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Euganean trachytic grinding stones in the *Caput Adriae* from Iron Age to Roman time: reassessment of the Protohistoric quarries

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Abstract

A group of Euganean trachytic grinding stones from Slovenia and the available data about the same type of artefacts in the whole *Caput Adriae* are here presented. The occurrence of Iron Age saddle querns in Karst and Istria is confirmed but our study suggests a likely provenance from Mts. Cero/Murale instead of Mt. Altore/Rocca Pendice, as previously suggested. Este, important Venetic centre, is just south of Mts. Cero/Murale, suggesting its central role in the production and distribution of saddle querns. During the Roman time, Euganean trachytes are still used for rotary millstones but new quarries (Mt. Rosso), relatively close to the ancient *Padua*, are exploited. Such shift in the position of millstone quarries most probably reflects the changed geopolitical framework.

Key words: *Caput Adriae*, Euganean trachyte, grinding stones, Iron Age-Roman period, Protohistoric quarries

INTRODUCTION AND ARCHAEOLOGICAL BACKGROUND

Euganean trachyte can be considered the most important volcanic raw material used in northern Italy and neighbouring areas to produce grinding stones in both the Protohistoric and Roman periods (Cattani et al., 1997; Crivellari, 1998; Antonelli et al., 2004; Antonelli & Lazzarini, 2012; Zara, 2018).

Characterization and provenance of Protohistoric and Roman volcanic millstones from *Caput Adriae* (north-eastern Italy, western Slovenia and north-western Croatia) have been discussed in two contributions dedicated to selected samples from Aquileia (Antonelli & Lazzarini, 2012), the most important Roman city of the region, and to Iron Age and Roman grinding stones discovered in pre-Roman hill forts of Istria and Trieste Karst (Antonelli et al., 2004). Data about volcanic grinding stones from other Protohistoric and Roman archaeological sites located in the Slovenian Karst are a few (e.g., Horvat & Župančič, 1987) or not available.

The review of the published data about the Euganean trachytic grinding stones from *Caput Adriae*, integrated with fresh evidence mainly from the Slovenian Karst (Figure 1a; Fabec & Žerjal, 2013), is here presented in order to detail their distribution and, when possible, the raw material exploitation areas. This effort has also taken advantage of a new geochemical dataset of the Euganean Hill (Germinario et al., 2018a) in addition to that one published by Capedri et al. (2000).

The Karst plateau and the Istrian peninsula at the north-eastern shore of the Adriatic Sea are marked by the presence of hundreds of Protohistoric settlements, generally located on hilltops. These sites, protected by dry-stone walls, locally called *castellieri*, *gradine* or *gradišča*, featured clear originality and cultural unity in pottery production, architectural models, defensive systems and funerary practices. They were settled for a very long time spanning from the late Early Bronze Age (hereafter EBA), approximately between 1800 and

1650 BC, to the advanced Iron Age (hereafter IA) (Mihovilić, 2013; Borgna et al., 2018; Teržan, 2021). The formation and rising of *castellieri* chronologically corresponds to the EBA II in the Italian relative chronological system (Cardarelli, 2009) and to the BZ A2 in the Central-Europe Reinecke's system (Hänsel, 2009).

All the grinding stones known from Bronze Age hill forts are part of saddle querns made from sedimentary rocks. In general, Bronze Age saddle querns from hill forts of Trieste area are made from local sandstones belonging to the Flysch succession (Bernardini, 2002) outcropping both north and south of the Karst anticline (Lenaz, 2000). Approximately during the same period, quartz arenitic sandstones collected from gravel deposits of the Isonzo river were used by the inhabitants of Karst hill forts for the production of whetstones (Bernardini et al., 2015a).

During the IA, the large occurrence of saddle querns made from Euganean trachytes in many hill forts of *Caput Adriae*, from the Karst to central Istria, testifies to long distance connections with the centre of Venetic cultural area in a period comprised mainly between the 6th and the 5th century BC (Antonelli et al., 2004; Bernardini, 2002, 2005a, 2005b). These cultural connections are confirmed by other traded or exchanged objects probably produced within the same Venetic territory and found in Karst and Istria too, such as, for example, fragments of red fired ceramic pedestal *situlae* with cordons and bands of black paint (Antonelli, 2004; Bernardini, 2002, 2005a, 2005b; Teržan & Turk, 2021), a typical Venetic pottery product (Peroni et al., 1975; Fogolari & Prosdocimi, 1988; Capuis, 1993; Gambacurta, 2007; Vitri, 2017). Saddle querns of the same type have been also found at various sites in Emilia and Veneto (Cattani et al., 1997; Crivellari, 1998). From the 6th century BC onwards, millstones made from the Etnean volcanites (trachybasalts and basaltic trachyandesites) reached for the first time Puglia and neighbouring areas of southern Italy (Lorenzoni et al., 2000a, b). Among the Protohistoric grinding stones from *Caput Adriae*, a few fragmented artefacts made from the same raw materials probably reflect the Magno-Greek, and in particular Syracusan, influence in the Adriatic region (Antonelli et al., 2004; Bernardini, 2005b) culminated with the foundation of several colonies during the 4th century BC (Braccesi, 1977).

After a first conflict between Rome and the inhabitants of Istria peninsula during the late 3rd century BC, Aquileia was founded in 181 BC and the area entered under the direct Roman influence in the first half of the 2nd century BC (Bandelli, 2004; Bernardini et al., 2013, 2015b, 2021; Bernardini & Duiz, 2021). During the Roman time, Euganean trachytic rotary millstones and building material testify the activation of new commercial routes and the exploitation of previously unexploited quarries (Renzulli et al., 1999; Antonelli et al., 2004; Antonelli & Lazzarini, 2010; Germinario et al., 2018a, 2018b; Zara, 2018; Paltineri et al., 2020). Grinding stones of imperial age from Aquileia (Antonelli & Lazzarini, 2012) indicate the presence in the territory of volcanic raw materials from multiple sources in addition to Euganean trachytes: leucite phonolite lavas from the Vulsini Volcanic District (Santi et al., 2004), trachybasalts and basaltic trachyandesites from Etna – already reported during late Protohistory – and Pantelleria basalts (Antonelli & Lazzarini, 2012).

MATERIALS AND METHODS

Six unpublished fragmented grinding stones have been analysed and compared with equivalent artefacts from the same region already described in literature. Petrographic and geochemical features of about 30 Protohistoric and Roman grinding stones from *Caput Adriae* have been then studied and compared with data available for the Euganean hills (Capedri el al., 2000; Germinario et al., 2018a). Among the new samples, CSA2 is part of a Protohistoric saddle quern (Table 1). Five of them are part of small Roman rotary millstones

(Table 1) but only three of them (corresponding to two upper stones and a lower stone) are big enough to reconstruct their original shape (Figure 1b). According to their typology, the millstones from Povir (POV and POV25), characterised by a considerable height (from about 15 to 25 cm) and a markedly oblique grinding surface, most probably date back to the late Republican period. It is worth mentioning that some unpublished 1st century BC-militaria, such as shoe hobnails of Alesia type D (Bernardini et al., 2021 and literature in there), are reported from the Povir hill fort (Laharnar, personal communication). The larger and flatter lower stone from Bukovica dates back to the imperial period (Fabec & Žerjal, 2013).

