well as the original museum catalogue.
[22] For comparison, inv. 5 (ISic003390) from Athens, which is a grey crystalline marble,is described in the inventory as « base marmorea » i.e. marble base
[23] Capodieci 1813, p.178 (other early editions make no reference at all to the stone type).
[24] Libertini 1929, p.120.
[25] Manganaro 1965, p.316.
[26] Manganaro 2005, p.141: « pietra scura, forse granito, ma non posso stabilirne il genere, se di Egitto o greco » (i.e. dark stone, maybe granite, but I cannot assess the type, whether from Egypt or Greece). In note 2 on the same page, he wishes for confirmation from expert friends (« attendo l'autopsia degli amici ») either Prof. L. Lazzarini (a geologist) or Prof. Patrizio Pensabene (an archaeologist) in the identification of the stone based on autopsy.
[27] Manganaro 2005, p.141, note 2: « vedi, ma per l'epoca imperiale, le notazioni interessanti di P. Pensabene, Le cave del Mons Claudianus: conduzione statale, appalti e distribuzione, JRA 12, 1999, pp. 721-736: segnalazione del Prof. Tomasello » (i.e. see, but for the imperial epoch, the interesting observations by P. Pensabene, as pointed out by Prof. Tomasello). The so-called « granito del foro », coming from Mons Claudianus, in Gebel Fatireh in Egypt is a granitoid rock, mostly composed of quartz and plagioclase, see for example Antonelli, Lazzarini, Cancelliere 2010.
[28] Manganaro 2005, p.150: « Nessuno si è posto il problema delle possibili ragioni, che abbiano potuto indurre i Siracusani a scegliere per la stele, su cui fecero incidere il testo della epistola di Gerone II, una pietra grigio-scura (probabilmente granito dell'Egitto), piuttosto insolita per la epigrafia greca. » (i.e. nobody has questioned the reasons for Syracusans to pick, for this stele on which they had carved the letter of Hieron II, a dark grey rock (probably granite from Egypt), quite unusual for Greek epigraphy).

ISic000827 has been alternatively described as « marmo grigio » (i.e grey marble)[29], « pietra calcarea di colore grigio » (i.e. grey limestone)[30] or « granite »[31]. Although Walthall correctly states that Manganaro « speculates »[32], he simply adopts the exotic origin for the support. The stele ISic000827 has frequently been described as a 'marble', but, like the other two, is not really a marble.

In the earlier publications, the two bases are described alternatively as '*marmo*' or '*pietra*', but consistently as coming from Taormina. Part of the problem is that multiple common names exist for specific rocks in the trade and in the building practice. In Italian the distinction should be clear (although this is not always reflected in non-specialist literature), and in the study of commodities is defined as follows: 'marmo' is a polishable rock, while 'pietra' is a rock which can be made smooth but not polished[33]. On the other hand, in geology, marble (true marble) is a metamorphic rock composed of at least 95% calcite or dolomite, resulting from the metamorphism of a carbonate sedimentary rock. The most visible effect of metamorphism is the saccharoidal texture of the marble, recognizable to the naked eye. All the examples of geological, crystalline marbles that are present in Sicily in Archaic and Hellenistic times have been imported from the Eastern Mediterranean (Turkey, Greek islands and mainland)[34]. As a matter of fact, there is no exploitable true marble in Sicily[35], while there are many polishable rocks, commonly known as 'marbles'. Long-distance trade connections are therefore demonstrated by marble artifacts in Sicily[36]. Describing a rock as a marble, without further details on the specific meaning of this word, can therefore be misleading as this implies material choices and trade connections without any correspondence to the historical knowledge and archaeological evidence.

