2023 IMEKO TC-4 International Conference on
Metrology for Archaeology and Cultural Heritage
Rome, Italy, October 19-21, 2023

Archaeometric investigations on ancient funerary stone elements from the National Archaeological Museum of Adria (Rovigo, Italy)

Simone Dilaria[1,2], Luigi Germinario[3], Chiara Girotto[1], Claudio Mazzoli[3], Caterina Previato[1], Giovanna Falezza[4], Alberta Facchi[5], Jacopo Bonetto[1]

[1] Department of Cultural Heritage, University of Padova
[2] Inter-Departmental Research Centre for the Study of Cement Materials and Hydraulic Binders, University of Padova
[3] Department of Geosciences, University of Padova
[4] Soprintendenza archeologia, belle arti e paesaggio per le province di Verona, Rovigo e Vicenza
[5] Museo Archeologico Nazionale di Adria (RO), Polo museale del Veneto

Abstract – **We analysed 22 stone samples from Roman and Pre-Roman funerary artefacts found in the ancient site of *Atria*, located in the deltaic plain of the Po River in Veneto region (Italy). The investigation of the artefacts, currently preserved at the National Archaeological Museum of Adria, was conducted by Polarized Light Optical Microscopy (PLM) and X-Ray Fluorescence (XRF) in order to determine their provenance and, consequently, the trade networks exploited for their supply. The results revealed the widespread presence of rock types sourced from the central-western part of Veneto. Among these, trachytes from the Euganean Hills were predominantly utilised, while the soft limestone known as "Pietra Tenera di Vicenza" from the Berici Hills and Scaglia Rossa limestone were used to a lesser extent. Furthermore, the use of rhyolites for the making of a Pre-Roman stele provides new insights into the stone resources quarried from the Euganean district prior the Roman era.**

I. INTRODUCTION

A. State of Art

The provenance of stone materials in archaeology is an interesting research topic for reconstructing the economic patterns and the engineering awareness of ancient societies, as it offers intriguing insights to localize the quarries cultivated in antiquity, the dynamics of exploitation of the natural resources, the trade routes of commercialized artefacts, and the possible diversification of rock types based on their final utilization.

The joint research projects promoted in the last years by the Department of Cultural Heritage and the Department of Geosciences of the University of Padua has substantially contributed to decipher the forms of quarrying, trade and use of stone materials in the regions of Veneto and Friuli Venezia-Giulia during the Roman and Pre-Roman ages [1, 2, 3].

The local stone resources used in ancient times in these territories are mainly constituted by sedimentary rock types, with a clear predominance of limestones from quarry sites located in the Veneto Prealps, Friulan Carnia, Classic Karst and Western Istrian peninsula.

Alongside sedimentary rocks, the Euganean Hills in Veneto are the main volcanic district of the region, connoted by differentiated eruptive events, occurred between Eocene and Oligocene [4]. From these outcrops, stiff and compact lavas (primarily trachytes) were quarried since the prehistory to make artefacts or to be used as raw building materials [3].

Analytical approaches generally employed for provenance determination are differentiated depending on the stone types under investigation.

For carbonate rocks, the provenance is usually determined by optical microscopy analyses, based on the recognition of index fossils, useful for the classification of microfacies [1, 5, 6]. In this way, the geological formation can be tracked with good approximation, although the identification of the specific quarry cannot be established, except in few occasions. Other analytical techniques, such as geochemistry or isotopic analysis, were sometimes combined with optical microscopy, although not systematically [7].

Regarding volcanic rocks, in past research, provenance determination was primarily based on the microscopic study of the textural and mineralogical features of stone types [8, 9].

In recent years, several studies have demonstrated the potential of geochemistry for a more effective mapping of provenances, by comparing the geochemical fingerprint of samples collected from known quarry sites with that of archaeological ones [10, 11]. Geochemical data, ordinarily acquired on bulk rocks via X-ray fluorescence, can be further corroborated with investigations of the phenocrysts by targeted Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) investigations [12, 13].