Microscopic observations

All the samples were carefully observed under a stereomicroscope and chemically analysed. Since the main focus of the study is the reassessment of the Protohistoric exploitation areas, the thin sections of the 15 Protohistoric artefacts published by Antonelli et al. (2004) have been re-considered on the basis of the new petrographic criteria proposed by Germinario et al. (2018a). Antonelli et al. (2004) already provided a detailed description of the Euganean tools presented in their research but they published the microphotograph of a single Protohistoric artefact and the petrographic criteria proposed by Germinario et al. (2018a) were not available.

An additional thin section of the Protohistoric sample (CSA2), published here for the first time, has been produced and studied. The thin sections have been observed using a polarizing microscope at the Department of Mathematics and Geosciences of the Trieste University in order to define their mineralogical and petrographic features.

Geochemistry

Major and trace elements compositions of all samples (BSN, CSA1-2, POV, POV25 and CE) were carried out by inductively coupled plasma emission and mass spectrometry (ICP-ES and ICP-MS), respectively, at the Acme Analytical Laboratories Ltd., Vancouver, Canada (Table 2). The analytical uncertainties are estimated to be between 5 and 10% (Govindaraju & Mevelle, 1987). The samples (about 20 gr for each artefact) were previously powdered using an agate mill at a 150-mesh fraction in the laboratory of Department of Mathematics and Geosciences of Trieste University. Major elements and some minor ones were analyzed following a lithium borate fusion and a dilute acid digestion of 0.2 g samples pulp. Rare earth and refractory elements were analyzed following a lithium borate fusion. Additionally, a fraction of 0.5 g was removed for digestion in aqua regia (heated to 95 °C) and analyzed for base metals and precious metals. The loss on ignition (LOI) was determined by measuring the weight lost during heating at 1000 °C over a three hour period.

Geochemical comparison with Euganean rocks

Geochemical features of the grinding stones from *Caput Adriae* have been then compared with the two geochemical datasets available for the Euganean Hills. They include the XRF data published by Capedri et al. (2000), used in the previous works on grinding stones from *Caput Adriae*, and those recently published by Germinario et al. (2018a). The last authors, following Maritan et al. (2013), suggest that some discrepancies between the concentrations of some elements (e.g. Ti, Th, Sr, and Zr) could be related to the preparation of the pellets for XRF analysis by Capedri et al. (2000). According to these authors, the grain-size of the powder was probably not fine enough (Germinario et al., 2018a, pp. 18-19). To show such a mismatch, Germinario et al. (2018a, fig. 12) have modified the Sr *vs*. Th scatterplot, the main discriminant diagram by Capedri et al. (2000), including also their new XRF geochemical data. However, the compositional mismatch showed by Zr (up to about 200 ppm) and Sr (up to about 250 ppm) seems too high to have been caused by a wrong sample preparation. This is even more unlikely in the case of Sr, which is not much affected by matrix effects. Being Sr a Large Ion Lithophile Elements (LILE), its concentration can be quite variable, even within the same quarry locality. In addition, the new chemical data generally show a lower Th concentration for many localities but this does not apply to all of them, such as the Zovon area, Rocca Pendice, Mt. Rusta. Alternative or concurrent hypotheses, such as compositional heterogeneities within the same quarry areas, cannot be therefore definitely ruled out. For these reasons, we have decided to use both datasets as comparison for the investigated grinding stones.

RESULTS AND DISCUSSION

The Roman artefacts are grey-greenish in colour while the Protohistoric ones are characterised by a reddish-brown surface. They show macroscopic aspect and minero-petrographic features typically coherent with those of the classical Euganean trachyte lavas.

Optical description of Protohistoric samples and comparison with the Euganean Hills

All the Protohistoric trachytic grinding tools analysed by Antonelli et al. (2004) share similar petrographic features and a hiatal grain-size distribution (Figure 2). They are fine-grained (with phenocrysts generally no larger than 5-8 mm^2), grey-brown to brown-reddish, mildly vesiculated and little porphyritic (Porphyritic Index[P.I.] = 5–20, usually 6–10; where the porphyritic index is defined as the area of phenocrysts and macro-phenocrysts, if present, over the total area of the thin section multiplied for 100) with phenocrysts of euhedral plagioclase, anhedral to subhedral anorthoclase and biotite. Zircon and apatite appear as accessories and generally can be mainly found in biotite and plagioclase phenocrysts. The matrix is composed of microlites of sanidine–plagioclase–opaques ± interstitial quartz that show subparallel dominant crystallization direction in a minute interstitial brownish glass (in order of decreasing abundance), suggesting a trachytic or a hyalopilitic matrix. In most of the samples the amount of anorthoclase crystals is generally similar to the plagioclase one (anorthoclase/plagioclase ratio generally approaches 1, rarely is higher).

The sample CSA2, here presented for the first time, is a mildly vesiculated and porphyritic (P.I. 10) trachyte with phenocrysts of anorthoclase, biotite and zoned plagioclase (optically labradorite-oligoclase), often surrounded by a rim of anorthoclase, besides zircon and apatite as accessories. The groundmass is mainly trachytic to hyalopilitic and mainly composed by microlites of anorthoclase-sanidine-plagioclase, scarce biotite and very rare interstitial quartz.

The low values of P.I. in the Protohistoric grinding stones (P.I. 5–20, usually 6–10) can be compared only with the trachytic rocks from Mt. Cero, Mt. Murale, and Mt. Trevisan, together with some samples from M. Oliveto and M. Alto, which show the lowest values in the whole magmatic complex (Germinario et al., 2018a). Fine-grained trachytes, such as the raw material of the grinding stones, are known from Mt. Murale, Mt. Cero, San Daniele, M. Oliveto, and M. Alto (Germinario et al., 2018a). Finally, the hiatal grain-size distribution and the anorthoclase/plagioclase ratio of most of the samples fit well the features reported for Mt. Cero and Mt. Murale (Germinario et al., 2018a).

Chemical characterization

Results of the geochemical analyses are summarized in Table 2. In the TAS (Total Alkali Silica; Le Maitre et al., 1989; Le Bas et al., 1992) classification diagram and in the bivariate K_2O *vs.* Na_2O plot (Figures 3a-b) the new trachytic grinding stones here studied are considered together with all those know from *Caput Adriae* (Antonelli et al., 2004 and Antonelli & Lazzarini, 2012).

All the samples plot in two separate fields where chemical differences well correspond to different chronology and general typology (i.e. Protohistoric saddle querns *vs.* Roman rotary millstones). Most Protohistoric samples are clustered and show alkali content higher than the Roman artefacts for comparable silica values. In facts, the Roman grinding stones are characterized by a more transitional behaviour plotting in correspondence of the alkaline-subalkaline border of Miyashiro, (1978). Nevertheless, all the Euganean samples published here for the first time are quartz (Q) and hypersthene (Hy) normative although the Roman ones show higher Q (11-13 vs. 7) and Hy (2.61-3.43 vs. 1.36) values than the Protohistoric one. It is interesting to note that most Roman artefacts fall within the field of Monte Rosso trachytes, while the Iron Age artefacts plot in an area where the fields of Mts. Cero/Murale, Mt. Merlo, Mt. Altore and Rocca Pendice overlap.

In the K_2O *vs.* Na_2O diagram (Figure 3b), most Protohistoric and Roman artefacts fall in two well separated clusters too. Make exception two Protohistoric saddle querns (samples CS3-4 from Antonelli et al., 2004) that show a depletion of K_2O for comparable Na_2O values with respect to other Protohistoric samples, the Roman millstone POV25 displaying the lowest Na_2O content, and the Roman millstone AQ5 (Antonelli & Lazzarini, 2012), characterised by the lowest K_2O and highest Na_2O values of the Roman artefacts (Figure 3b). Samples CS3-4 and AQ5 have been compared to the Euganean alkaline trachyandesites (Milani et al., 1999) by Antonelli et al. (2004) and Antonelli & Lazzarini (2012), respectively. Samples CS3 and CS4 are not shown in the next diagrams since they show a peculiar chemical behaviour already discussed by Antonelli et al. (2004).