As noted, building-stone traders in fact use a different terminology, where 'marble' applies to hard, polishable rocks, including true marbles, but also extending to limestones and igneous rocks. Sicily offers a wide variety of decorative stones in this

[29] DIMARTINO 2006, p.707.
[30] DIMARTINO 2015, p.39.
[31] WALTHALL 2024, p.82: « heavily damaged gray granite block ».
[32] WALTHALL 2024, p.104, note 1: « The dark-colored granite stone used for the inscription is unlike anything quarried on Sicily; Manganaro (2005: 141) speculates the stone may have come from a quarry in Egypt or Greece. »
[33] Even though traditional names for construction and decoration rocks are still used and accepted, 'pietra' (stone) is not a geological term, and should not be used as a synonym for 'roccia' (rock), which is the geologically correct word for any natural assemblage of minerals constituting the Earth's crust.
[34] Carrara marble, or Lunense, did not become a commodity across the Mediterranean until after the 1st c. BC, see COLI, CRISCUOLO 2021.
[35] Except for a few and very small outcrops in Mt. Peloritani in North-Eastern Sicily, see CARBONE, MESSINA, LENTINI 2007, whose exploitation has never been recorded.
[36] E.g. BASILE, LAZZARINI 2012; LAZZARINI, MARCONI 2021.

broader category[37]. Limestones are sedimentary rocks composed of carbonatic minerals, such as calcite, aragonite and/or dolomite. The limestones and true marbles share a common carbonatic composition, but with completely different genetic processes, while igneous rocks are commonly mostly silicatic.

Granite, on the other hand, is an intrusive igneous rock. In similar fashion to the word 'marble', 'granite' has a specific meaning in geology, but is widely applied to identify granitoid rocks, mainly composed of quartz, plagioclase and alkali feldspar. The abovementioned Marmor Claudianum (granite from Egypt) has a granodiorite to tonalite composition, and is not a true granite, containing more plagioclase than alkali feldspar[38].

The overlap in terminology used across different fields, as highlighted above, should carefully be considered, especially in interdisciplinary studies such as those involving archaeometry and, in this case, applied geosciences, in order to minimise misunderstandings and ensure fruitful discussions.

In the archaeometrical panorama, it appears that provenance studies on epigraphic supports are not common, in contrast with work on architectural and sculptural elements, especially if made of true marble, and much of the focus is on the Roman period[39]. The observations by Manganaro on the possible significance of an exotic rock such as granite being employed as an epigraphic support for ISic000827[40] could have paved the way for interdisciplinary research and pioneering results in this field. However, there has been no attempt at a rigorous scientific approach in this sense, and the speculative identification is scarcely supported by the historical evidence. A proper geological approach, with the deployment of an appropriate analytical approach, expertise and comparison with relevant references and the use of precise terminology minimising misunderstandings, on the other hand, is very likely either to clarify the existing trade connections, as attested by the historical sources, or to highlight new ones which could be absent from them.

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[37] See BELLANCA 1969, p.7: « Gli antichi davano indistintamente il nome di marmo a tutte le rocce dure suscettibili di acquistare un bel lucido col pulimento sia che esse fossero rocce silicate o rocce calcaree. [...] In senso commerciale, però, il nome marmo ha conservato il vecchio significato [...] » (i.e. the ancients indiscriminately gave the name of marble to all hard rocks susceptible to acquiring a nice shine with polishing, whether they were silicate rocks or calcareous rocks. [...] In a commercial sense, however, the name marble has retained its old meaning). Notably, the title of the book by Bellanca is « Marmi di Sicilia ».

[38] ANTONELLI, LAZZARINI, CANCELLIERE 2010. The paper also highlights a remarkable similarity with granitoids from Nicotera, Calabria, which were also quarried between the 1st and 4th c. AD.

[39] For example, DODGE 1988 and DODGE 1991 for the diffusion of true marbles and decorative stones across the Mediterranean (the lack of data on Sicily is notable), and TAELMAN 2022 for an extensive survey of analytically provenanced true marbles in the Roman Mediterranean. As far as the authors are aware, no such extensive studies exist for pre-Roman times.

[40] MANGANARO 2005, p.150.

In the following we describe a fully non-invasive analytical methodology applied to the three epigraphic supports belonging to the collections of the Regional Archaeological Museum "Paolo Orsi" in Siracusa, highlighting both the potentialities and limitations of such a non-conventional minero-petrographic approach to Cultural Heritage objects.