By matching the results inferred from geochemical and petro-mineralogical investigations it is possible to determine the quarry sites of Euganean volcanic stones with an high confidence degree.

B. *Objective of the research*

In the present paper, we analysed 22 stone materials from Roman (20) and Pre-Roman (2) funerary elements (stele, sarcophagus lids), nowadays preserved at the National Archaeological Museum of Adria (Fig. 1) and found in the ancient city of *Atria* o from its surroundings [14]. The town is located in the deltaic plain of the Po River south of the Lagoon of Venice. The stone elements used in the city were therefore quarried far from the urban territory and imported in the town.

The objective of the research was to determine the provenance of the stones to understand the trade networks that *Atria* relied on for obtaining stone materials and the quarry sites exploited by this town in antiquity.

II. MATERIALS AND METHODS

Of the 22 samples, 5 are constituted by sedimentary rocks while the remaining 17 are volcanic rocks. Therefore, the two datasets of samples were characterized following two different approaches.

Sedimentary rocks were characterized by Polarized Light Optical Microscopy (PLM) using a Leica DM 750P polarized light optical microscope with an integrated Flexacam C1 camera. This technique allowed to define the rock type and, consequentially, its provenance with high confidence.

The study of volcanic rocks followed a multi-analytical approach, involving PLM investigations on thin sections coupled with bulk-rock X-Ray Fluorescence (XRF) analyses. Provenance was determined using bivariate scatterplots of specific discriminant major and trace elements, where the analyses performed on the archaeological samples were compared with those of samples form known quarries of trachytes and rhyolites, either analysed in this work or gathered from literature data [12, 13, 15]. The instrument used for this research consists of a WDS Panalytical Zetium sequential spectrometer, operating under vacuum conditions and equipped with a 2.4 kW Rh tube. Samples for XRF analysis were prepared in glass beads using lithium tetraborate. Loss on ignition (LOI) was also determined separately before the XRF analyses.

Through discriminant analysis, carried out using Statgraphics Centurion Pro 19, the definition of provenances was further refined. This is a powerful multivariate technique, already adopted in geoarchaeological studies concerning the provenance determination of volcanic rocks and glasses [16, 17]. The best matches between archaeological and quarry samples were identified by using the known geological provenances as classification factor and a selection of discriminant chemical elements as independent variables.

The provenance of the volcanic rocks was eventually established by comparing the results inferred from the geochemistry with the observations gathered via PLM, which were confirmed to be congruous, thus demonstrating that this approach can permit the identification of quarry sites with high accuracy.

Fig. 1 – A selection of funerary stone artifacts' samples from the National Archaeological Museum of Adria. Sample AD_172 is a sarcophagus lid whereas the remaining ones are different types of Roman stele, apart from the Pre-Roman one AD_197.

III. RESULTS

A. *Sedimentary rocks*

The most part of the sedimentary rocks (samples AD_26, 62, 74, 206) are Vicenza Stone. This rock type, also known as "Pietra Tenera" (Soft Stone), refers to soft and easily workable limestones quarried in the Berici Hills, south of Vicenza. All the samples refer to the Oligocene *Castelgomberto Limestone Formation* [18] and they can be defined as grainstones, having a sparitic cement and abundant encrusting coralline Red Algae, ialyne foraminifera (nummulites and asterigerinids), bryozoans, serpulids and echinoids. The presence of benthonic miliolids foraminifera is relevant in the Costozza Stone variety (samples AD_74, Fig. 2).

The last sample (AD_53) pertains to the *Scaglia Rossa Formation* (late Cretaceous - inf. Eocene). Outcrops of this rock type, also called as Pietra di Prun, are present in some areas of the Veneto region including the sedimentary successions of the Euganean Hills and Western Prealps (Lessinia). The sample is a wakestone displaying a micritic cement and abundant planktonic foraminifera (calpionellids, *globigerina*), globotruncana, radiolaria and calcispheres, rare bivalves, echinoids, and sponges (Fig. 3). Cracks can be filled with hydroxides and clay minerals.