In the Zr *vs.* V diagram (Figure 3c), sometimes used for the identification of the main sources of Italian millstone (Williams-Thorpe, 1988; Antonelli & Lazzarini, 2012), we have plotted the Euganean Hills data by Capedri et al. (2000; black circles) and Germinario et al. (2018a; white circles) and the field of the Euganean Hills according to Antonelli & Lazzarini (2012). The latter was drawn by using data from Capedri et al. (2000); however, a few samples very rich in Zr were not included.

The trachyte grinding stones are distributed in three separate groups, characterized by different Zr contents. More precisely, the high Zr (>800 ppm) group 1 (Figure 3c) includes only Protohistoric samples and plots outside the Euganean field proposed by Antonelli & Lazzarini (2012). The group shows V values comparable to those suggested by Antonelli & Lazzarini (2012) but higher Zr concentration (up to about 200 ppm). Similarly, the intermediate group 2 includes only Protohistoric samples and plots at the edge of the Euganean field by Antonelli & Lazzarini (2012), while the Roman artefacts (group 3) show the lowest Zr content and V values higher than Protohistoric grinding stones, probably reflecting a slightly different source and magmatic history (Figure 3c). Finally, the sample POV25 plots not far from the Roman ones.

In addition, it is worth stressing that there are no significant differences in the Zr and V concentrations between the whole datasets of Capedri et al. (2000) and Germinario et al. (2018a), with exception of the few samples of Capedri et al. (2000) with high Zr concentrations comparable to those of Group 1.

When the samples are plotted in the Sr *vs*. Th diagram proposed by Capedri et al. (2000) for discriminating the quarries of Euganean Hills, here integrated with the data from Germinario et al. (2018a), Roman and Protohistoric artefacts are well clustered in (or close to) field 4 (Mt. Oliveto 1, Mt. Bello, Mt. Cero, Mt. Lonzina, Mt. Lozzo, Mt. Merlo, Mt. Murale, Mt. Rosso) and field 3 (Mt. Altore and Mt. Pendice) of Capedri et al. (2000), respectively (Figure 4a). Makes exception the sample POV25 that falls between the fields 1 (Monselice) and 2 (Mt. Trevisan).

However, according to the new geochemical data (Germinario et al. 2018a), fields 3 and 4 partially overlap, leaving open the question if the Protohistoric artefacts really belong to field 3 (Mt. Altore and Mt. Pendice) of Capedri et al. (2000) or if they could originate from one of the other areas included within field 4. For this reason, we have modified TiO_2 *vs.* Zr diagram (Figure 4b) proposed by Capedri et al. (2000) to detail the quarries of field 4. It is worth noting that Protohistoric samples (mainly those belonging to group 1 of Figure 3c), which should have originated from Mt. Altore and Mt. Pendice according to Antonelli et al. (2004; field 3 of Figure 4a), fall in or close to areas corresponding to Mts. Murale and Cero based on Capedri and al. (2000) and Germinario et al. (2018a) datasets (field 4 of Figure 4a). Most samples of Protohistoric group 2 plot between Mt. Cero + Mt. Murale and Mt. Merlo, Mt. Pendice and Mt. Altore according to Germinario et al. (2018a) and close or within Mt. Merlo and Mt. Altore according to Capedri et al. (2000).

The Roman samples fall near the Mt. Rosso area, in agreement with Sr *vs*. Th diagram (Antonelli et al., 2004; Antonelli & Lazzarini, 2012), with the exception of POV25 and AQ5 that plot outside the diagram because of the low content of Zr and the high content in TiO_2, respectively.

To limit possible weathering effects, that could have affected Large Ion Lithophile Elements (LILE) such as Sr, we propose a discrimination diagram based on less mobile High Field Strength Elements (HFSE), and in particular Zr *vs.* Nb, that can help discriminating among the most probable quarries of Euganean Hills for both Roman and Protohistoric grinding stones (Figure 4c). These elements indicate that the Protohistoric samples probably belong to rock types included in the field 4 of Figure 4a, and in particular to those outcropping in the Mts. Murale-Cero areas (Figures 4a-c). Protohistoric group 1 falls within the Mts. Murale-Cero areas according to the data of Capedri et al. (2000). Protohistoric group 2 falls very close to Mts. Murale-Cero and well separated from Mt. Merlo according to Germinario et al. (2018a) while it falls between Mts. Murale-Cero and Mt. Merlo according to Capedri et al. (2000).

In the same diagram the Roman sample POV25 plots far from Mt. Rosso, Monselice and Mt. Trevisan, showing the lowest Zr and Nb contents. The Nb content of POV25 is so far not reported for the Euganean Hills, making its provenance definition uncertain.

According to Germinario et al. (2018a), the most informative binary plots to discriminate Euganean quarries are V *vs*. Nb (especially useful for Monselice, Mt. Rosso, Mt. Trevisan, and Mt. Merlo areas) and TiO_2 *vs*. Zr, TiO_2 *vs*. K_2O, Na_2O *vs*. Zr, Rb *vs*. Zr, Al_2O_3 *vs*. Zr, and Ce *vs*. Nd. We have then followed such recommendation, selecting the V *vs*. Nb, TiO_2 and Na_2O *vs*. Zr plots, to test the indications given by previous diagrams. In these plots, we have also added the data by Capedri et al. (2000) only for the relevant possible quarrying sites under discussion (always represented by solid lines and with the same colour as the one of the corresponding fields of Germinario et al., 2018a).

In the V *vs*. Nb plot (Figure 5a) most Roman millstones fall close or within the field of Mt. Rosso, with the exception of two samples falling within Mt. Bello + Mt. Lonzina field (CP6 and CP7), POV25 and AQ5. However, in the TiO_2 *vs*. Zr plot (Figure 5b), all the samples, with the exception of POV25 and AQ5, plot within or very close to Mt. Rosso field and well separated from Mt. Bello + Mt. Lonzina field.

In the V *vs*. Nb plot all Protohistoric grinding stones fall very close to Mt. Cero and Mt. Murale and well separated from Mt. Merlo according to both the datasets by Capedri et al. (2000) and Germinario et al. (2018a). Similarly, in the TiO_2 *vs*. Zr and Na_2O *vs*. Zr diagrams the same samples fall within or very close to the field of Mt. Cero and Mt. Murale and well separated from Mt. Merlo. Mt. Altore and Mt. Pendice (Figure 5b-c).

Rare earth elements

Although all the Euganean grinding stones investigated in this paper for the first time show similar patterns (Figure 6a, 1), the Protohistoric sample CSA2 is characterized by slightly different La/Yb, La/Ce and La/Sm chondrite-normalized ratios with respect to the Roman millstones (35.58 *vs.* 10.06-17.42, 2.49 *vs.* 01.34-1.49, 6.89 *vs.* 4.11-4.84, respectively). These geochemical features are not related to weathering effects and imply slight genetic differences, which likely exclude the exploitation of the same quarrying area in the Euganean Hills, as already suggested by Antonelli et al. (2004). Among the Roman samples, POV25 shows a lower La/Yb_{CN} ratio (10.06), an evident Eu negative anomaly (Eu/Eu* =0.65) and a quite flatter Dy/Yb_{CN} (1.06 *vs.* 1.31-1.57).