Methodological approach

Traditionally, minero-petrographic approaches require minimally invasive sampling, i.e. the removal of a fragment of the support, in order to perform laboratory analyses. These are, in principle, non-destructive, meaning that the sample brought to the laboratory is preserved and not destroyed during the analysis. Typically, a portion of the sample is prepared as a thin section, allowing for the identification of the minerals constituting the rock and their arrangement through a petrographic optical microscope (OM), while another portion is powdered and subjected to X-ray diffractometry (XRD), which reveals the mineralogical phases and their proportions. Both the thin section and powder are preserved and can be re-analysed as needed.

In the framework of the Crossreads project, as the objects under investigation belong to Cultural Heritage and invasive sampling cannot be assumed, an innovative approach is proposed. This is based on a systematic fully non-invasive approach using a digital microscope (DM), to observe the fabric of rocks in detail without removing a sample, and portable X-ray fluorescence (pXRF) spectrometry, for the chemical characterization of the rocks directly in the museum or storage room. Although advantageous in terms of preservation of the objects and speed of data acquisition, some drawbacks should be highlighted for pXRF, particularly the impossibility of obtaining data on the mineralogical composition of rocks, and especially the lack of data on low-Z elements and their minerals, such as some rock-constituting silicates and dolomite. Furthermore, Sicilian rock references have rarely been characterized through this type of fully non-invasive approach, meaning that there is a lack of suitable reference data: the minero-petrographic characterization of epigraphic supports within the Crossreads project also aims to meet this specific need, with geological and archaeological samples becoming internal references for cross comparisons.

An additional step is the comparison with rock references and the geological maps of Sicily, and with the well-established literature on the decorative and building stones which were traded across the Mediterranean in Antiquity. Even though Greek marble

reached Sicily in Archaic and Hellenistic times[41], the Mediterranean trade in rocks increased in both volume and variety with the Romans, who pursued access to exotic lithotypes, previously unknown beyond a regional scale[42]. Hence, in parallel with the geological maps, the relevant historical sources on quarries and trade should be considered in the interdisciplinary work[43].

A digital microscope DinoLite model AM7915MZTL with polarizer was used at magnifications of ca. 35 and 70× directly on the inscribed blocks, recording images on multiple areas to document the rocks' variablity. A portable X-ray fluorescence (pXRF) spectrometer Bruker Tracer IV-SD was used to analyse the chemical composition of the rocks. A dedicated set of standards was used to correct the obtained spectral data into semi-quantitative compositions.

Some reference materials in the collections of the Museo di Mineralogia, Petrografia e Vulcanologia of the University of Catania were considered for comparison.

Results

Under microscope observation, ISic000823 (Fig. 1) and ISic003331 (Fig. 2) have very similar petrographic features.