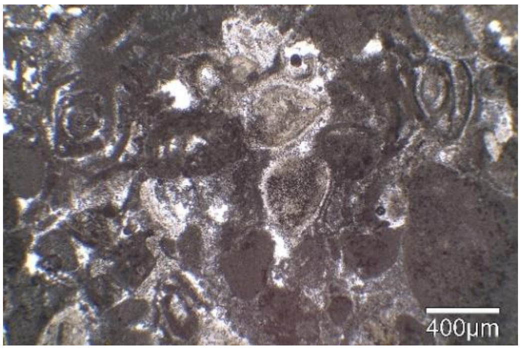

Fig. 2 – AD_74, Pietra di Vicenza limestone (PLM – plane polars).

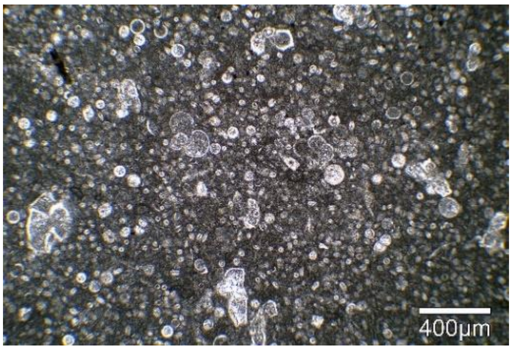

Fig. 3 – AD_53, Scaglia Rossa limestone (PLM – plane polars).

B. *Volcanic rocks*

According to the TAS (*Total Alkali vs. Silica*) diagram, most of the volcanic rock samples fall in the field of the trachytes, while only AD_197 falls in that of rhyolites due to the high content of SiO_2 (72.15 %). This distribution is compatible with that of the magmatic rocks of the Euganean Hills [4].

By comparing a selection of descriptive mayor and trace elements concentrations [based on 12, 13, 16, 19] of the archaeological samples with that of Euganean trachytes and rhyolites from known quarries, most of the rocks shows a strong compatibility with M. Oliveto, as observable in K_2O vs. TiO_2 scatterplot (Fig. 4). Indeed, these stones present a glomero-porphyritic hiatal texture, with a felty microcrystalline groundmass as observed in certain trachytes of this area (Fig. 5). Major phenocrysts are constituted by anorthoclase and plagioclase, with subordinated concentrations of quartz, biotite and accessory opaque minerals, apatite, epidote and zircon.