A few rare earth elements (La, Ce and Nd) of the Euganean quarry areas are available from Germinario et al. (2018a). Despite the few available elements, the La/Ce_{CN} ratio (0.82 and 1.03, respectively) of two selected samples from Mt. Cero (MUR-05) and Mt. Murale (MUR-03) is quite similar to the values of the Protohistoric grinding stones (1.51-2.67) (Figure 6a, 3).

Incompatible elements

In general, all the Euganean samples show similar behaviours, characterized by slight Ba, Nb and more pronounced Sr, P and Ti negative anomalies (Figure 6a, 2). However, the Sr and P negative anomalies are more pronounced in the Protohistoric sample CSA2 than in the Roman ones CSA1, BSN and POV (Ce/Sr_{PM} = 5.43 *vs.* 2.67-2.97; Zr/P_{PM} = 4.50 *vs.* 2.05-2.17). Similar geochemical features are reported also for the outcrops of Mts. Cero (Zr/P_{PM} = 4.43-6.57), Murale (Zr/P_{PM} = 2.78-6.99) and Merlo (Zr/P_{PM} = 5.17) in the Euganean Hills (Capedri et al., 2000). The patterns of two selected samples from Mt. Cero (MUR-05) and Mt. Murale (MUR-03) from Germinario et al. (2018a) confirm such similarity fitting quite well (Ce/Sr_{PM} = 6.35 and 7.67, respectively; Zr/P_{PM} = 7.50 and 37.95, respectively) the field of Protohistoric grinding stones (Ce/Sr_{PM} = 2.59- 9.19, respectively; Zr/P_{PM}: 1.88-6.87; Figure 6a, 4).

The Roman sample POV25 differs; it shows the lowest values in several incompatible elements, a more pronounced negative Nb anomaly (K/Nb: 3.5 *vs.* 1.8-1.9).

DISCUSSION AND CONCLUSIONS

The relatively large occurrence of saddle querns made from Euganean trachytes in the coastal regions of *Caput Adriae* has been already reported by previous studies and it has been considered as evidence of the Venetic cultural influence in the area during the advanced IA (Antonelli et al., 2004; Bernardini, 2002). During the IA, Este, located on the southern slope of Euganean Hills and very close to Mts. Cero and Murale, becomes one of the main centres of the Venetic area (Bianchin Citton et al., 1998; Ruta Serafini, 2002; Capuis & Gambacurta, 2015) and probably plays a crucial role in both the exploitation of trachytic rocks and production of saddle querns; the latter have been found in a wide area at least from Emilia to Istrian peninsula (Antonelli et al., 2004; Cattani et al., 1997). The revision and integration of petrographic and geochemical data concerning Protohistoric grinding stones from *Caput Adriae* make this hypothesis stronger, showing that the most probable sources of Iron Age trachytic saddle querns precisely correspond to Mts. Cero/Murale (Figure 6b) and not to the Mt. Altore and Rocca Pendice quarries, as previously suggested (Antonelli et al., 2004). This conclusion agrees with the results of the chemical and petrographic characterization of Protohistoric saddle querns from Emilia and Veneto, whose provenance was mainly attributed to Mt. Cero and/or Murale (Cattani et al., 1997; Crivellari, 1998; Zara, 2018). The trachytic saddle querns were most probably exported taking advantage of the different paleoenvironmental conditions. From about three ka cal BC to Roman times, the Adige River run through Montagnana, Este and Conselve, reaching the southern Venetian lagoon (Piovan et al., 2010, 2012). The grinding stones could have been transported (as cargo or as ballast) by the Adige River up to the Venice Lagoon and then, by sea, to the coasts of the Karst and Istria, reaching sites placed at most about 20 km from the sea.

During the Roman time, Euganean trachytes were still used for the production of rotary millstones but the available data confirm the exploitation of new quarries (Mt. Rosso for most of the artefacts) and the abandon of the Protohistoric exploitation areas close to Este. The Roman Mt. Rosso source, probably active from the late Republican period, is located along the northern margin of the Euganean Hills and relatively close to the ancient *Padua*. Such shift in the position of quarries most probably reflects the changed geopolitical framework (Paltineri et al., 2020). Beside the use of Mt. Rosso trachyte for the production of millstones, a growing need of building material explains the exploitation of multiple trachytic sources by the Romans (Previato et al., 2014; Germinario at al., 2018a; Zara, 2018; Paltineri et al., 2020). The exclusive use of the Mt. Rosso trachyte for the production of rotary millstones can be perhaps explained assuming particularly good abrasive properties of the raw material or specialised workshops in the area.

However, among the materials here discussed for the first time, some uncertainties about the origin of the Roman sample POV25 still remain; in fact, it shows a general geochemistry in agreement with that of the Euganean magmatic complex, including the behaviour of the vicariant HFSE elements (i.e., Zr *vs*. Hf and Nb *vs*. Ta), but quite peculiar chemical features related to a slightly different genesis are also evident. This suggests the sample could have been collected from a quarry completely exhausted in ancient time or from an area not yet identified.

Finally, the present paper allows to make some considerations about the geochemical datasets available for the Euganean Hills and their use in provenance studies (Capedri et al., 2000, Germianrio et al., 2018a), especially in relation to the hypothesis that the data by Capedri at al. (2000) would be no reliable due to a possible wrong sample preparation (Maritan et al., 2013; Germianrio et al., 2018a): (a) Considering Mt. Cero + Mt. Murale, it is very likely that Capedri et al. (2000) and Germinario et al. (2018a) sampled different areas. The composition of Protohistoric group 1 fits well the composition of the Mt. Cero + Mt. Murale by Capedri et al. (2000) but has no comparison in the dataset by Germinario et al. (2018a). (b) The differences in the Sr and Zr contents between the two datasets are so high for some localities (up to 200 and 250 ppm, respectively) that cannot be due to matrix effects, which are generally very limited for Sr. (c) The Capedri's dataset cannot be dismissed and can be still useful for archaeometric purposes, even if the main discrimination diagram Sr *vs.* Th is not reliable for most quarry localities, as well shown by Germinario et al. (2018a).

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.

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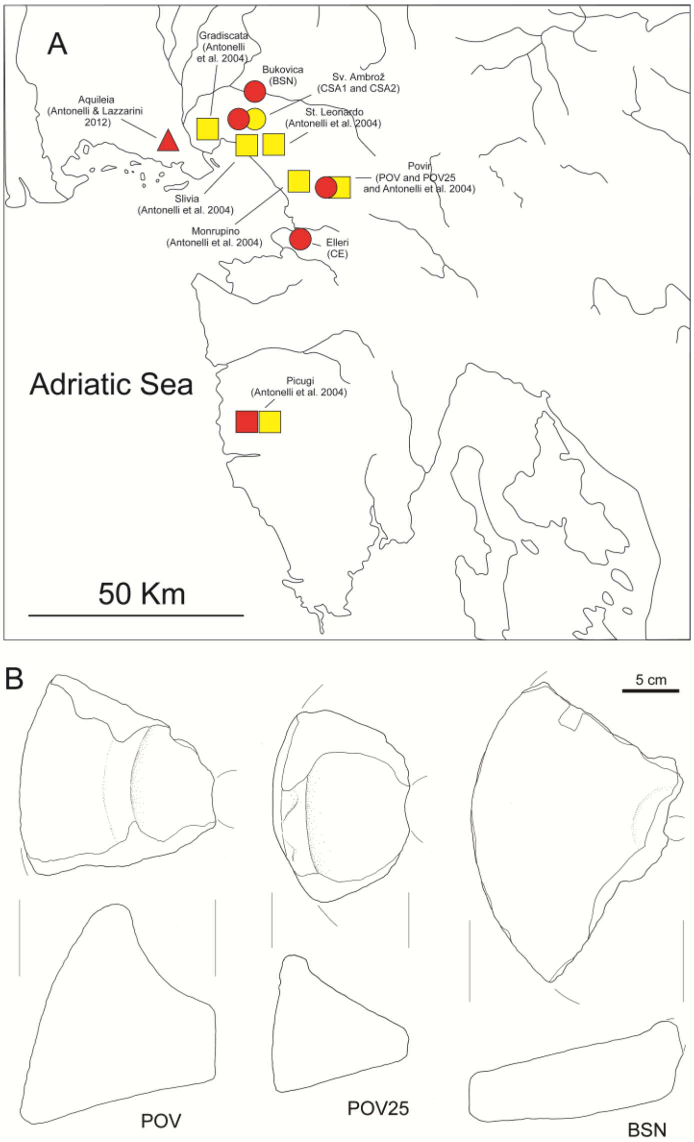

