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# The Euganean trachyte flagstones ("*basoli*") used by the Romans along the mid-Adriatic coast (Marche, central Italy): an archaeometric study

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ABSTRACT. — Trachytes from the Euganean hills (Veneto) were used by the Romans as flagstones (*basoli*) along the northernmost stretch of the *Via Flaminia* (between *Fanum Fortunae,* now called Fano, and *Ariminum,* now Rimini) and in a pavement of the old town centre of Ancona (*Ancona*). The latter represents, up to date, the southern limit of spread of the Euganean *basoli* in the Roman period. Source identification of these volcanic rocks came from mineralogical constraints (*e.g.* presence of anorthoclase), major oxide geochemistry (*e.g.,* $K_2O/Na_2O \leq 1$), and patterns of trace elements (*e.g.,* lack of Nb-Ta negative anomaly). In addition, comparison of petrographic and chemical parameters of these flagstones with those of the Euganean trachyte quarries discriminated three sites of provenance: Monselice (*basoli* from *Ancona* and *Via Flaminia*), Mt. Oliveto and Mt. Merlo (*basoli* from *Via Flaminia*). These three quarries are located in the eastern margin of the Euganean hills, perfectly located for trading trachyte blocks along the nearby Adriatic, easily achieved by means of the network of drainage channels and canals (*e.g., Fossa Philistina*) linked to the rivers Brenta (*Meduacus*), Bacchiglione (*Edrone*) and Adige (*Atesis*). In the Roman period, the *Atesis* ran close to Monselice (before the catastrophic flood of 589 A.D.) and the palaeo-Adige was therefore a further waterway linking the Adriatic coast with the Euganean hills. In order to reach the mid-Adriatic coast, the Romans could also transport the *basoli* down to *Ravenna* along the so-called *Via Endolagunare*, an inner waterway running parallel to the *Via Popilia*.

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RIASSUNTO. — In epoca Romana, nel tratto più settentrionale della *Via Flaminia* (tra *Fanum Fortunae, i.e.* Fano e *Ariminum, i.e.* Rimini) e in una pavimentazione nel centro storico di Ancona (*Ancona*) sono stati utilizzati basoli trachitici dei Colli Euganei (Veneto). Sulla base dei dati raccolti, *Ancona* rappresenta attualmente il limite meridionale di diffusione dei basoli euganei in epoca romana. La provenienza di queste rocce vulcaniche è stata determinata attraverso vincoli di tipo mineralogico (*e.g.* la presenza di anortoclasio) e geochimico (*e.g.* i rapporti $K_2O/Na_2O \leq 1$ e l'assenza di anomalie negative di Nb e Ta). Inoltre, la comparazione dei parametri petrografici e chimici dei basoli studiati con quelli delle trachiti delle cave euganee ha permesso di discriminare tre siti estrattivi: Monselice (basoli di *Ancona* e della *Via Flaminia*), Monte Oliveto e Monte Merlo (basoli della *Via Flaminia*). Queste tre cave sono localizzate nel margine orientale dei Colli Euganei, una posizione ideale per il commercio dei basoli di trachite attraverso il vicino mare Adriatico, raggiungibile facilmente con la rete di canali artificiali (e.g. la *fossa Philistina*) legata ai fiumi Brenta (*Meduacus*), Bacchiglione (*Edrone*) e Adige (*Atesis*). Quest'ultimo in particolare, che in epoca romana (prima della catastrofica alluvione del 589 A.D.) attraversava il territorio di Monselice, rappresentava un'importante via d'acqua che collegava l'Adriatico ai Colli Euganei. Per trasportare i basoli verso le destinazioni costiere medio-adriatiche i Romani avevano inoltre a disposizione, almeno fino a *Ravenna*, una via d'acqua endolagunare interna (*Via Endolagunare*) che correva parallela alla *Via Popilia*.

KEY WORDS: Euganean hills, trachyte, flagstones, *basoli*, petrology, archaeometry, Romans, Marche, *Via Flaminia, Ancona.*

## INTRODUCTION

The Euganean hills are located in north-eastern Italy (Fig. 1) and belong to the Venetian Tertiary Volcanic Province (Upper Paleocene-Upper Oligocene) which developed during the Alpine orogenesis under an extensional regime (De Vecchi *et al.*, 1974, 1976; De Pieri *et al.*, 1983; Milani *et al.*, 1999). Recent Rb/Sr radiochronological data indicate the Lower Oligocene as the most probable time of eruptions for the Euganean area (Zantedeschi, 1994). Prevailing rhyolite and trachyte lava domes with a moderate Na-alkaline magmatic affinity were erupted over an area of about 100 $km^2$; latite and basaltic lavas are subordinate (Piccoli *et al.*, 1975). Quarrying in the trachyte domes of the Euganean hills was often favoured by the fact that the rocks are of columnar jointed type, making them easier to split (Capedri *et al.*, 2000).

The exploitation and trade of Euganean trachyte, documented since palaeo-Venetian times (VII-VI centuries B.C.; Zantedeschi and Zanco, 1993), became economically important during the Roman period and has continued until the present day, although the environmental impact on the gently sloping hills was devastating. In northern Italy, Euganean trachytes were mainly used by the Romans for pavements (*e.g., Via Aemilia* and *Via Popilia,* Fig. 2) or bridges (*e.g.,* the Roman bridge in *Parma*). It was also used as a building material (*e.g.* for columns), funerary monuments, cinerary urns, and *cippi* throughout the Po Plain and the Veneto and Emilia regions (Rodolico, 1964; Negri, 1966; Filippi, 1981; Zantedeschi and Zanco, 1993; De Vecchi and Lazzarini, 1994; Capedri *et al.*, 2000). Some Euganean trachytes were also used by the Romans to make millstones and mortars (Santi *et al.*, 2000; Renzulli *et al.*, 2002). The resistance to mechanical abrasion and alteration of this rock and its easy transport along the waterways linked to the Po Plain were the main reasons which led the Romans to export trachytes throughout central-northern Italy. Euganean trachyte flagstones have been found as far as Bressanone (*Brixentes*) and *Aquileia,* respectively north and north-east of the Euganean hills; westwards, they are found in Pavia (*Ticinum;* Capedri *et al.*, 2000). Trachyte flagstones from the Euganean hills were also used by the Romans to pave the northernmost stretch of the *Via Flaminia* along the mid-Adriatic coast in central Italy (Fig. 2; Renzulli *et al.*, 1999). The new discovery (present work) of Euganean trachyte flagstones used to pave a Roman road in the old city centre of *Ancona* (Fig. 3) has shifted the spread of these Venetian lithotypes 50 km southwards. The recent issue of a petrographic and chemical database of the Euganean trachyte quarries (Capedri *et al.*, 2000) was very welcome and greatly stimulated identification of the quarrying sites of the flagstones found in *Ancona* and on the *Via Flaminia.* On the basis of petrographic and geochemical investigations, combined with archaeological data, we hypothesise here how the Euganean trachyte flagstones were moved by the Romans from the quarries to the mid-Adriatic coast.