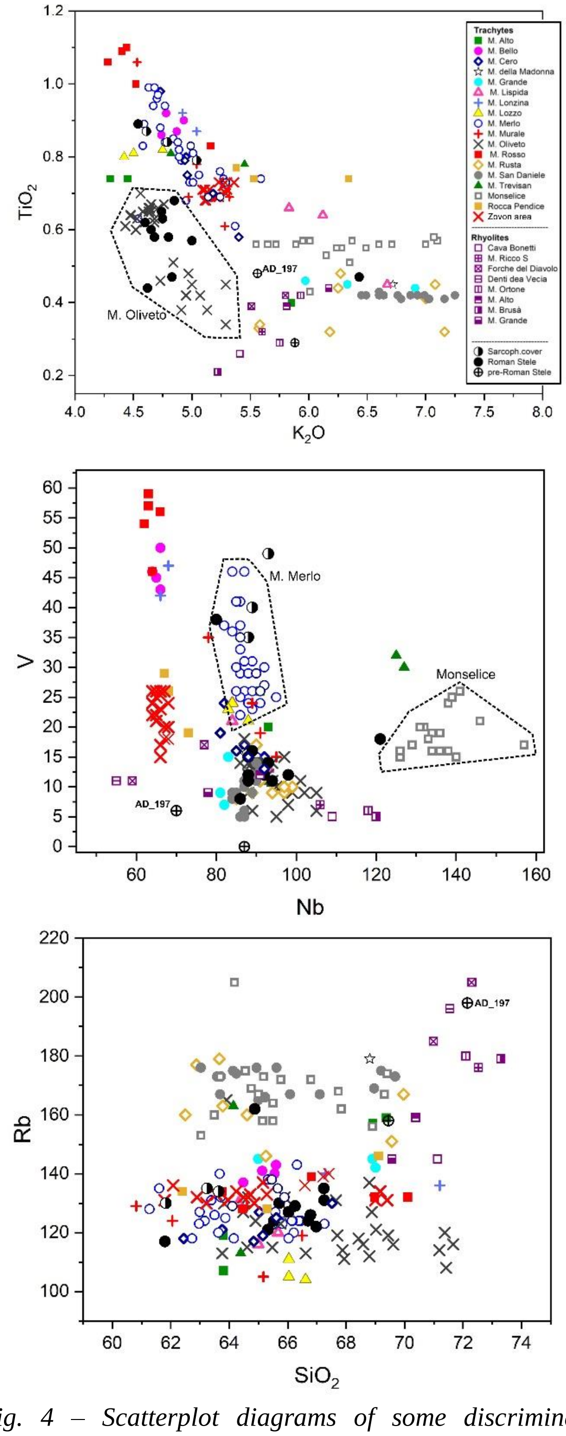

Fig. 4 – Scatterplot diagrams of some discriminant chemical elements used for the determination of Euganean trachyte and rhyolite outcrops.

Sarcophagus lids samples AD_166, 172 and 181 plus the stele AD_188 overlap the field of M. Merlo, as detectable by the V vs Nb scatterplot. This is confirmed by the peculiar glomero-porphyritic seriate texture with microcrystalline felty groundmass of these samples (Fig. 6), compatible with that of M. Merlo where also the concentration of augite phenocrysts is much higher than in M. Oliveto. In the V vs. Nb scatterplot, only sample AD_150 falls close to the fairly isolated field of the Monselice quarry, connoted by the high content in Nb respect to all the other Euganean trachytes.

By the observation of the scatterplots, it was not possible to unequivocally identify a precise matching for both the Pre-Roman stele samples AD_197 and 198. From a petrographic point of view, both samples present a glomero-porphyritic hiatal texture with a felty microcrystalline groundmass, that connotes certain trachytes of M. San Daniele and M. Grande. Typical is the relevant amount of quartz, that is abundant in particular in AD_197 (Fig. 7).

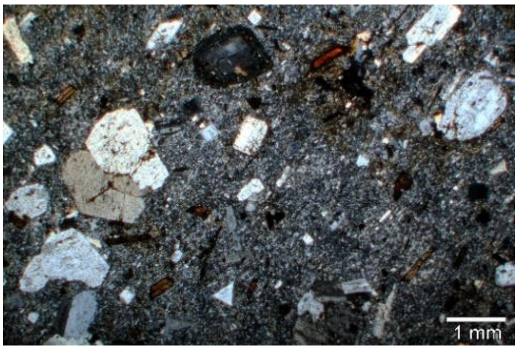

Fig. 5 – AD_79, Trachyte from M. Oliveto (PLM – crossed polars).

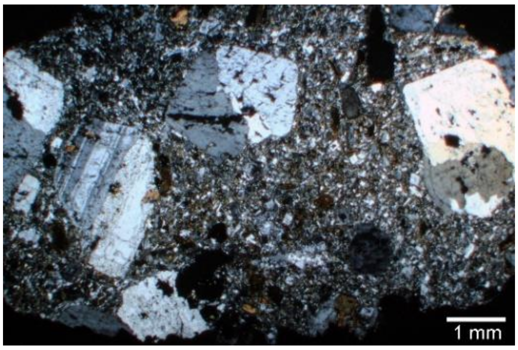

Fig. 6 – AD_172, Trachyte from M. Merlo (PLM – crossed polars).