Figure 1- (A) Distribution of Protohistoric (yellow symbols) and Roman (red symbols) grinding stones made from Euganean trachyte in the *Caput Adriae*. The squares correspond to literature data from Antonelli et al., 2004; the triangle to literature data from Antonelli & Lazzarini, 2012; the circles represent newly analysed samples.
(B) Fragmented upper (POV and POV25) and lower (BSN) stones of some of the investigated Roman rotary millstones. Drawings by Teja Gerbec.

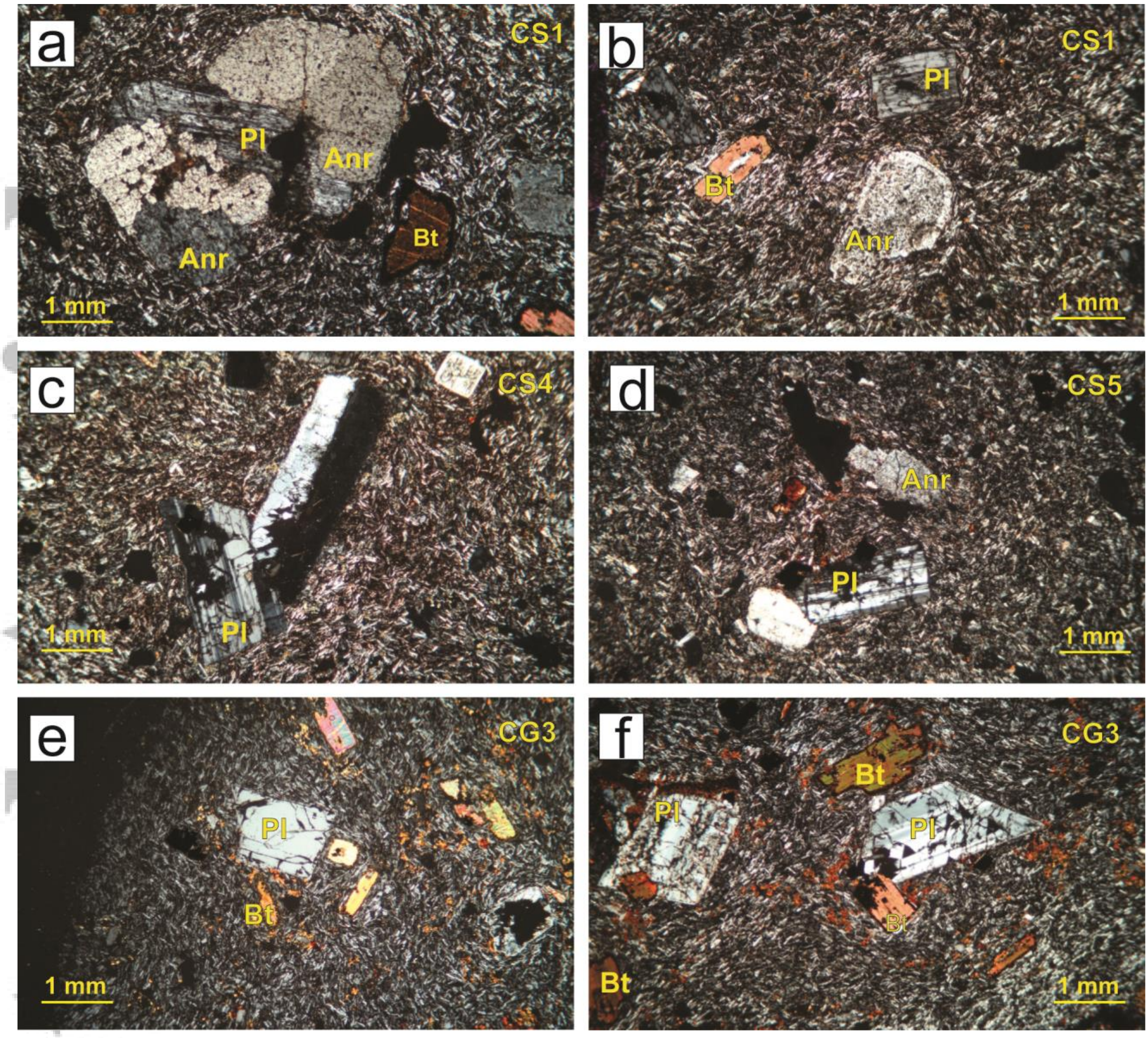

Figure 2 - Thin-section photomicrographs (crossed polarized light) of selected Protohistoric grinding stones from *Caput Adriae.* They show anorthoclase (Anr), plagioclase (Pl) and biotite (Bt) phenocrysts in a microcrystalline(-trachytic) groundmass mainly composed by microlites of sanidine-plagioclase-opaques.