## ARCHAEOLOGICAL SITES AND SAMPLING

The trachyte flagstones from *Ancona* belong to a pavement which dates back to the first Roman Imperial Age (Luni, 2000), first discovered in 1987 during restructuring of a building in the old city centre. Sebastiani (1998) describes this road-stretch as 8 meters long and 5.4 m wide, paved with *basoli* «of unknown composition and provenance», slightly cemented to each other. The pavement has a NNW-SSE orientation, a difference of 0.5 m in level, and is bounded by limestone ramps on each side (Fig. 3a). The flagstones are irregular in size, being on average 0.6 × 0.4 m, and ancient tracks of carts can even be detected in them. Macroscopically, all the flagstones,

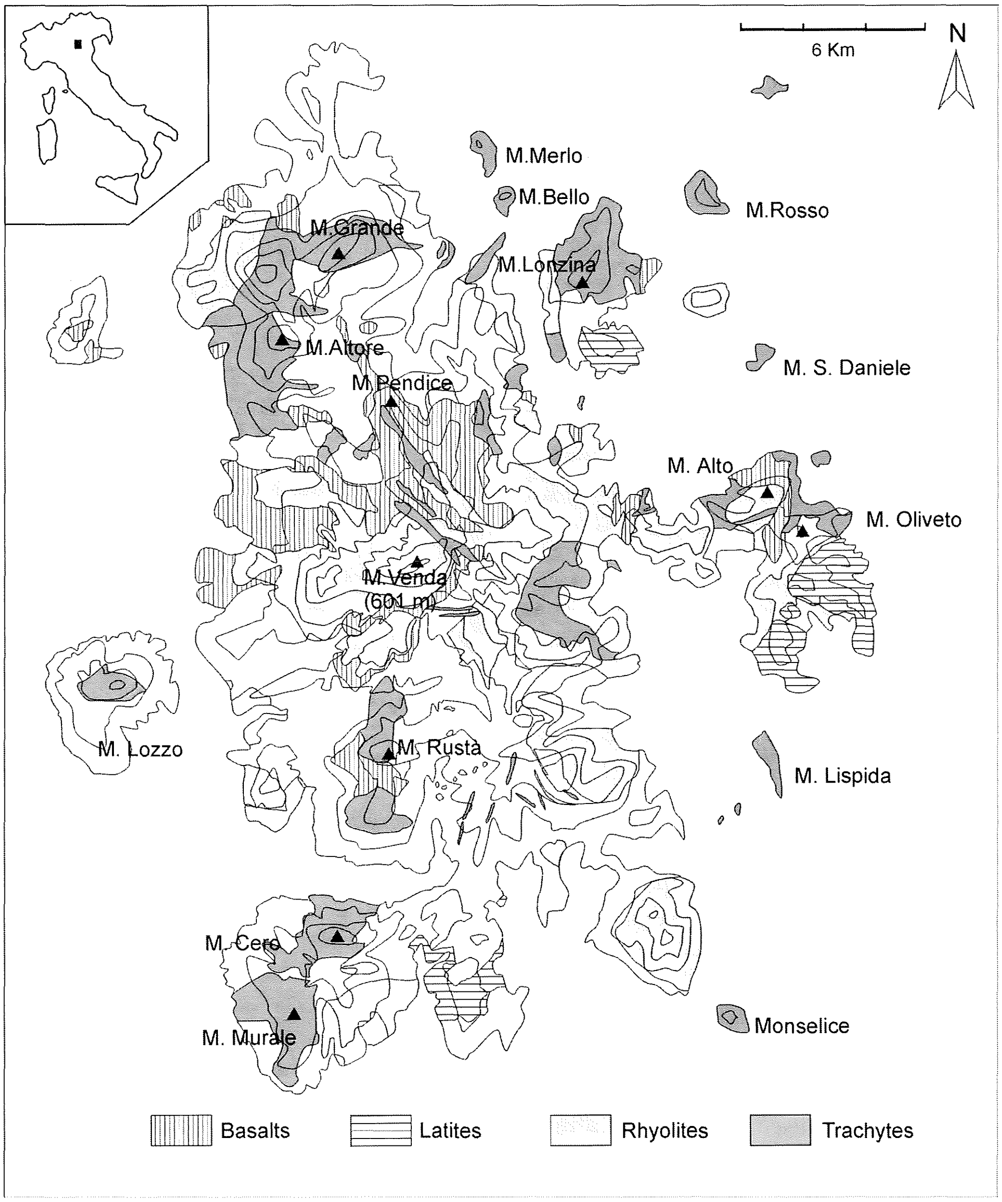


Fig. 1 - General geological map of Euganean hills (after Piccoli *et al.*, 1975).

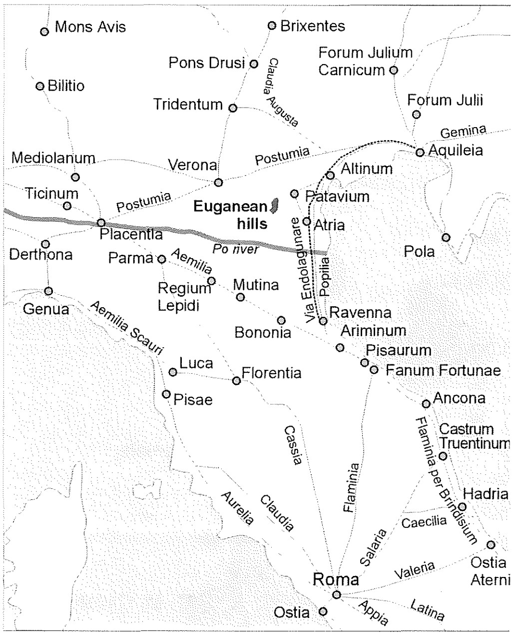


Fig. 2 - *Viae Publicae* in central-northern Italy during Roman period. Location of Euganean hills are also shown (modified after Capedri *et al.*, 2000).

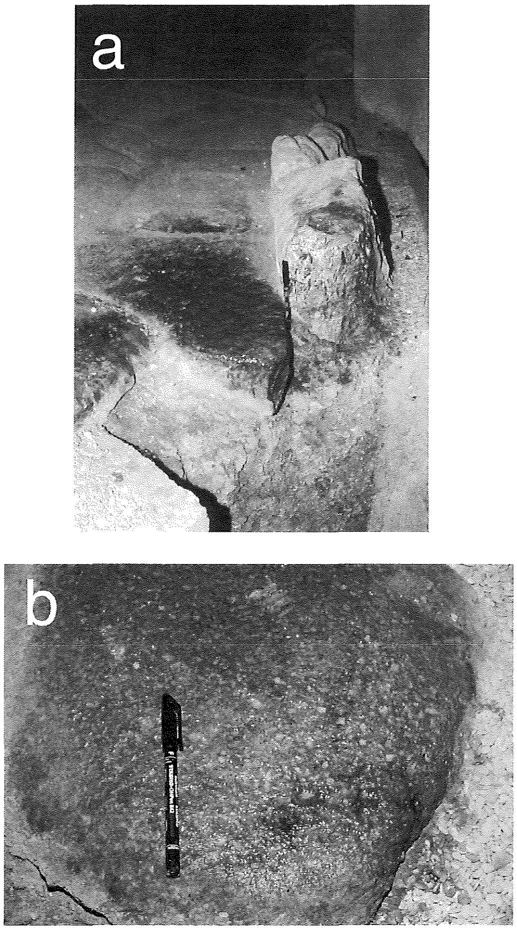


Fig. 3 - *Ancona* pavement: a) limestone ramps (right) border pavement consisting of trachyte flagstones; b) close-up of trachyte flagstone, showing yellowish-grey groundmass and abundant white feldspar phenocrysts, up to 1 cm in size.

characterised by abundant feldspar phenocrysts up to 1 cm in size, have the same yellowish-grey colour, and the same porphyritic index and crystal populations (Fig. 3b).