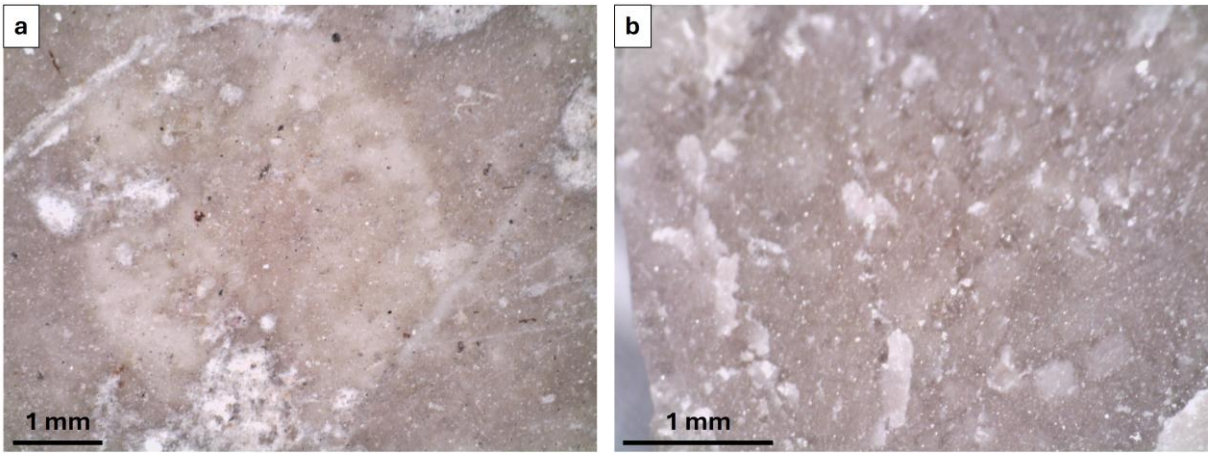

Fig. 1: Dinolite images of different surface areas of ISic000823: a) a rounded whitish structure is visible in the pinkish groundmass, with whitish calcitic veins and surface alteration; b) a crystalline portion of pinkish-grey colour without visible structures and a grainy appearance, crossed by very fine grey-looking veins.

[41] See BASILE, LAZZARINI 2012 and LAZZARINI, MARCONI 2021.
[42] See for example DODGE 1988 and RUSSELL 2013, pp. 9-18.
[43] Although extensive and comprehensive, DODGE 1988, DODGE 1991 and RUSSELL 2013 all refer to a much later timeframe.

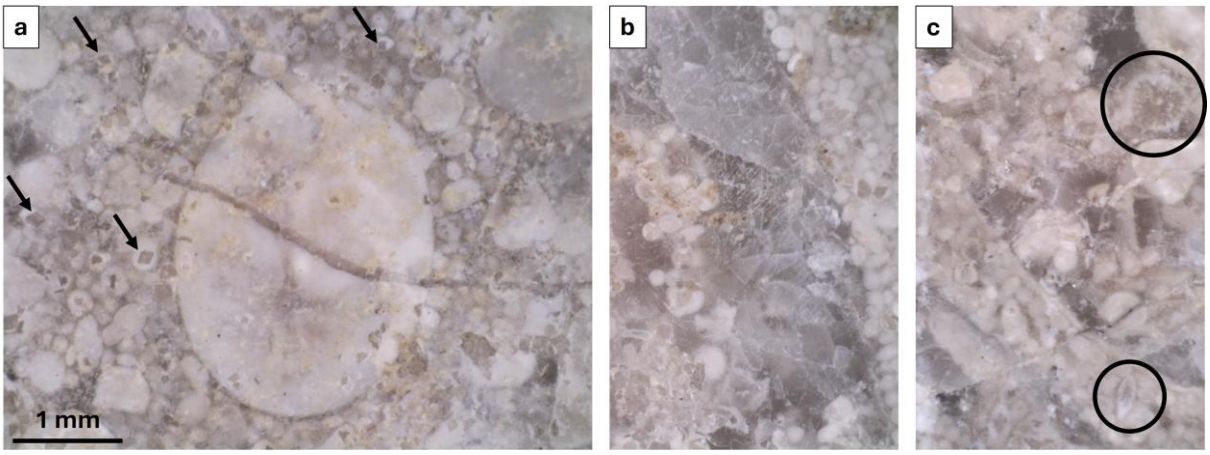

Fig. 2: Dinolite images of different surface areas of ISic003331: a) rounded structures are visible in the picture, including a large one crossed by a calcitic vein (the arrows indicate dolomite crystals); b) detail of a calcite vein with grey polygonal crystals; c) detail of microorganisms.

The large size of the blocks allows identification of a variety of recurring features, such as: a slightly pinkish undertone to the grey colour (Figs. 1 and 2), homogeneous crystalline areas (Fig. 1b), whitish and translucent veins of varying thickness (from less than 1 mm in Fig. 1b, to a few mm in Fig. 2b, in the latter case they appear grey and with large polygonal crystals), round and oval whitish structures similar to peloids or oolites, up to ca. 10 mm, sometimes isolated in the background (Fig. 1a), sometimes densely packed (Fig. 2a and 2b). These whitish rounded structures sometimes show, with the highest magnification and in areas with high polish and no surface alterations, dolomite crystals characterised by more or less regular diamond shapes and slightly darker colour (Fig. 2a). Finally, microorganisms are sometimes visible (Fig. 2c).