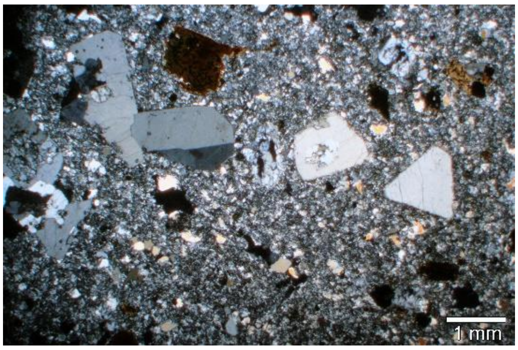

Fig. 7 – AD_197, Rhyolite, probably from Forche del Diavolo outcrop (PLM – crossed polars).

The geochemistry of this latter sample is also peculiar as it is Ba and Sr depleted and Rb enriched, as recurrent in Euganean rhyolites. In fact, by scatterplot analyses, it reports strong affinities with the geological samples of *Forche del Diavolo,* whose texture and petrography appears compatible with that of sample AD_197 too.

Discriminant analysis was crucial for unambiguously certifying the provenance of the volcanic stone samples. The discriminant chemical elements for trachytes (Na_2O, Al_2O_3, K_2O, TiO_2, V, Rb, Sr, Zr, Nb, Ce, Nd, based on [12, 13]) and for rhyolites (SiO_2, Ba, Sr based on [19], and Rb, based on [16]) were selected as independent variable, and the chemical data of the samples from known quarries as classification factors. The resulting probabilistic table confirms the observations previously suggested, identifying the best matching for AD_197 with *Forche del Diavolo* rhyolite and that of AD_198 with M. Grande trachyte (Tab. 1).

Table 1 – Results of the discriminant analysis. Legend: RS = Roman stele; SL = Sarcophagus lid; PRS = Pre-Roman stele

Sample / Element		Provenance 1st	Prob. (%)	Provenance 2nd	Prob. (%)
AD_002	RS	M. Oliveto	100	n.d.	
AD_013	RS	M. Oliveto	100	n.d.	
AD_038	RS	M. Oliveto	100	n.d.	
AD_044	RS	M. Oliveto	100	n.d.	
AD_046	RS	M. Oliveto	99.0	M. Alto	0.1
AD_057	RS	M. Oliveto	100	n.d.	
AD_070	RS	M. Oliveto	100	n.d.	
AD_079	RS	M. Oliveto	99.7	M. Alto	0.3
AD_150	RS	Monselice	100	n.d.	
AD_166	SL	M. Merlo	100	n.d.	
AD_172	SL	M. Merlo	100	n.d.	
AD_181	SL	M. Merlo	100	n.d.	
AD_188	RS	M. Merlo	100	n.d.	
AD_192	RS	M. Oliveto	100	n.d.	
AD_197	PRS	F. del Diav.	100	n.d.	
AD_198	PRS	M. Grande	100	n.d.	
AD_199	RS	M. Oliveto	99.8	M. Alto	0.2

IV. DISCUSSION AND CONCLUSIONS

The archaeometric results we obtained provide interesting information for reconstructing the cultivated quarries and the supply networks exploited by the citizens of ancient *Atria* for the realization of the funerary artefacts.

From what it has been possible to observe, most of the stones were sourced in the central-western part of the Veneto region (Berici Hills and Euganean Hills in particular, Fig. 8, a). The materials probably reached the town through the river network that connected these territories with the Po delta [21].

In detail, trachyte from M. Oliveto appears substantially exploited for the realization of steles (Fig. 8, b). This is a recurrent aspect observed also in previous studies [22]. On the other hand, trachyte from M. Merlo seems primarily devoted to sarcophagus lids.