The flagstones from the northernmost stretch of the *Via Flaminia* (Fig. 2) were sampled from remains of pavements near the Arch of *Augustus* in Fano (*Fanum Fortunae*) and between Pesaro (*Pisaurum*) and Rimini (*Ariminum*). The *Via Flaminia* (Luni, 1995, 2000) was opened around the year 220 B.C. to join Rome to Rimini although, according to the *Itinerarium Antonini* (Radke, 1981), the name *Flaminia* was also used for the road joining *Ancona* to *Brindisium* (Brindisi), south along the Adriatic coast. The *Via Flaminia stricto sensu* (Fig. 2) ran along the valley of the Tiber, crossing the Apennines over the Scheggia Pass. It then continued along the valley of the Metauro, reaching the Adriatic at *Fanum Fortunae*, then turned north through *Pisaurum*, and finally reached *Ariminum*. The *Via Flaminia* was the most important route used by the Romans to reach northern Italy and all the northern provinces of the Roman Empire. In the following centuries, the northernmost stretch of the *Flaminia* continuously ran along the same route, and the original trachyte pavement of Augustean age, deeper than the present topography, is locally still well preserved. Along the ancient pavement, the flagstones are irregular, fitting tightly, with an average size of 0.55 × 0.4 m. There are frequent signs of ancient tracks of carts.

The samples studied here come from original blocks of the remains of pavement or from flagstones removed from their original position and re-used as constructional material in the Medieval city walls of Fano. Macroscopically, they show contrasting colours (grey, light grey, yellowish, pinkish) and a variable porphyritic index, with feldspar phenocrysts up to 1 cm in size. Among these samples, some were already studied and classified by Renzulli *et al.* (1999) as Na-trachytes from the Euganean hills. However, in order to compare flagstones with trachytes quarried in the Euganean hills (Capedri *et al.*, 2000), samples were re-analysed for more detailed petrographic study and complete geochemical characterization.

## Analytical methods

Trachytes were geochemically analysed at the Actlabs laboratory (Ontario, Canada) by ICP-OES (for major elements; Inductively Coupled Plasma-Optycal Emission Spectrometry) and ICP-MS (for trace elements; Inductively Coupled Plasma-Mass Spectrometry). Samples for the ICP-OES-MS method were mixed with a flux of lithium metaborate and lithium tetraborate and fused in an induction furnace. The molten melts were immediately poured into a solution of 5% nitric acid containing an internal standard, and mixed continuously until completely dissolved. The prepared sample solutions were run for major oxide and trace elements on a Thermo Jarrel-Ash ENVIRO II ICP and a Perkin Elmer SCIEX ELAN 6000 ICP-MS, respectively. Error is ≤ 1% for major oxides and ≤ 3% for trace elements.

For comparisons on whole-rock analytical techniques, some samples were also analysed by XRF at the Institute of Geological and Nuclear Sciences (Lower Hutt, New Zealand). These analyses were performed on fused glass discs (major elements) and pressed powder discs (trace elements) using a Siemens SRS303AS wavelength-dispersive unit. Error is ≤ 3% for major oxides and ≤ 5% for trace elements.

The complete geochemical data-set of the flagstone samples is listed in Table 1. To avoid damage to the ancient pavements, sampling was performed on very small flagstone fragments already broken off. Samples were crushed and powdered in an agate mortar to avoid contamination of trace element compositions.

## Petrography and geochemistry

All the flagstones are composed of trachytes (total alkali-silica classification; Le Bas *et al.*, 1986) consisting of anorthoclase + Na-sanidine + plagioclase + biotite + kaersutitic amphibole ± clinopyroxene as phenocryst modal mineralogy (Fig. 4); their $K_2O/Na_2O$ ratios range between 0.82 and 1.12 (Table 1). These petrochemical features, together with the lack of a Nb-Ta negative anomaly in the incompatible trace element patterns (Fig. 5), are typical of highly evolved Na-alkaline rocks which erupted in a within-plate extensional setting (Wilson, 1988). All the volcanic rocks from the Neogene-Quaternary magmatism of the Tyrrhenian region (Serri, 1990) are not geochemically compatible with the trace element compositions of our flagstones. By contrast, the mineralogy and geochemistry of Na-trachyte from the Euganean hills (Schiavinato, 1944; De Vecchi *et al.*, 1974, 1976; De Pieri *et al.*, 1977, 1978; De Pieri and Molin, 1980; De Pieri and Gregnanin, 1982; Milani *et al.*, 1999; Capedri *et al.*, 2000) virtually coincide with those of the *basoli* used by the Romans at *Ancona* and along the *Via Flaminia*. As the Euganean rocks extensively exploited by the Romans are petrographically and geochemically unique in Italy, we conclude that all the flagstones come from this volcanic area.

TABLE 1

*Whole-rock major and trace element compositions of trachyte flagstones from Ancona pavement and Via Flaminia*