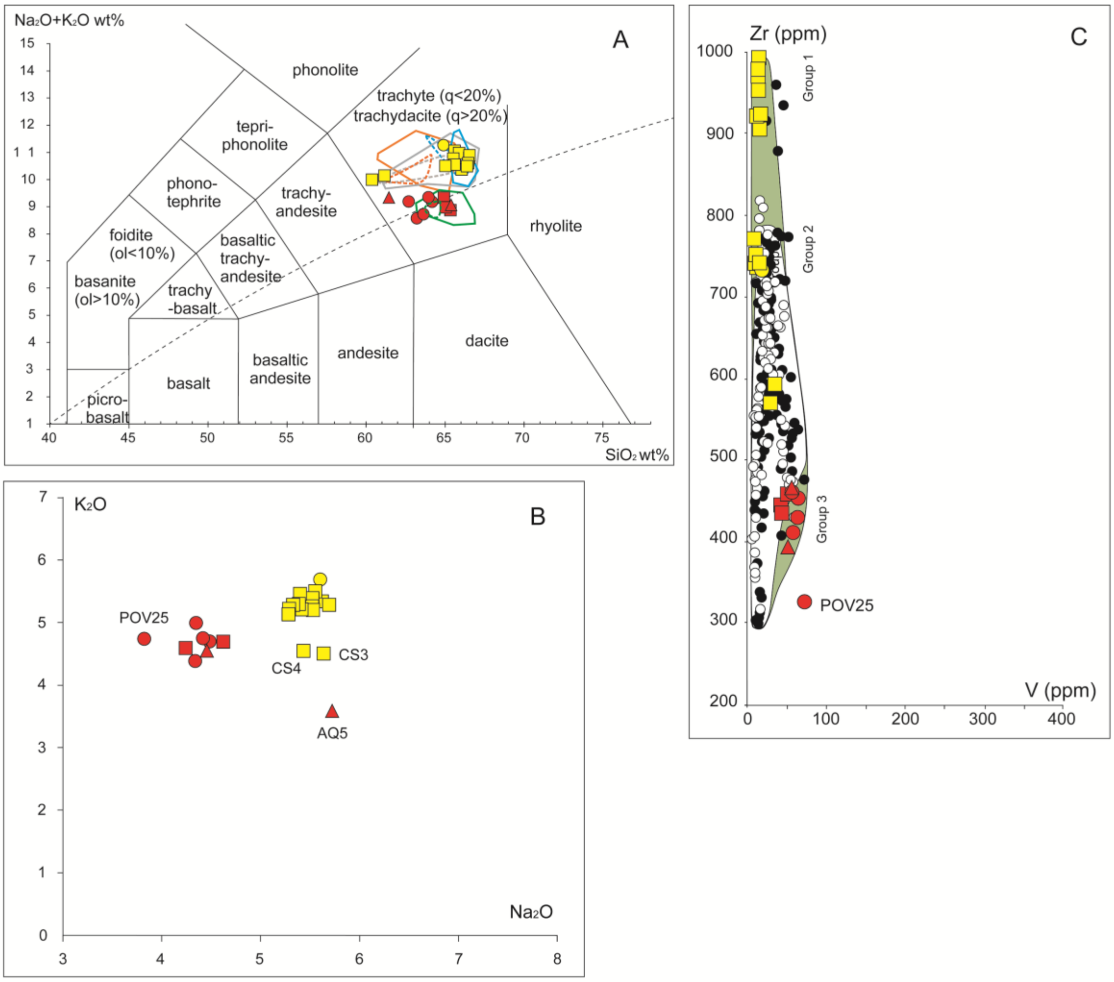

Figure 3 - (A) Total alkali *vs*. silica classification diagram, (Le Bas et al., 1992) for the analysed samples. Fields of the possible provenance areas are plotted for comparison. Green field, Mt. Rosso; orange field, Mt. Merlo; grey field, Mt. Cero and Mt. Murale; light blue, Mt. Altore and Mt. Pendice. Fields from Capedri et al. (2000) are within solid lines, while those from Germinario et al. (2018a) are within dotted lines. The dashed line divides the diagram into alkaline and subalkaline fields (Miyashiro, 1978). (B) K_2O *vs.* Na_2O diagram of the investigated samples. (C) Zr *vs.* V discrimination diagram (after Williams-Thorpe, 1988, modified by Antonelli & Lazzarini, 2012) for the investigated samples. The white field corresponds to the Euganean Hills according to Antonelli & Lazzarini (2012), while the green field represents the composition of the *Caput Adriae* grinding stones produced with the Euganean trachytes. Black and white circles correspond to all Euganean Hills samples from Capedri et al. (2000) and Germinario et al. (2018a), respectively. Symbols and colours as in Figure 1.

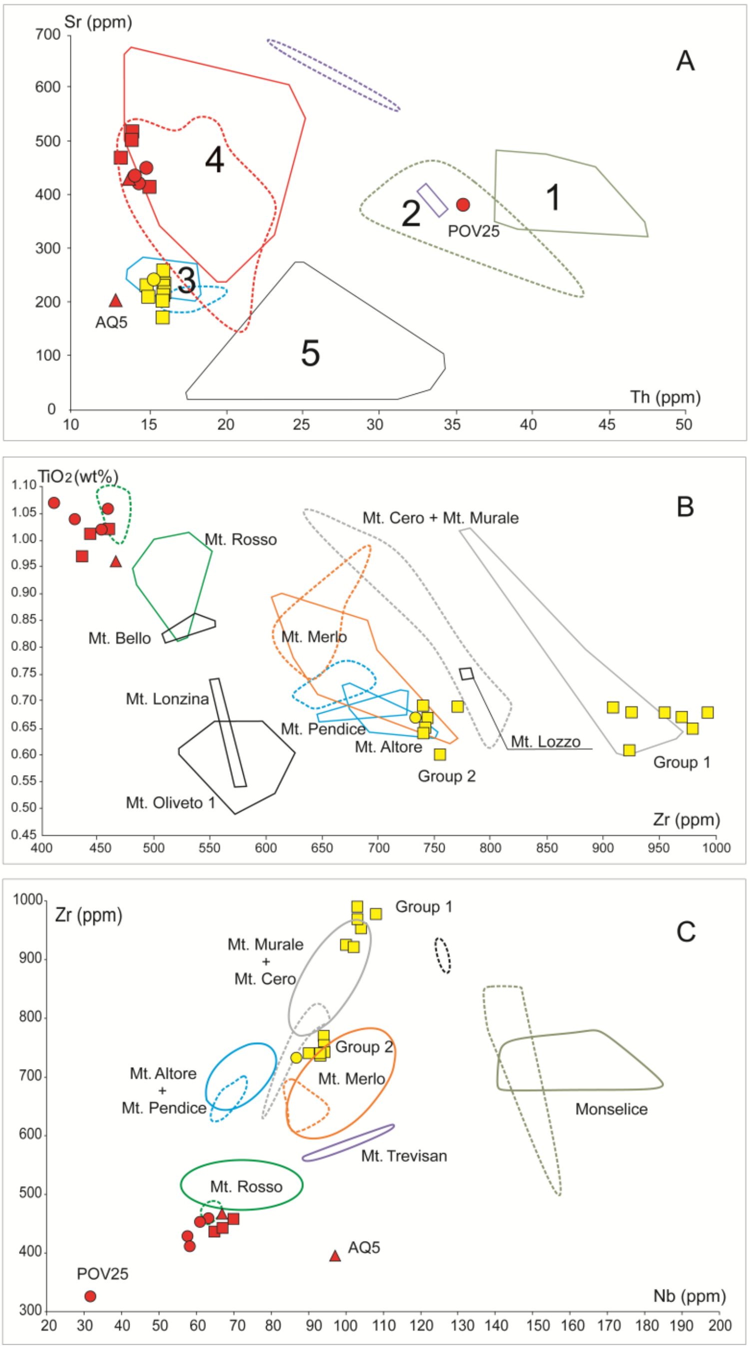

Figure 4 - (A) Th *vs.* Sr (ppm) diagram after Capedri et al. (2000; fields enclosed by solid lines) modified including data from Germinario et al. (2018a; fields enclosed by dotted lines). Fields: 1 (Monselice), 2 (Mt. Trevisan), 3 (Mt. Altore and Mt. Pendice), 4 (Mt. Oliveto1, Mt. Bello, Mt. Cero, Mt. Lonzina, Mt. Lozzo, Mt. Merlo, Mt. Murale, Mt. Rosso), 5 (Mt. Alto, Mt. Grande, Mt. Lispida, Mt. Oliveto2, Mt Rustà, Mt. S. Daniele). (B) Zr (ppm) *vs.* TiO_2 (%) diagram after Capedri et al. (2000) modified adding the fields of Mt. Altore and Mt. Pendice (Capedri et al., 200) and the fields of Mt. Merlo, Mt. Altore + Mt. Pendice and Mt. Cero + Mt. Murale of Germinario et al. (2018a; fields within dotted lines). POV25 and AQ15 fall outside the diagram. (C) Nb *vs.* Zr (ppm) diagram. The fields of Mt. Rosso, Mt. Merlo, Mt. Cero + Mt. Murale and Mt. Altore + Mt. Pendice, Monselice and Mt. Trevisan have been drawn based on the literature data by Capedri et al. (2000; fields within solid lines) and Germinario et al. (2018a; fields within dotted lines). Symbols and colours as in Figure 1.