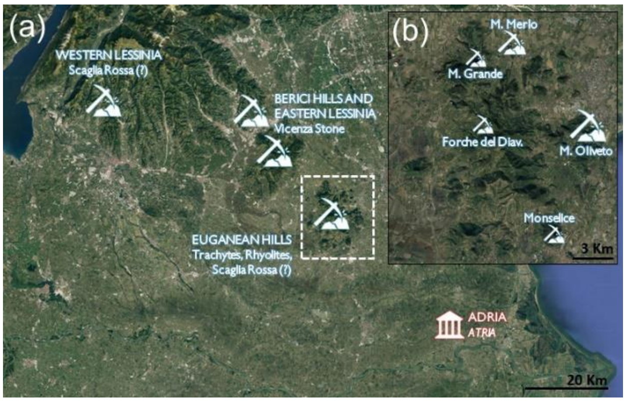

Fig. 8 – Provenance of the stone types exploited for the making of the analysed funerary artifacts (edited from Google Earth version 9.193.0.1); (a) Regional view of the quarry zones; (b) Enlarged sketch of the area enclosed within the dotted white line in subfigure (a).

Fig. 9 – The rhyolite dyke at Forche del Diavolo (central-western Euganean Hills).

These trends may be explained with the diversification of professional domains of stoneworker's companies. Otherwise, it could rely on an intentional choice based on the physical features of stones from these two outcrops. However, not all the Roman stele of Adria come from M. Oliveto, since they often consist of soft limestones of Vicenza Stone, which was alternatively employed for the making of these artefacts due its workability. *Scaglia Rossa* limestone was only occasionally employed for this purpose.

The sourcing of stone materials for the making of the Pre-Roman stele AD_197 and 198 is also intriguing. In fact, the provenance of the rock types is different in respect to the Roman ones and it seems that not only trachyte, but also rhyolites were used for this purpose.

For AD_197, the quarry site determined by discriminant analysis is probably *Forche del Diavolo* outcrop (Fig. 9). Although there is no evidence of historical quarries, the site is characterised by a rhyolite dyke intruded within basalts, the dimension of which is suitable for being quarried. This might represent the first evidence of Euganean rhyolite utilization in antiquity whose exploitation along time needs to be investigated further. The main results of the research raise many questions about the way the land resources were managed between pre-Roman and Roman times, offering new insights on the forms of exploitation of the ancient quarries, which became the ones historically cultivated until the contemporary era.

V. REFERENCES

[1] C.Previato, "Aquileia. Materiali, forme e sistemi costruttivi dall'età repubblicana alla tarda età", Antenor Quaderni, vol.32, Padova University Press, Padova, 2015.

[2] S.Paltineri, S.Binotto, A.Zara 2020, "L'impiego dei materiali lapidei a Padova nell'età del Ferro tra simbologia, funzione e rapporti con il territorio", Preistoria Alpina, vol.50, pp. 53–88.

[3] A.Zara, "La trachite euganea. Archeologia e storia di una risorsa lapidea del Veneto antico", Antenor Quaderni, vol.44.1/2, Edizioni Quasar, Roma, 2018.

[4] G.Astolfi, F.Colombara, "La geologia dei Colli Euganei", Padova, 1990.

[5] E.Flügel, C.Flügel, "Applied Microfacies Analysis: Provenance Studies of Roman Mosaic Stones", Facies, vol.37, 1997, pp. 1–48.

[6] E.Roffia, R.Bugini, L.Folli, "Stone Material of the Roman villas around Lake Garda (Italy)", in ASMOSIA VII, Proc. of the 7th International Conference of the Association for the Study of Marble and Other Stones in Antiquity, Bulletin the Correspondence Hellénique, suppl.51, Athens, 1997, pp. 559–570.