| | Ancona pavement | | | | | | | Via Flaminia | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| sample | AN1° | AN1* | AN2° | AN3° | AN3* | AN4° | AN4* | 2MFA° | 2MFA* | 1MFD° | 1MFD* | 5BFF° | 5 BFF* | 4 BF° |
| **Major elements** | | | | | | | | | | | | | | |
| $SiO_2$ | 63.29 | 62.90 | 63.29 | 63.76 | 62.64 | 63.22 | 62.46 | 60.86 | 61.34 | 63.78 | 64.93 | 61.65 | 62.24 | 61.96 |
| $TiO_2$ | 0.52 | 0.55 | 0.51 | 0.52 | 0.54 | 0.52 | 0.54 | 0.57 | 0.59 | 0.58 | 0.59 | 0.81 | 0.84 | 0.72 |
| $Al_2O_3$ | 17.61 | 18.07 | 17.76 | 17.88 | 18.20 | 17.96 | 18.24 | 18.15 | 18.07 | 16.65 | 16.78 | 17.01 | 17.13 | 17.34 |
| $Fe_2O_3$ | 3.32 | 3.27 | 3.22 | 3.28 | 3.33 | 3.57 | 3.50 | 3.27 | 3.35 | 3.57 | 3.66 | 4.49 | 4.50 | 4.10 |
| MnO | 0.12 | 0.12 | 0.11 | 0.11 | 0.11 | 0.08 | 0.09 | 0.13 | 0.13 | 0.04 | 0.04 | 0.10 | 0.10 | 0.09 |
| MgO | 0.26 | 0.31 | 0.22 | 0.28 | 0.28 | 0.32 | 0.38 | 0.38 | 0.28 | 0.57 | 0.47 | 1.15 | 1.16 | 0.80 |
| CaO | 1.49 | 1.55 | 1.43 | 1.43 | 1.42 | 1.40 | 1.37 | 2.09 | 2.05 | 1.91 | 1.85 | 2.12 | 2.14 | 2.08 |
| $Na_2O$ | 5.86 | 5.97 | 6.00 | 5.93 | 6.11 | 5.97 | 6.03 | 5.67 | 5.70 | 5.39 | 5.52 | 5.34 | 5.40 | 5.63 |
| $K_2O$ | 5.89 | 6.27 | 5.42 | 5.48 | 6.01 | 5.82 | 6.11 | 5.85 | 6.37 | 4.48 | 4.73 | 4.76 | 5.04 | 4.63 |
| $P_2O_5$ | 0.26 | 0.22 | 0.24 | 0.26 | 0.22 | 0.29 | 0.23 | 0.22 | 0.18 | 0.34 | 0.31 | 0.44 | 0.42 | 0.40 |
| LOI | 0.65 | 0.59 | 0.68 | 0.64 | 0.65 | 0.78 | 0.67 | 1.71 | 1.46 | 1.54 | 0.88 | 0.80 | 0.62 | 1.09 |
| Total | 99.28 | 99.82 | 98.88 | 99.58 | 99.51 | 99.94 | 99.62 | 98.90 | 99.52 | 98.84 | 99.76 | 98.67 | 99.59 | 98.84 |
| $K_2O/Na_2O$ | 1.00 | 1.05 | 0.90 | 0.92 | 0.98 | 0.97 | 1.01 | 1.03 | 1.12 | 0.83 | 0.86 | 0.89 | 0.93 | 0.82 |
| **Trace elements** | | | | | | | | | | | | | | |
| V | 20 | 25 | 18 | 18 | 21 | 20 | 23 | 25 | 21 | 16 | 19 | 33 | 33 | 20 |
| Cr | | 1 | | | 1 | | 1 | | | 2 | | 6 | | 1 |
| Co | 2 | <1 | 2 | 2 | 2 | 2 | <1 | 2 | 5 | 3 | 3 | 5 | 7 | 4 |
| Ni | | 4 | | | 7 | | 7 | | | 4 | | 3 | | 5 |
| Cu | | 4 | | | 11 | | 7 | | | <1 | | 4 | | 9 |
| Ga | 31 | 30 | 31 | 29 | 29 | 32 | 30 | 28 | 29 | 25 | 23 | 21 | 24 | 22 |
| Rb | 202 | 193 | 190 | 158 | 167 | 190 | 179 | 178 | 189 | 124 | 123 | 111 | 132 | 115 |
| Sr | 454 | 426 | 484 | 477 | 473 | 476 | 471 | 430 | 416 | 389 | 392 | 454 | 475 | 455 |
| Y | 34 | 35 | 35 | 34 | 36 | 36 | 35 | 31 | 34 | 20 | 20 | 23 | 27 | 22 |
| Zr | 718 | 660 | 690 | 724 | 681 | 703 | 669 | 722 | 725 | 558 | 527 | 666 | 644 | 657 |
| Nb | 165 | | 158 | 153 | | 170 | | 193 | | 124 | | 99 | | 113 |
| Ba | 876 | 781 | 952 | 930 | 810 | 871 | 750 | 893 | 840 | 771 | 749 | 772 | 750 | 905 |
| La | 120 | 128 | 117 | 111 | 118 | 125 | 129 | 131 | 130 | 77.0 | 69.0 | 85.4 | 81.0 | 82.8 |
| Ce | 207 | | 201 | 195 | | 209 | | 210 | | 107 | | 141 | | 137 |
| Pr | 20.0 | | 20.2 | 18.9 | | 20.7 | | 17.5 | | 10.5 | | 11.7 | | 11.5 |
| Nd | 68.0 | | 67.5 | 64.7 | | 72.7 | | 63.8 | | 39.1 | | 44.9 | | 43.4 |
| Sm | 10.5 | | 10.3 | 10.3 | | 11.4 | | 10.4 | | 6.7 | | 8.0 | | 7.7 |
| Eu | 2.74 | | 2.80 | 2.83 | | | 2.94 | 2.62 | | 2.01 | | 2.34 | | 2.42 |
| Gd | 8.3 | | 8.4 | 8.0 | | 8.7 | | 8.4 | | 5.4 | | 6.6 | | 6.2 |
| Tb | 1.3 | | 1.2 | 1.2 | | 1.3 | | 1.1 | | 0.7 | | 0.9 | | 0.8 |
| Dy | 6.8 | | 6.6 | 6.7 | | 7.2 | | 5.5 | | 3.5 | | 4.1 | | 4.0 |
| Ho | 1.3 | | 1.2 | 1.2 | | 1.3 | | 1.0 | | 0.6 | | 0.7 | | 0.7 |
| Er | 3.5 | | 3.4 | 3.4 | | 3.4 | | 3.0 | | 1.9 | | 2.0 | | 2.1 |
| Tm | 0.51 | | 0.49 | 0.50 | | 0.50 | | 0.45 | | 0.27 | | 0.27 | | 0.30 |
| Yb | 3.1 | | 2.9 | 3.2 | | 3.3 | | 2.6 | | 1.7 | | 1.7 | | 1.9 |
| Lu | 0.43 | | 0.41 | 0.42 | | 0.45 | | 0.36 | | 0.24 | | 0.21 | | 0.26 |
| Hf | 16.3 | | 15.7 | 15.8 | | 16.5 | | 15.9 | | 12.5 | | 12.4 | | 13.5 |
| Ta | 13.0 | | 12.4 | 12.6 | | 13.2 | | 14.3 | | 8.0 | | 6.4 | | 6.6 |
| Pb | 12 | 11 | 13 | <5 | 10 | 14 | 12 | 17 | 21 | 22 | 6 | 16 | 11 | 19 |
| Th | 37.5 | | 36.9 | 36.6 | | 38.1 | | 35.1 | | 12.9 | | 14.1 | | 10.4 |
| U | 7.1 | | 7.0 | 8.7 | | 9.6 | | 10.8 | | 3.3 | | 4.2 | | 3.6 |

° analyses by ICP-OES-MS; * analyses by XRF

*Basoli from Ancona*

The *basoli* from the *Ancona* pavement are composed of Na-trachyte with a Porphyritic Index (hereafter P.I.) around 25%. They all show exactly the same porphyritic (not seriate) texture, modal mineralogy and petro-chemical parameters, so that provenance from the same quarry may be inferred. Phenocrysts and glomerophyres of allotriomorphic to subhedral anorthoclase are the most abundant (≥ 90% of all phenocrysts) with crystals reaching 10 mm in size. The anorthoclase phenocrysts often have a spongy texture, typical of unstable minerals in reaction with the host melt. These crystals may show very thin rims of anorthoclase overgrowths. Phenocrysts of Na-sanidine, biotite, plagioclase, kaersutitic amphibole and clinopyroxene are also present in decreasing order of abundance, together with rare glomerophyres of feldspar + amphibole ± biotite ± opaques. Euhedral to subhedral plagioclase phenocrysts are never rimmed by anorthoclase or Na-sanidine. Biotite and amphibole are often oxidised and embayed, with opaque rims. Among accessory minerals, opaques are ubiquitous and apatite prevails over titanite. The microcrystalline groundmass shows a pilotassitic texture (Fig. 4a), composed of feldspar microlite laths strongly aligned by magmatic flow, ± opaques ± mafic microlites.