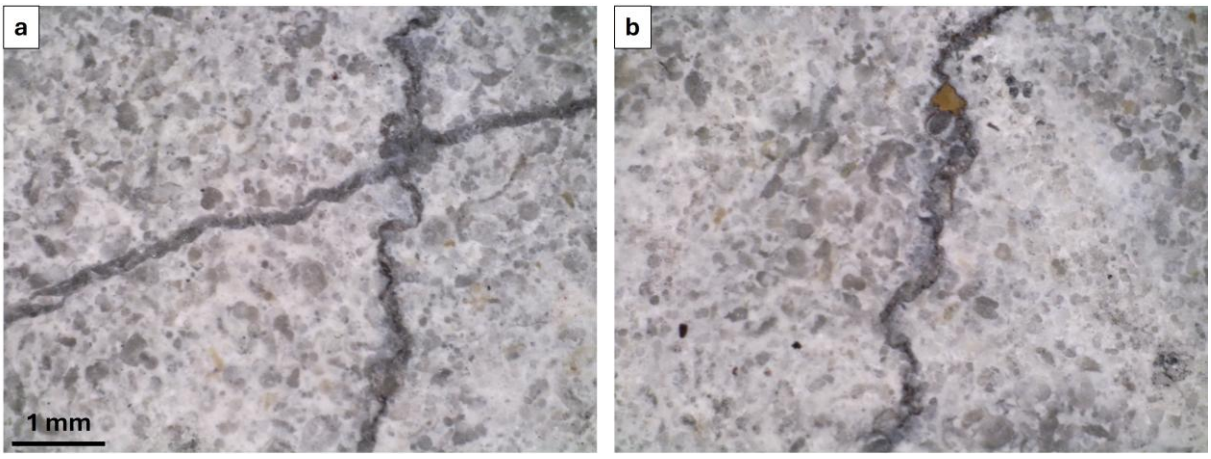

Fig. 3: Dinolite images of ISic000827: a) detail of a stylolite crossing a vein; b) yellow grain in a stylolite and black grains in the groundmass.

The stele ISic000827, on the other hand, appears slightly different (Fig. 3): the overall colour is a cooler grey, with stylolites, and black, reddish and yellow grains. The greyish grains (less than 0.5 mm) can also be interpreted as peloids or oolites, of different size and shape compared to the ones in Figs. 1 and 2. Digital microscopy does not allow the observation of more specific features. Calcium is the main element in this rock, with some potassium, titanium, manganese and iron. Due to constraints deriving from the physical principles involved in pXRF analyses, magnesium (the element characterising dolomite) is not detectable.

Discussion

All the features observed for ISic000823 and ISic003331 find excellent correspondence with the Mesozoic limestones outcropping in the Taormina area, and more specifically with the so-called « pietra » or « marmo » from Taormina44, as identified by Orsi and Libertini45. This is a carbonate rock formed in the Lower Jurassic and belongs to the limestones and dolostones of Taormina formation (DOA)46. It is compact, often crystalline, greyish-white in colour, and contains remains of various allochems (peloids / oolites and microfossils). From the mineralogical point of view, it has a calcitic composition at the base of the formation, and fades into dolomite towards the top, turning to greyish or pinkish hues. It emerges in the area of Capo Taormina, from the sea level up to the ancient theatre, the castle and towards the North in the Roccella and Monte Veneretta areas.

It appears evident that the formation of the Taormina lime-dolostone shows an internal variability in terms of abundance of allochems such as peloids / oolites and microfossils remains and dolomitization, that explains the different features according to the analysed portion of the block (Figs. 1 and 2). Nonetheless, there are sufficient indications and cross comparisons to support Taormina as the origin for these blocks. Moreover, the area of Taormina was under the influence of Hieron II after 263 BCE, and it was not only the forest areas of Mount Etna being exploited for timber, as stated by Walthall, but the stone as well[47]. The polishable grey 'marble' outcropping from Tauromenion acropolis down to