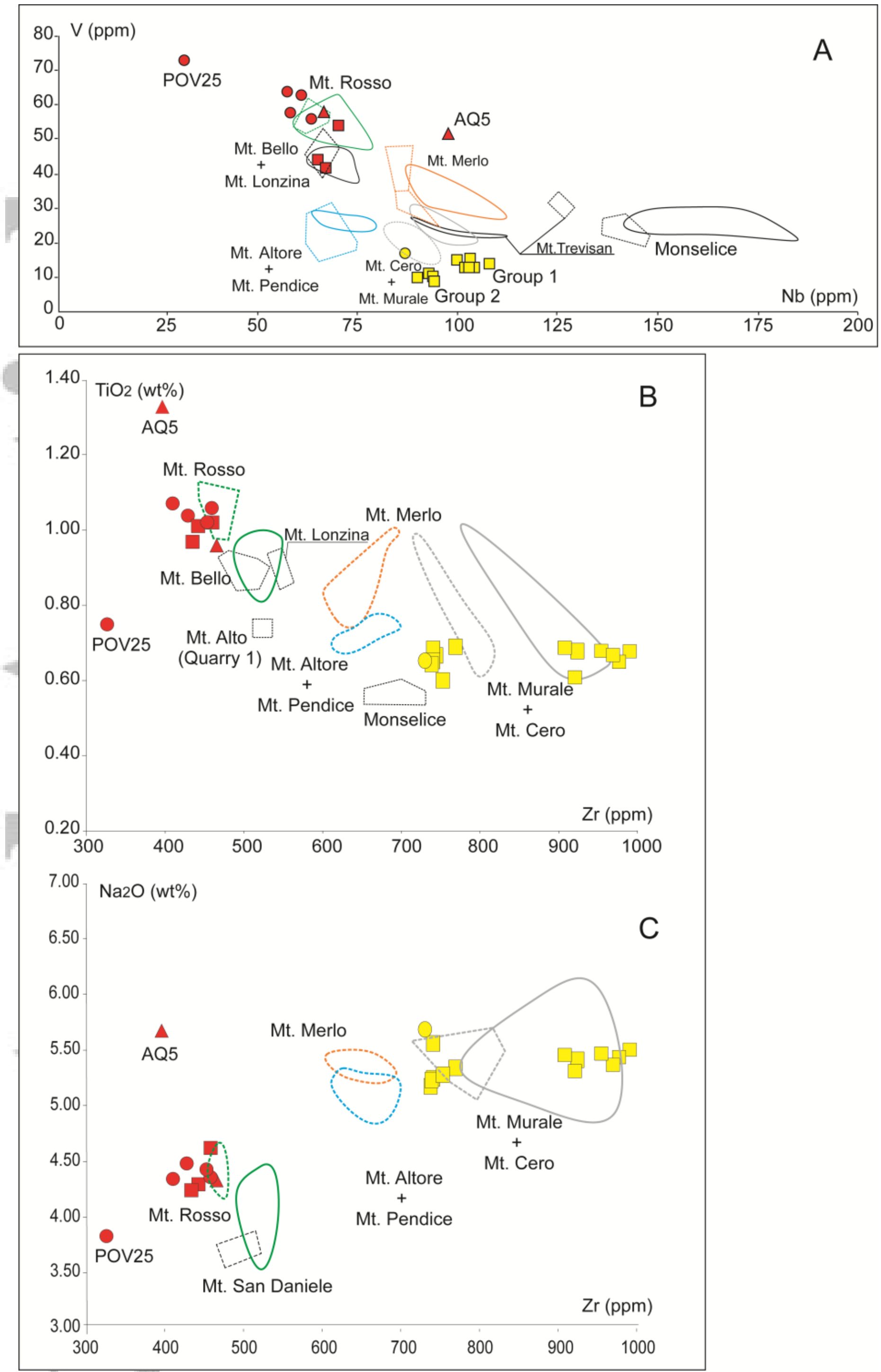

Figure 5 - (A) V *vs*. Zr (ppm) diagram after Germinario et al. (2018b; fields within dotted lines) modified adding the fields of the same localities based on Capedri et al. (2000; fields within solid lines with the same colour as the one of the corresponding fields of Germinario et al. (2018a). (B-C) TiO_2 *vs*. Zr and Na_2O *vs*. Zr plots after Germinario et al. (2018b; fields within dotted lines) modified adding the fields of Mt. Rosso and Mt. Cero + Mt. Murale based on Capedri et al. (2000; fields within solid lines with the same colour as the one of the corresponding fields of Germinario et al., 2018a). Symbols and colours as in Figure 1.