As shown in Table 1, the geochemistry of the flagstones from the *Ancona* pavement (AN1, AN2, AN3, AN4) is quite homogeneous for

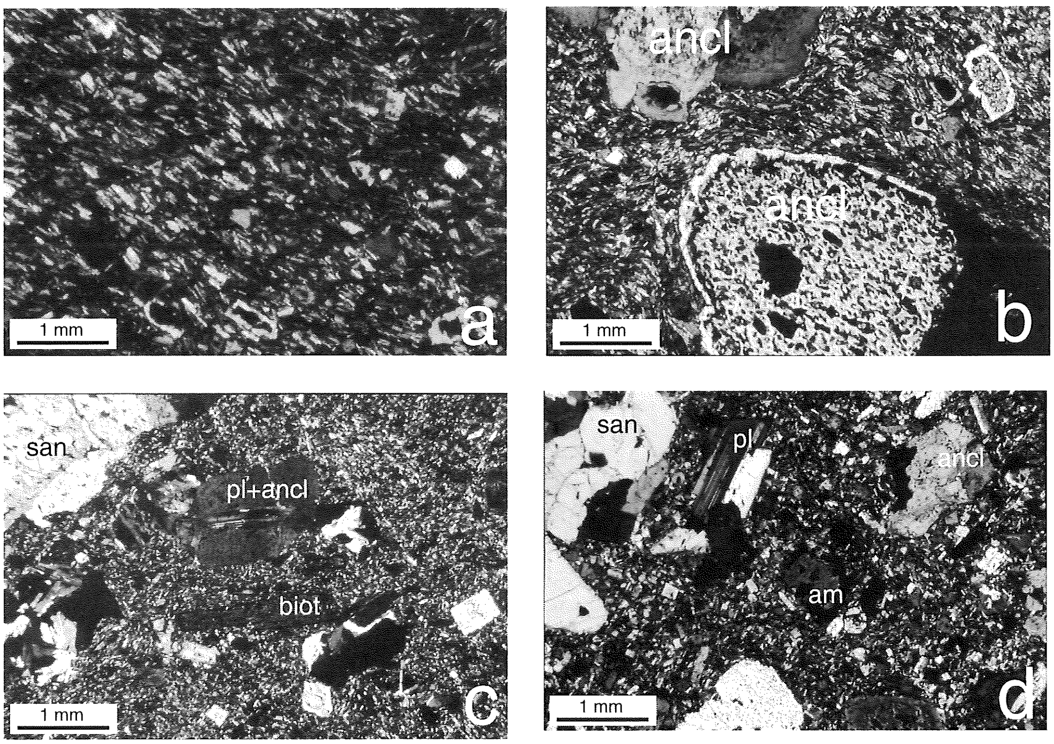


Fig. 4 – Thin-section petrography of Euganean trachytes used by Romans as flagstones along mid-Adriatic coast: a) sample AN2 (*Ancona*), inferred to come from Monselice quarry; b) sample 2MFA (*Via Flaminia*), from Monselice quarry; c) sample 1MFD (*Via Flaminia*), from Mt. Oliveto quarry; d) sample 5BFF (*Via Flaminia*), from Mt. Merlo quarry. Abbreviations of minerals: ancl=anorthoclase, pl=plagioclase, san=sanidine, biot=biotite, am=amphibole. For textures, see text.

both major ($SiO_2$ 62.5-63.8%, $TiO_2$ 0.5%, $Al_2O_3$ 17.6-18.2%, MgO 0.2-0.4%, $Na_2O$ 5.9-6.1%, $K_2O$ 5.4-6.3%) and trace elements. They are characterised by relatively high Rb (158-202 ppm), Nb (153-170 ppm), Th (37-38 ppm) Y (34-36 ppm), Ta (12-13 ppm), LREE (La 111-129, Ce 195-209, Nd 65-73 ppm) and HREE (Yb 2.9-3.3, Lu 0.41-0.45 ppm). They all have extremely similar incompatible trace elements and REE patterns, characterised by strong Th and Ta positive anomalies and relative enrichment in LREE ($La_N$ and $Ce_N$ 300-400) with respect to HREE ($Yb_N$ and $Lu_N$ 10-20; Fig. 5).

*Basoli from the northern stretch of the Via Flaminia*

Flagstones from the *Via Flaminia* pavement are Na-trachytes with P.I. between 20 and 35%. Various lithotypes are present and therefore different quarries may be inferred from textures, modal mineralogy and petrographic-chemical parameters.

Sample 2MFA (Fig. 4b) has the same petrographic texture, modal mineralogy (Table 2) and major-trace element abundances (Table 1; Fig. 5) as the *Ancona* flagstones.

Sample 1MFD is porphyritic, slightly seriate, with a P.I. between 20-25%. Feldspar phenocrysts (up to 8 mm) are by far dominant (95% of phenocryst populations), with euhedral plagioclase ≤ to allotriomorphic-subhedral anorthoclase, locally showing a spongy texture. Euhedral plagioclase is optically zoned and texturally sieved with rims of anorthoclase or Na-sanidine overgrowths (Fig. 4c). Among the other phenocrysts, biotite and amphibole are often strongly resorbed and oxidised; clinopyroxene is rare. Opaque minerals and apatite constitute accessory phases; titanite is absent. The groundmass is microcrystalline, weakly pilotassitic, and consists of feldspars ± quartz. The whole-rock major-element composition is $SiO_2$ *ca.* 64.5%, $TiO_2$ *ca.* 0.6%, $Al_2O_3$ *ca.* 16.5%, MgO *ca.* 0.5%, $Na_2O$ *ca.* 5.5%, $K_2O$ *ca.* 4.5%. The trace element contents of sample 1MFD (Fig. 5) are significantly different from that of sample

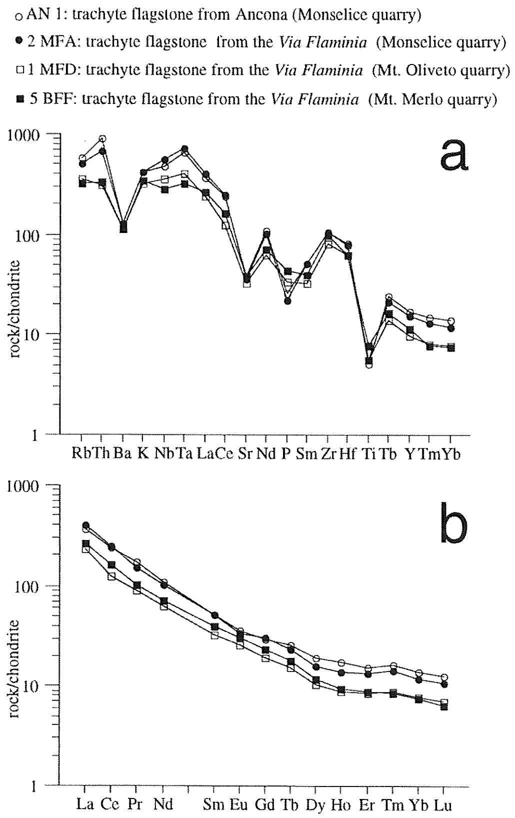


Fig. 5 - Incompatible trace element (a) and REE (b) spidergrams for *Ancona* pavement and *Via Flaminia* trachyte flagstones. Normalization to chondrite for incompatible trace elements and REE are from Thompson *et al.* (1984) and Nakamura (1974), respectively.