[44] Catalano *et alii* 2010.
[45] Orsi 1896 and Libertini 1929, p.121.
[46] Referred to as DOA in Catalano *et alii* 2010, pp. 51-52.
[47] Walthall 2024, pp. 97-98: « His kingdom encompassed the major ports at Syracuse, Tauromenion, and Kamarina, as well as smaller harbors along the east and south coast. Four major rivers – the Chrysas, Hyblaeus, Gornalunga, and Symaithos – served as navigable arteries connecting the interior to the coast. Tauromenion provided the king with access to the old-growth forests that scaled the slopes of Mt. Etna, a source of precious timber resources. » P.108, note 77: « Hieron's task was how to effectively extract resources

sea level must have been a valued commodity, especially in Siracusa which is surrounded by the Hyblean plateau to the North, West and South for ca. 100 km as the crow flies. The geological map of the area of Siracusa shows a varied panorama of calcarenites and calcirudites, i.e. sedimentary rocks of powdery and grainy appearance which have been used since Antiquity[48], but which cannot be polished[49]. The appeal of a shiny, light-coloured rock, which could hold fine detail in carving, and which was simultaneously being quarried for the theatre in Tauromenion, must have been exploited to mark the importance of monumental statues for both Hieron and Gelon[50].

A final comment is worth adding on the presence of the signals of copper and lead in both ISic000823 and ISic003331, both in the letters (although no visible traces of colour remain) and on the surface. The authors interpret this as a contamination from metallic artifacts, which is compatible with the stone being in contact with either a statue or clamps.

As far as ISic000827 is concerned, granitoids are not compatible with the observations both on chemical and microscopic appearance (Fig. 4). In the published literature[51], « granito del foro » from Mons Claudianus in Gebel Fatireh, Egypt, has been compared with a similar rock outcropping in Nicotera (Calabria). A comparison with a granite from the Alps (Tremola, Gotthard Pass) and a tonalite from Calabria (both granitoid rocks in the collections of the Museo di Mineralogia, Petrografia e Vulcanologia of the University of Catania), reveals substantial differences both in the macro- and microscopic appearance, as well as, as expected, in the pXRF obtained chemical composition. Both granitoids show shiny white and grey grains of ca. 1-2 mm size, with black shiny crystals of comparable size. The main component of the rocks is silicon, present in all the constituting minerals: quartz, plagioclase and alkali feldspar.

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from his kingdom, a subject that will be the focus of the second part of the book. » ISic002987, part of a series of engraved civic accounts from second-/first-century BCE Taormina records the export of blocks and slabs of local stone, alongside timber (col. 2, lines 25-27); see MANGANARO 1964, p.51.

[48] See for example MÈGE *et alii* 2020.

[49] In the authors' opinion, this means that there are no polishable limestones available locally at Siracusa, contrary to what is implied by DIMARTINO 2017b for ISic003331, unless 'locale' here means that it came from anywhere in the wider kingdom of Syracuse.

[50] A rough estimate of their weight, based on current size and density value for compact limestones, yields a weight of ca. 1000 kg for ISic000827 and ca. 400 kg for ISic003331 (incomplete). The data presented in RUSSELL 2013, p.103 and p.111 suggests that the relative costs of (1) extracting such a block from the quarry, (2) transporting it down to the coast, and (3) shipping it along the coast to Siracusa would each be roughly equivalent, but converting that cost into monetary terms is far from straightforward.

[51] ANTONELLI, LAZZARINI, CANCELLIERE 2010.