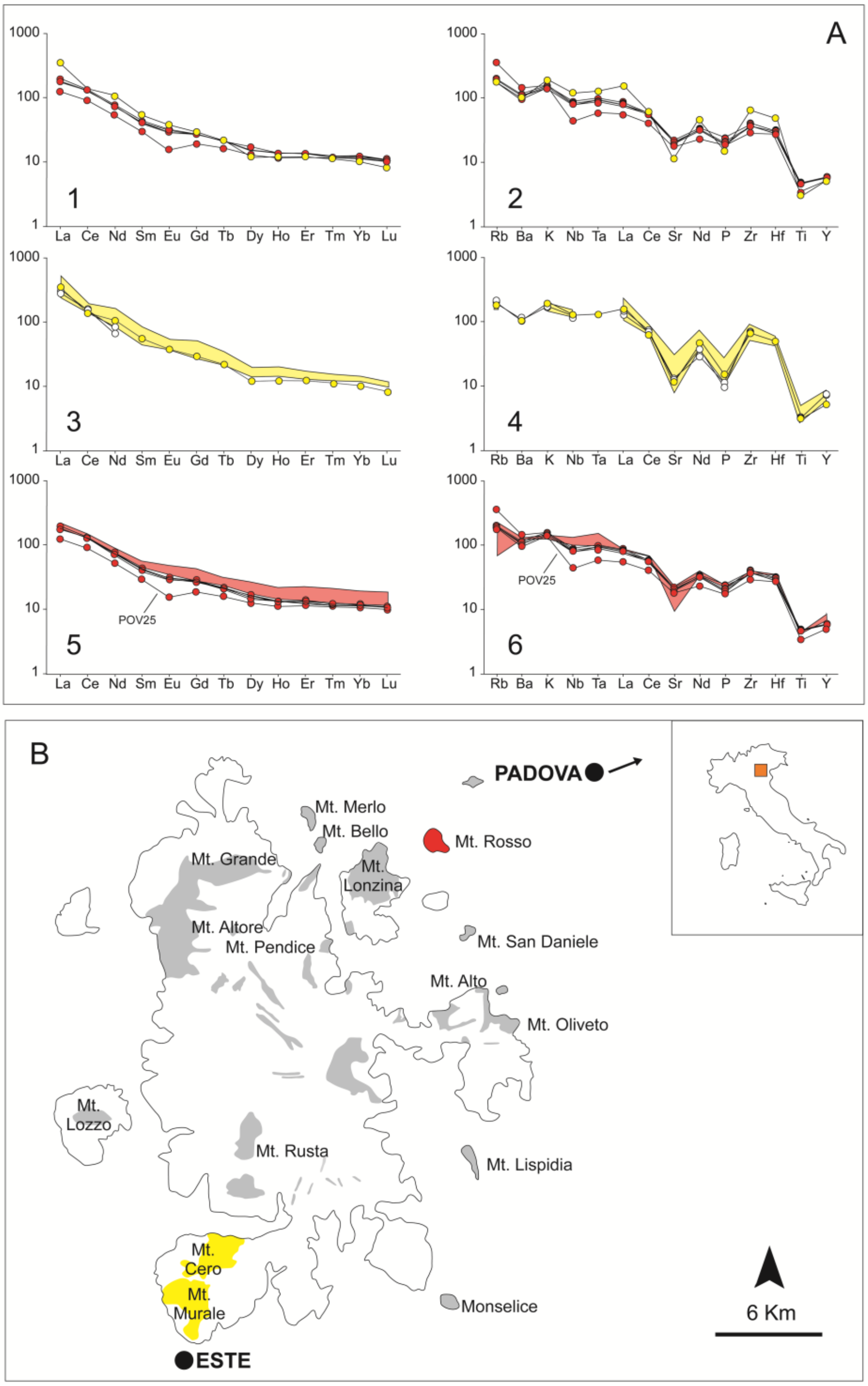

Figure 6 - (A) Rare earth and incompatible elements of the artefacts analysed in the present paper (1 and 2, respectively) and a comparison with the literature data on Protohistoric (3-4; Antonelli et al., 2004) and Roman grinding stones (5-6; Antonelli & Lazzarini, 2012). Selected samples from Mt. Cero (MUR-05) and Mt. Murale (MUR-03) from Germinario et al. (2018a; white circles) are plotted in diagrams 3-4, for comparison. The chondrite values used for the normalization of the REE patterns are after Boynton (1984), while the PM values (Primitive Mantle) of McDonough & Sun (1995) have been used for the normalization of the IE. (B) Trachyte outcrops of Euganean Hills with the indications of probable Protohistoric (in yellow) and Roman (in red) sources of the grinding stones found in *Caput Adriae*.

Table 1 - Resuming table of the finding site, chronology and typology of both the grinding stones here investigated and already described in literature.

Sample	Site	Chronology	Typology	Literature
CSA2	Sv. Ambrož (SLO)	Protohistoric	Saddle quern	This work
CSA1	Sv. Ambrož (SLO)	Roman	Rotary quern	This work
POV	Povir (SLO)	Roman	Rotary quern	This work
POV25	Povir (SLO)	Roman	Rotary quern	This work
BSN	Bukovica (SLO)	Roman	Rotary quern	This work
CE	Elleri/ Jelarji (ITA/SLO)	Roman	Rotary quern	This work
CS1	Slivia (ITA)	Protohistoric	Saddle quern	Antonelli et al., 2004
CS2	Slivia (ITA)	Protohistoric	Saddle quern	Antonelli et al., 2004
CS3	Slivia (ITA)	Protohistoric	Saddle quern	Antonelli et al., 2004
CS4	Slivia (ITA)	Protohistoric	Saddle quern	Antonelli et al., 2004
CS7	Slivia (ITA)	Protohistoric	Undetermined	Antonelli et al., 2004
CS8	Slivia (ITA)	Protohistoric	Undetermined	Antonelli et al., 2004
CG1	Gradiscata (ITA)	Protohistoric	Saddle quern	Antonelli et al., 2004
CG3	Gradiscata (ITA)	Protohistoric	Saddle quern	Antonelli et al., 2004
CSL1	S. Leonardo (ITA)	Protohistoric	Saddle quern	Antonelli et al., 2004
CSL3	S. Leonardo (ITA)	Protohistoric	Saddle quern	Antonelli et al., 2004
CSL5	S. Leonardo (ITA)	Protohistoric	Undetermined	Antonelli et al., 2004
CPO1	Povir (SLO)	Protohistoric	Saddle quern	Antonelli et al., 2004
CM1	Monrupino (ITA)	Protohistoric	Saddle quern	Antonelli et al., 2004
CP1	Picugi (CRO)	Protohistoric	Saddle quern	Antonelli et al., 2004
CP3	Picugi (CRO)	Protohistoric	Saddle quern	Antonelli et al., 2004
CP5	Picugi (CRO)	Roman	Rotary quern	Antonelli et al., 2004
CP6	Picugi (CRO)	Roman	Rotary quern	Antonelli et al., 2004
CP7	Picugi (CRO)	Roman	Rotary quern	Antonelli et al., 2004
AQ3	Aquileia (ITA)	Roman	Rotary quern	Antonelli & Lazzarini, 2012
AQ5	Aquileia (ITA)	Roman	Rotary quern	Antonelli & Lazzarini, 2012

Table 2 - Major and trace elements' composition of the investigated samples. Major elements are expressed as anhydrous analyses in wt%, while the trace elements are expressed in ppm.

	CSA2	POV	POV 25	CSA1	BSN	CE
SiO2 (wt%)	64.94	62.68	63.26	64.00	64.21	63.62
TiO2	0.67	1.04	0.75	1.06	1.02	1.07
Al2O3	17.58	17.14	19.49	16.40	16.37	16.36
Fe2O3	3.12	5.16	2.86	4.70	4.82	4.87
MgO	0.56	1.41	1.30	1.18	1.06	1.38
MnO	0.05	0.05	0.03	0.06	0.06	0.07
CaO	1.39	2.93	3.36	2.81	2.88	3.37
Na2O	5.60	4.48	3.82	4.35	4.42	4.34
K2O	5.68	4.69	4.74	4.99	4.74	4.39
P2O5	0.33	0.42	0.39	0.45	0.42	0.53
Ni (ppm)	<20.00	<20.00	<20.00	<20.00	<20.00	<20.00
V	17.00	64.00	73.00	56.00	63.00	58.00
Cr	-	-	34.15	-	-	8.53
Rb	115.10	112.60	230.20	124.80	127.90	119.40
Ba	701.00	812.00	1017.00	729.00	715.00	668.00
Th	15.40	14.90	35.50	14.40	13.20	14.20
U	4.30	4.20	12.90	4.10	4.00	3.90
Pb	25.00	5.20	5.10	12.40	4.70	7.50
Sr	243.40	453.80	384.70	424.00	470.90	438.50
Nb	86.80	57.50	31.60	63.30	60.90	58.20
Ta	5.30	3.50	2.40	4.10	3.60	3.70
Zr	732.30	428.60	326.40	459.10	452.80	410.10
Hf	15.20	9.90	8.70	9.70	9.70	9.50
Y	23.80	27.00	23.20	27.00	27.30	26.70
La	106.60	59.70	38.20	60.80	59.70	54.40
Ce	111.20	105.90	72.80	106.10	105.90	105.60
Pr	18.87	11.88	8.74	11.8	12.18	11.97
Nd	62.60	46.40	31.60	43.4	46.60	43.00
Sm	9.73	8.12	5.76	7.9	8.39	8.33
Eu	2.60	2.20	1.15	2.14	2.19	2.30
Gd	7.30	7.16	4.86	7.03	7.33	6.96
Tb	1.02	1.03	0.76	0.99	1.03	1.02

Dy	4.80	5.21	4.18	4.77	5.42	5.46
Ho	0.85	0.99	0.83	0.96	0.97	0.97
Er	2.43	2.70	2.52	2.49	2.85	2.52
Tm	0.34	0.36	0.37	0.37	0.39	0.38
Yb	2.02	2.37	2.56	2.36	2.31	2.26
Lu	0.28	0.34	0.36	0.33	0.36	0.34