2MFA and flagstones from *Ancona*, with lower Rb (123-124 ppm), Nb (124 ppm), Th (13 ppm), Y (20 ppm), Ta (8 ppm), LREE (La 77, Ce 107, Nd 39 ppm) and HREE (Yb 1.7, Lu 0.24 ppm).

Samples 5BFF and 4BF show a porphyritic seriate to slightly seriate texture with a P.I. between 30 and 35% (Fig. 4d). Feldspars, which constitute the most abundant phase among the phenocryst populations, may reach a maximum size of 9 mm. Anorthoclase may be both euhedral and allotriomorphic, with a local

TABLE 2

*Main petrographic parameters of trachyte flagstones from Ancona pavement and Via Flaminia. Compatible quarrying sites are according to petrographic parameters of Euganean trachyte quarries (Capedri et al., 2000).*

| **Sample reference** | AN 1, AN 2, AN 3, AN 4 *(Ancona)* 2MFA *(Via Flaminia)* | 1MFD *(Via Flaminia)* | 5BFF, 4BF *(Via Flaminia)* |
|---|---|---|---|
| **Rock-type** | Trachytes | Trachyte | Trachytes |
| **Texture** | Porphyritic, not-seriate with microcrystalline pilotassitic groundmass. *Compatible quarrying sites: Monselice* | Porphyritic, slightly seriate with microcrystalline, weakly pilotassitic groundmass. *Compatible quarrying sites: Mt. Oliveto, Mt. Lispida* | Porphyritic, seriate to slightly seriate with microcrystalline medium-grained, felty groundmass. *Compatible quarrying sites: Mt. Merlo, Mt. Lozzo, Mt. Rustà, Mt. Trevisan, Mt. Rosso* |
| **Porphyritic Index (P.I.)** | *ca.* 25% *Compatible quarrying sites: Monselice, Mt. Alto, Mt. S. Daniele, Mt. Grande, Mt. Rustà, Mt. Oliveto, Mt. Lonzina, Mt. Bello (V)* | 20-25% *Compatible quarrying sites: Monselice, Mt. Alto, Mt. S. Daniele, Mt. Grande, Mt. Rustà, Mt. Oliveto, Mt. Lonzina, Mt. Bello (V)* | 30-35% *Compatible quarrying sites: Mt. Pendice, Mt. Rosso, Mt. Altore, Mt. Merlo, Mt. Bello (U), Mt. Lozzo* |
| **Max. size of feldspars** | 10 mm *Compatible quarrying sites: Monselice, Mt. Altore, Mt. Oliveto, Mt. Merlo, Mt. Lozzo, Mt. Lonzina, Mt. Murale* | 8 mm *Compatible quarrying sites: Monselice, Mt. Altore, Mt. Oliveto, Mt. Merlo, Mt. Lozzo, Mt. Lonzina, Mt. Murale* | 9 mm *Compatible quarrying sites: Monselice, Mt. Altore, Mt. Oliveto, Mt. Merlo, Mt. Lozzo, Mt. Lonzina, Mt. Murale* |
| **Modal anorthoclase/ plagioclase ratio** | anorthoclase > plagioclase *Compatible quarrying sites: Monselice, Mt. Alto, Mt. S. Daniele, Mt. Grande, MT. Rustà; Mt. Pendice; Mt. Altore, Mt. Merlo, Mt. Lozzo* | anorthoclase = plagioclase *Compatible quarrying sites: Mt. Oliveto* | anorthoclase > plagioclase *Compatible quarrying sites: Monselice, Mt. Alto, Mt. S. Daniele, Mt. Grande, Mt. Rustà, Mt. Pendice, Mt. Altore, Mt. Merlo, Mt. Lozzo* |
| **Inferred quarrying sites** | Monselice quarry | Mt. Oliveto quarry | Mt. Merlo quarry |

spongy texture and thin rims of feldspar overgrowths. It is more abundant than euhedral plagioclase, which is often mantled by thick overgrowths of anorthoclase or Na-sanidine. Mafic minerals are well represented (up to 15% of all phenocrysts), with biotite and amphibole (always characterised by opaque rims and frequent embayments) prevailing over a little euhedral or resorbed clinopyroxene. Apatite is the most common accessory phase, found both as microlites or within glomerophyres, associated with biotite + feldspar ± amphibole ± opaques. The groundmass is microcrystalline, showing a medium-grained felty texture (microlites are in the range 0.1-0.05 mm), composed of feldspar laths, interstitial mafic minerals, mainly altered to a celadonite-like material, and small grains of opaques. $SiO_2$ is 61.6-62.2%, $TiO_2$ 0.7-0.8%, $Al_2O_3$ 17.0-17.3%, MgO 0.8-1.2%, $Na_2O$ 5.3-5.6% and $K_2O$ 4.6-5.0% (Table 1). Like sample 1MFD, they have relatively low Rb (111-132 ppm), HFSE (Nb 99-113, Th 10-16, Y 22-27, Ta 6-7 ppm), LREE (La 81-85, Ce 137-141, Nd 43-45 ppm) and HREE (Yb 1.7-1.9, Lu 0.21-0.26 ppm; Table 1).

Samples 1MFD, 5BFF and 4BF do not show Th and Ta spikes and are depleted in most incompatible trace elements (including REE) when compared with the *Ancona* flagstones and sample 2MFA from the *Via Flaminia* (Fig. 5).

## QUARRIES

The Euganean provenance of the trachyte flagstones used by the Romans for paving the northern stretch of the *Via Flaminia* of Augustean age was already established by Renzulli *et al.* (1999). However, only a rough discrimination of the quarries was made by these authors, since no detailed petrographic and geochemical data of trachyte from the Euganean quarries were available for comparisons in the past. Recently, Capedri *et al.* (2000) proposed a diagnostic scheme based on petrographic (mainly texture, modal mineralogy, feldspar size, feldspar texture and anorthoclase/plagioclase phenocryst ratios) and geochemical parameters to discriminate quarries in the Euganean hills. The Euganean trachytes have very similar abundances of most major elements and are therefore not easily distinguishable in terms of these oxides. By contrast, as proposed by Capedri *et al.* (2000), trace element distributions and $TiO_2$ contents are sufficiently variable among the different quarries to allow good discrimination. This is possible because trachyte from individual quarries is chemically quite homogeneous.