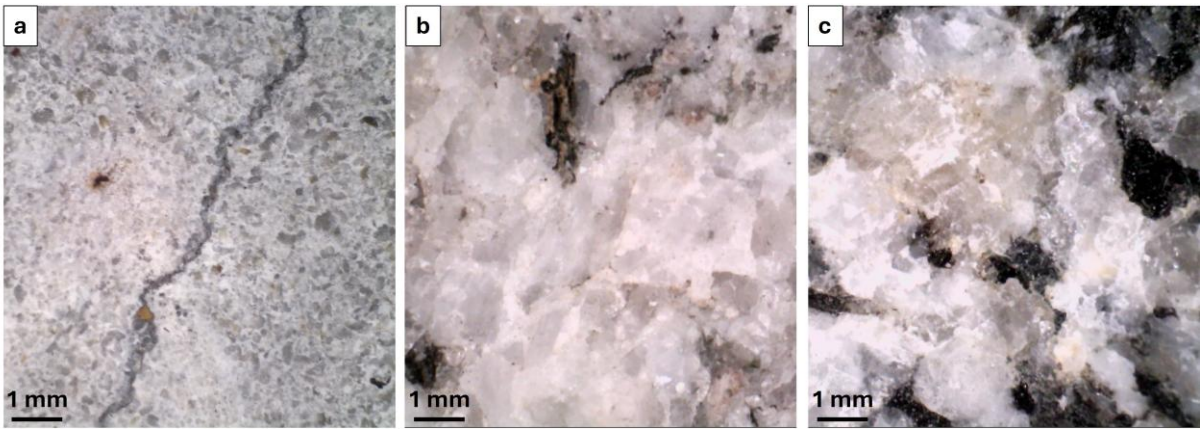

Fig. 4: Dinolite images of: a) ISic000827; b) granite reference (Gotthard pass); c) tonalite reference (Calabria).

It appears from pXRF analyses that ISic000827 is a carbonatic sedimentary rock. Calcium is the main element, with lower potassium than the pietra di Taormina samples, while comparable titanium, and higher levels of manganese, iron, strontium and rubidium can be detected. These features, as well as the appearance, make this rock also incompatible with a grey marble, in the geological sense.

No apparent microscopic similarities could be highlighted between the rock of ISic000827 and other inscriptions studied to date; also, the pXRF data do not precisely match any other inscription support or reference material analysed so far.

The combined survey of the geological map of Sicily and of the extension of the kingdom of Hieron II[52] highlights outcrops of compact grey limestones in the area of Taormina (and not around Siracusa), but the lack of laboratory-based analytical results hampers a more precise identification. The comparison with other materials of known provenance, starting from other grey Mesozoic limestones from the Taormina region, and above all the sampling of a small fragment will be able to clarify the issue definitively, specifically through the identification of the presence of dolomite, and of other rock-constituting minerals with XRD and the observation of a thin section (detailed study of peloids / oolites, identification of allochems and accessory minerals) through the petrographic microscope. Targeted fieldwork based on the cross-interpretation of the analytical results and the geological map of Sicily would then lead to a reliable provenance for this epigraphic support.

[52] As depicted in WALTHALL 2024, p.86.

Conclusions and perspectives

What emerges clearly from a review of the existing literature on these three epigraphic monuments is the lack of consistency and rigour in description. Epigraphers traditionally emphasise the value of autopsy (direct personal study) for the establishment of the text; but materials analysis requires the same level of attention, combined with the relevant specialist knowledge and methodologies (and hence proper interdisciplinary collaboration). The fully non-invasive approach adopted here proved effective in confirming the identification of ISic000823 and ISic003331 as « pietra » or « marmo » from Taormina – a polishable limestone of non-local origin, but nonetheless from within the bounds of the kingdom of Hieron. In other words, a deliberate choice of higher quality and suitability for a prominent public monument than the immediately local rock of the Syracusan area (and entailing more cost and effort). The near contemporary export of Taormina stone is confirmed in other epigraphic documents, suggesting that the stone had a recognised regional status and value. On the other hand, while this approach was able to identify ISic000827 as a carbonatic sedimentary rock, and so refute on analytical bases the proposed identifications of granite, or geological marble, it was unfortunately not successful in precisely identifying the rock. To do so would require the removal of a small sample in order to apply the conventional, minimally-invasive, minero-petrographic analytical methodologies and to allow for proper geological comparisons. It is clear that to do so would shed further light on the commercial trade routes, relationships, and aesthetic values in play in the kingdom of Hieron, and clarity as to whether the stone has a Sicilian origin (internal or external to the kingdom) or a more exotic provenance would have genuine historical significance.

The three Hieronian stones are relatively unusual in the Sicilian epigraphic landscape in having a fairly precise historical and geographical context; but the similar analyses being undertaken in the Crossreads project across a wide range of the island's epigraphic output have the potential to shed considerable light on our understanding of patterns of choice across the island and commercial connections across Sicily and the wider Mediterranean. The data acquired, whether from non-invasive analysis, as here, or based upon sampling, will in turn complement existing and future analyses across a wider range of stone objects and constructions, enabling us to build up an ever richer picture of such connections in ancient Sicily.

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