[7] L.Maritan, C.Mazzoli, E.Melis, "A multidisciplinary approach to the characterization of Roman

gravestones from Aquileia (Udine, Italy)", Archaeometry, vol.45, No.3, 2003, pp. 363–374.
[8] M.Cattani, L.Lazzarini, R.Falcone, "Macine protostoriche dall'Emilia e dal Veneto: note archeologiche, caratterizzazione chimico-petrografica e determinazione della provenienza", Padusa, vol.31, 1997, pp. 105–137.
[9] E.Bianchin Citton, G.De Vecchi, "L'impiego della trachite euganea nella fabbricazione di macine in età preromana, Dinamiche insediative nel territorio dei Colli Euganei dal Paleolitico al Medioevo", in E.Bianchin Citton et al. (eds.), Dinamiche insediative nel territorio dei Colli Euganei dal paleolitico al Medioevo, Padova, 2015, pp. 139–150.
[10] S.Capedri, R.Grandi, G.Venturelli 2003, "Trachytes Used for Paving Roman Roads in the Po Plain: Characterization by Petrographic and Chemical Parameters and Provenance of Flagstones", JAS, vol.30, pp. 491–509.
[11] L.Maritan, C.Mazzoli, R.Sassi, F.Speranza, A.Zanco, P.Zanovello, "Trachyte from the Roman aqueducts of Padua and Este (north-east Italy): a provenance study based on petrography, chemistry and magnetic susceptibility", EJM, vol.25, 2013, pp. 415–427.
[12] L.Germinario, A.Zara, L.Maritan, J.Bonetto, J.M.Hanchar, R.Sassi, S.Siegesmund, C.Mazzoli, "Tracking trachyte on the Roman routes: Provenance study of Roman infrastructure and insights into ancient trades in northern Italy", Geoarchaeology, vol.33, No.4, 2018, pp. 417–429.
[13] L.Germinario, J.M.Hanchar, R.Sassi, L.Maritan, R.Cossio, A.Borghi, C.Mazzoli, "New petrographic and geochemical tracers for recognizing the provenance quarry of trachyte of the Euganean Hills, northeastern Italy", Geoarchaeology, vol.33, 2018, pp. 430–452.
[14] S.Bonomi, R.Sigolo, L.Zega (eds.), "Le pietre parlano: il lapidario romano di Adria", Apogeo Editore, Adria, 2006.
[15] P.Cornale, P.Rosanò, "Le pietre tenere del vicentino: uso e restauro", Camera di Commercio Industria Artigianato Agricoltura di Vicenza, Vicenza, 1994.
[16] V.Brombin, "Geochimica delle rocce magmatiche dei Colli Euganei (PD) e dei Monti Berici (VI)", unpublished MA thesis, supervisor Prof. A. Marzoli, Department of geoscience of the University of Padova, 2013/2014.
[17] S.Columbu, A.M.Garau, C.Lugliè, "Geochemical characterisation of pozzolanic obsidian glasses used in the ancient mortars of Nora Roman theatre (Sardinia, Italy): provenance of raw materials and historical-archaeological implications", AAS, vol.11, 2019, pp. 2121–2150.
[18] S.Dilaria, C.Previato, J.Bonetto, M.Secco, A.Zara, R.De Luca, D.Miriello, "Volcanic pozzolan from the Phlegraean Fields in the structural mortars of the Roman Temple of Nora (Sardinia)", Heritage, vol.6, No.1, 2023, pp. 567–587.
[19] L.Milani, L.Beccaluva, M.Coltorti, "Petrogenesis and evolution of the Euganean Magmatic Complex, Veneto Region, North-East Italy", EJM, vol.11, 1999, pp. 379–399.
[20] C.Previato, A.Zara, "Il trasporto della pietra di Vicenza in età romana. Il relitto del fiume Bacchiglione", Marmora, vol.10, 2014, pp. 59–78.
[21] S.Capedri, G.Venturelli, "Trachytes employed for funerary artefacts in the Roman Colonies *Regium Lepidi* (Reggio Emilia) and *Mutina* (Modena) (Italy): provenance inferred by petrographic and chemical parameters and by magnetic susceptibility", JCH, 4, 2003, pp. 319–328.