All the trachyte flagstones from the present study belong to the group of Euganean trachytes with K-feldspar phenocrysts and aggregates sized between 4 and 10 mm (*i.e.*, Monselice, Mt. Altore, Mt. Oliveto, Mt. Merlo, Mt. Lozzo, Mt. Lonzina, Mt. Murale; Capedri *et al.*, 2000). Among these quarries, only the Monselice trachyte has a well-defined pilotassitic groundmass and is therefore compatible with all the *Ancona* samples (AN1, AN2, AN3, AN4) and sample 2MFA from *Via Flaminia.* These flagstones also show titanite microlites and microphenocrysts only found in the Monselice lithotype (very subordinate at Mt. Trevisan; Capedri *et al.*, 2000). The P.I., modal anorthoclase/plagioclase ratios and feldspar textures of all samples from *Ancona* and sample 2MFA are also consistent with trachyte from Monselice (Table 2). In the Th *vs.* Sr discriminating diagram of the Euganean trachytes, these samples are within or just outside the field of the Monselice quarry. It should be noted that this very slight average difference in Th content may be due to differences in the accuracy between ICP-MS (this work) and XRF (Capedri *et al.*, 2000) analyses. However, due to very different petrographic parameters, none of these samples can be attributed to the Mt. Trevisan quarry, which has the closest high Th field with respect to Monselice (Fig. 6a).

Among the Euganean trachyte group discriminated by feldspar size between 4 and 10 mm (Capedri *et al.*, 2000), the weakly pilotassitic groundmass of the Mt. Oliveto trachyte is the sole lithotype consistent with sample 1MFD. The fit of this flagstone sample with trachytes from Mt. Oliveto is also well constrained by all the other petrographic parameters (Table 2) and the Zr *vs.* $TiO_2$ diagram (Fig. 6b), virtually ruling out any other provenance.

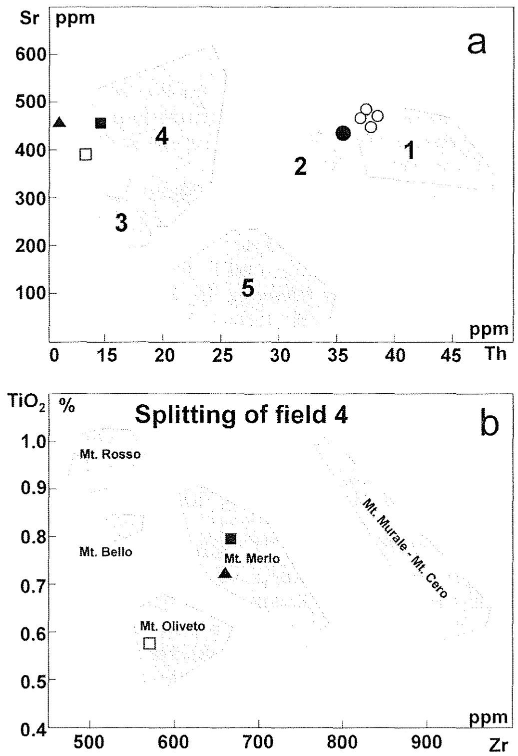


Fig. 6 - Th *vs.* Sr (a) and Zr *vs.* $TiO_2$ (b; splitting of Field 4 of Th *vs.* Sr) discriminating diagrams for trachyte quarries of Euganean hills (from Capedri *et al.*, 2000). Field 1: Monselice; Field 2: Mt. Trevisan; Field 3: Mt. Altore, Mt. Pendice; Field 4: Mt. Oliveto, Mt. Bello, Mt. Cero, Mt. Lonzina, Mt. Lozzo, Mt. Merlo, Mt. Murale, Mt. Rosso; Field 5: Mt. Alto, Mt. Grande, Mt. Lispida, Mt. Oliveto 2, Mt. Rustà, Mt. San Daniele. Open circles: samples from *Ancona* (AN1, AN2, AN3, AN4); closed circle: 2MFA (*Via Flaminia*); open square: 1MFD (*Via Flaminia*); full triangle: 4BF (*Via Flaminia*); full square: 5BFF (*Via Flaminia*).

Good discriminating petrographic features of samples 5BFF and 4BF are size of feldspar between 4 and 10 mm, P.I. ≥ 30%, and a porphyritic seriate texture with felty groundmass. These parameters, together with compatible modal/anorthoclase ratios and feldspar texture, suggest Mt. Merlo as the most probable quarry of provenance (Table 2). The Zr *vs.* $TiO_2$ geochemical diagram (Fig. 6b) confirms that flagstones 5BFF and 4BF from the *Via Flaminia* were quarried from Mt. Merlo.

## TRADE

The quarries of Monselice, Mt. Oliveto and Mt. Merlo, inferred to be the sites from which the flagstones derive, are located in the eastern margin of the Euganean hills - the best position to develop a flagstone trade through the network of drainage channels and canals linked to the rivers Brenta (*Meduacus*), Bacchiglione (*Edrone*) and Adige (*Atesis*), connecting the eastern Euganean hills to the Adriatic. Archaeological data (Bosio, 1991) suggest that, within the *Venetia* region (*X Regio*), in the Roman period navigation was also possible along the *Via Endolagunare* (Fig. 2) running inland from the coast from *Ravenna* to *Altinum* (parallel to the *Via Popilia*) and then to *Aquileia*. According to the *Itinerarium Antonini* (Cuntz, 1929), the Romans used the *Via Endolagunare* through *Septem Maria* (seven seas) and many canals (*fossae*) crossing (*per transversum*) the main waterway, connecting the delta branches of the Po Plain rivers with the Adriatic. One of the most important canals was the *Fossa Philistina* (Plin., III, 120) which allowed ships to reach the ancient city of *Clodia* (Chioggia) from the Euganean hills. All these hypotheses on waterways used by the Romans in eastern *Venetia* are supported by the fact that most of these areas were extensively reclaimed only after the Middle Age.

In conclusion, in the *X Regio,* Roman ships could sail along well-developed networks of canals, from the Adriatic as far as the quarries of the eastern Euganean hills. Thus, flagstones could be conveniently (in terms of time and costs) shipped to the mid-Adriatic coast, and the Romans could also take advantage of the *Via Endolagunare* to transport the *basoli* southwards quite easily, at least as far as *Ravenna.* From the Adriatic, the Romans could also reach the Monselice quarry by sailing up the northernmost branch of the river *Atesis*, which ran at the foot of the southern Euganean hills. In fact, palaeo-channels of the Adige have been found near Montagnana, Este, Monselice and Conselve (Castiglioni *et al.,* 1997). The Adige shifted to its present course after October 589 A.D., when a catastrophic flood caused a breach at Ronco all'Adige (the so-called «Rotta della Cucca», about 25 km ESE of Verona). Before this date and, therefore, in the Roman period, the last stretch of this river ran about 12 km north of its present course, as also testified by historic maps (Zerbinati, 1987).

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## REFERENCES

BOSIO L. (1991) — *Le strade romane della Venetia e dell'Histria.* Editoriale Programma, 283 pp.

CAPEDRI S., VENTURELLI G. and GRANDI R. (2000) — *Euganean trachytes: discrimination of quarried sites by petrographic and chemical parameters and by magnetic susceptibility and its bearing on the provenance of stones of ancient artefacts.* J. Cul. Herit., **1**, 341-364.

CASTIGLIONI G.B., BIANCOTTI A., BONDESAN M., CASTALDINI D., CIABATTI M., CREMASCHI M., FAVERO V., PELLEGRINI G.B., CAVALLIN A., ELMI C. and GASPERI G. (1997) — *Carta geomorfologica della Pianura Padana* (scala 1:250.000), Progetti Nazionali M.U.R.S.T., S.E.L.C.A., Firenze, 1997.

CUNTZ O. (1929) — *Itineraria Romana,* I, Lipsiae.

DE PIERI R. and MOLIN G.M. (1980) — *Trachyte pyroxenes in the Euganean hills (Northern-Eastern Italy).* N.Jb.Miner.Abh., **138**, 64-80.

DE PIERI R. and GREGNANIN A. (1982) — *Trachyte amphiboles in the Euganean hills (North-Eastern Italy).* Rend. Soc. It. Min. Petrol., **38**, 657-666.

DE PIERI R., DE VECCHI G., GREGNANIN A. and PICCIRILLO E.M. (1977) — *Trachyte and rhyolite feldspars in the Euganean hills (Northern Italy).* Mem. Sci. Geol., **32**, 1-22.

DE PIERI R., GREGNANIN A. and PICCIRILLO E.M. (1978) — *Trachyte and rhyolite biotites in the Euganean hills (Northern-Eastern Italy).* N. Jb. Miner. Abh., **132**, 309-328.

DE PIERI R., GREGNANIN A. and SEDEA R. (1983) — *Guida alla escursione sui Colli Euganei.* Mem. Soc. Geol. It., **26**, 371-381.

DE VECCHI G. and LAZZARINI L. (1994) — *Marmi e pietre di Padova Romana.* In: ZAMPIERI G. and CISOTTO NALON M. (eds.): *Padova Romana.* Electa, Milano 1994, 106-116.

DE VECCHI G., GREGNANIN A. and PICCIRILLO E.M. (1974) — *Le rocce eruttive dei Colli Euganei: chimismo, nomenclatura e considerazioni petrogenetiche.* Mem. Ist. Geol. Mineral., Univ. Padova, **30**, 1-25.

DE VECCHI G., GREGNANIN A. and PICCIRILLO E.M. (1976) — *Tertiary volcanism in the Veneto: magmatology, petrogenesis and geodynamic implications.* Geol. Rund., **65**, 701-710.

FILIPPI E. (1981) — *Ricerche sull'industria italiana delle pietre da taglio. Le trachiti dei Colli Euganei.* Marmi Graniti Pietre, **118**, 39-58.

LE BAS M.J., LE MAITRE R.W., STRECKEISEN A. and ZANETTIN B. (1986) — *A chemical classification of volcanic rocks based on the total alkali-silica diagram.* J. Petrol., **27**, 745-750.

LUNI M. (1995) — *L'età classica.* In: Mariano F. (ed.): *Architettura nelle Marche*, Nardini, Firenze, 26-27.

LUNI M. (2000) — *Studi su Fanum Fortunae.* Edizioni Quattroventi, Urbino, 124-139.

MILANI L., BECCALUVA L. and COLTORTI M. (1999) — *Petrogenesis and evolution of the Euganean Magmatic Complex, Veneto Region, North-East Italy.* Eur. J. Mineral., **11**, 379-399.

NAKAMURA N. (1974) — *Determination of REE, Ba, Fe, Mg, Na and K in carbonaceous and ordinary chondrites.* Geoch. Cosmoch. Acta, **38**, 757-773.

NEGRI A. (1966) — *L'impiego della trachite euganea nei monumenti storici in Padova.* Marmo Tecnica Architettura. Milano, **7**, 89-100.

PICCOLI G., SEDEA R., BELLATI R. and DI LALLO E. (1975) — *Note illustrative della Carta Geologica dei Colli Euganei alla scala 1:25.000.* Mem. Ist. Geol. Mineral., University of Padova, **31**, 1-38.

RADKE G. (1981) — *Viae Publicae Romanae.* Cappelli Editore, 429 pp.

RENZULLI A., ANTONELLI F., SANTI P., BUSDRAGHI P. and LUNI M. (1999) — *Provenance determination of lava flagstones from the Roman «Via Consolare Flaminia» pavement (Central Italy) using* *petrologic investigations.* Archaeometry, **41**, 2, 209-226.

RENZULLI A., SANTI P., NAPPI G., LUNI, M. and VITALI D. (2002) — *Provenance and trade of volcanic rock millstones from Etruscan-Celtic and Roman archaeological sites in Central Italy.* Eur. J. Mineral., **14**, 175-183.

RODOLICO F. (1964) — *Le pietre delle città d'Italia.* Le Monnier, Firenze, 501 pp.

SANTI P., RENZULLI A., NAPPI G., LUNI M. and VITALI D. (2000) — *Studio archeometrico delle macine del sito etrusco-celtico (IV-III sec. a.C.) di Monte Bibele (Emilia Romagna) e del sito romano (II sec. a.C.-VI sec. d.C.) di Fossombrone (Marche).* Atti del I Congr. Nazionale AIAr, 209-223.

SCHIAVINATO G. (1944) — *Studio chimico-petrografico dei Colli Euganei.* Mem. Ist. Geol., Univ. Padova, **15**, 1-62.

SEBASTIANI S. (1998) — *Città antiche in Italia. Ancona.* Ed. «L'Erma» di Bretschneider, 118 pp.

SERRI G. (1990) — *Neogene-Quaternary magmatism of the Tyrrhenian Region: characterization of the magma sources and geodynamic implications.* Mem. Soc. Geol. It., **41**, 219-242.

THOMPSON R.N., MORRISON M.A., HENDRY G.L. and PARRY S.J. (1984) — *An assessment of the relative roles of a crust and mantle in magma genesis: an elemental approach.* Phil. Trans. R. Soc. Lond., **A310**, 549-590.

WILSON M. (1988) — *Igneous Petrogenesis.* London, Unwin Hyman, 465 pp.

ZANTEDESCHI C. (1994) — *New Rb-Sr radiometric data from Colli Euganei (North-Eastern Italy).* Mem. Sci. Geol. **46**, 17-22.

ZANTEDESCHI C. and ZANCO A. (1993) — *Distinctive characteristics of Euganean trachytes for their identification in ancient monuments.* Sci. Techn. Cult. Herit., **2**, 1-10.

ZERBINATI E. (1987) — Mappa del Territorio Atestino nell'epoca Romana. In: *Il Veneto nell'età Romana* (Banca Popolare di Verona Ed.), **2**, Verona 1987, 238.