*RENDICONTI Società Italiana di Mineralogia e Petrologia, 38 (3): pp. 1459-1470*
Comunicazione presentata alla Riunione della SIMP in Rende-Cetraro (Cosenza) il 27-10-1982

# MINERALOGICAL, PETROGRAPHIC AND GEOCHEMICAL ANALYSES OF IRON AGE POTTERY FROM TORRE MORDILLO (COSENZA)

MARIA CARRARA
CRAI (Consorzio per la Ricerca e le Applicazioni di Informatica), Cosenza

GINO MIROCLE CRISCI, ANNA MARIA DE FRANCESCO
Dip. di Scienze della Terra, Univ. della Calabria, 87030 Castiglione Cosentino Stazione (Cosenza)

ABSTRACT. — Pottery from the First Iron Age necropolis at Torre Mordillo (Spezzano Albanese, Cosenza) is here investigated in order to ascertain the composition of its paste and the source of its raw material.

The macroscopic differences observed enable this pottery to be divided into two well-defined groups called Group A and Group B, respectively. A representative number of samples from each group as well as samples from all the rock units outcropping in the necropolis area are analyzed from the mineralogical, petrographic and geochemical view point. All the analyses contribute to a better understanding of pottery evidence; geochemical investigation, in particular, permits to localize the source of the material used for the Group A in Torre Mordillo itself, while that of the Group B is not to be found either in the necropolis area or in its environs. Consequently, it can be stated that the vessels of the first group were produced locally, whereas those of the second were imported. The archaeological implications are remarkably significant in order to the reconstruction of the socio-economic aspects of the First Iron Age culture in Calabria.

RIASSUNTO. — La ceramica proveniente dalla necropoli della prima età del ferro di Torre Mordillo (Spezzano Albanese, Cosenza), viene qui esaminata onde accertarne la composizione degli impasti e la fonte della materia prima.

Tale ceramica è divisa su base macroscopica in due gruppi, A e B, nettamente differenziati.

Un numero rappresentativo di campioni per ogni gruppo e, per confronto, una serie di campioni di tutti i litotipi affioranti nell'area della necropoli, vengono sottoposti ad analisi mineralogica, petrografica e geochimica. Tutte le analisi effettuate forniscono un contributo alla migliore conoscenza della ceramica in questione; l'ultima, in particolare, consente di affermare che il materiale usato per i vasi del gruppo A proviene dall'area della necropoli, mentre quello del gruppo B non trova riscontro nè nella medesima, nè nelle zone circostanti. Se ne deduce la produzione locale dei primi e la importazione dei secondi, ciò che assume grande importanza ai fini della ricostruzione della cultura cui è riferibile la necropoli, sotto il profilo socio-economico.

## 1. Introduction

In the last few decades methods and techniques proper to earth sciences have been increasingly applied in analysing ancient ceramics (PEACOCK, 1970; WILLIAMS and JENKINS, 1976; HACKENS et al., 1979; VERAEGHE, 1979). The philosophy behind such an approach, exhaustively discussed by the above mentioned authors, lies in the assumption that ceramic is essentially a metamorphosed sedimentary rock. Hence, mineralogical, petrographic and geochemical techniques can be used in establishing the composition of the pastes and in localizing the source of the raw materials. However, the full potential of earth sciences methodologies has not been generally exploited to date: careful strategies for sampling both vessels and possible source material have rarely been designed; it is even more rare to find more than one analytical technique used in the same project, in spite of the fact that a multi-analytical approach has proved to be both feasible and wortwhile (WILLIAMS and JENKINS, 1976). This is particularly true for the majority of studies carried out in Italy where the cooperation between the geologist and the archaeologist is still in its infancy, presumably due to the humanistic formation of the latter (MARIANI et al., 1960; DE ANGELIS et al., 1961; GUERRESCHI,

1966; MANNONI, 1980; WILLIAMS, 1980; BARRA BAGNASCO et al., 1981).

The pottery from the First Iron Age necropolis at Torre Mordillo (Spezzano Albanese, Cosenza) displays features which enable it to be divided into two distinct groups traditionally named coarse-dark-undecorated and fine-light painted, respectively. For a better understanding of such features and for relating them to the manufacture processes and compositional characteristics, objective methods have been applied in this investigation. These methods include both technological examination, whose results will be more exhaustively illustrated in a forthcoming paper by the same authors, and mineralogical, petrographic and geochemical analyses, here presented and discussed. An attempt is then made to identify a possible source for the raw materials used by comparing vessel samples with samples of all the rock units outcropping in the necropolis area. The ultimate scope is so that of establishing the provenance of the two groups of pottery and evaluating their cultural significance.

## 2. The Torre Mordillo site

### 2.1. *Archaeological Setting*

The Torre Mordillo necropolis was excavated in 1888 and the digged material was partly published in the same year (PASQUI, 1888). Since a detailed description of the archaeological features is behind the scope of this paper, here it will be sufficient to mention that the necropolis consisted of 229 single graves containing the remains and the personal belongings of the deceased (metal weapons, tools and jewelry; pottery vessels, etc.). Due to the number of graves and wealth of the objects found, Torre Mordillo is considered one of the finest examples of the so called « Fossa-Grave Culture », present in Southern Italy during the First Iron Age (IX-VIII centuries B.C.).

#### 2.1.1. *Pottery*

Of the 237 vessels found during the excavation, 166 can be referred to the coarse-dark-undecorated and 71 to the fine-light-painted groups, called A and B, respectively in the present paper.

Fig. 1. — Two examples of Torre Mordillo pottery from Group A (left) and Group B (right), respectively.

The paste, color and decoration, together with the shape — the former simply described, the latter ranged by type — notoriously form the corner-stones of the traditional classification of these vessels.

As previously mentioned, such features have been firstly related to the technical processes whereby they have been determined, namely forming, shaping, finishing, painting, firing (CARRARA et al., in progress). As a result, the pottery in Group A (fig. 1 left) has exhibited a very wide range of variations, while that in Group B (fig. 1 right) has appeared to be rather homogeneous. Yet, both groups can be lead to manufacture procedures basically unitary within but diverging between in their every phase.

Consequently, the traditional classification criteria appear in good agreement with and substantially confirmed by the technological data.

### 2.2. *Geomorphological and Geological Setting*

The site area is located about 15 km from the Ionian Sea where the Crati river and its main left tributaries, the Esaro and Coscile, join to form a wide alluvial plain — the Plain of Sibari — bounded to the north and south by the Pollino and Sila massifs, respectively (fig. 2). Locally, elongated hills with steep sides and flat tops rise at different (40 to 100 m) elevations above the plain. These hills represent the erosional remnants of various orders of terraces, from Upper Pliocene to Olocene in age and from marine to continental in nature, which reflect the intense neotectonic and geomorphic activity that characterized the north-eastern part of

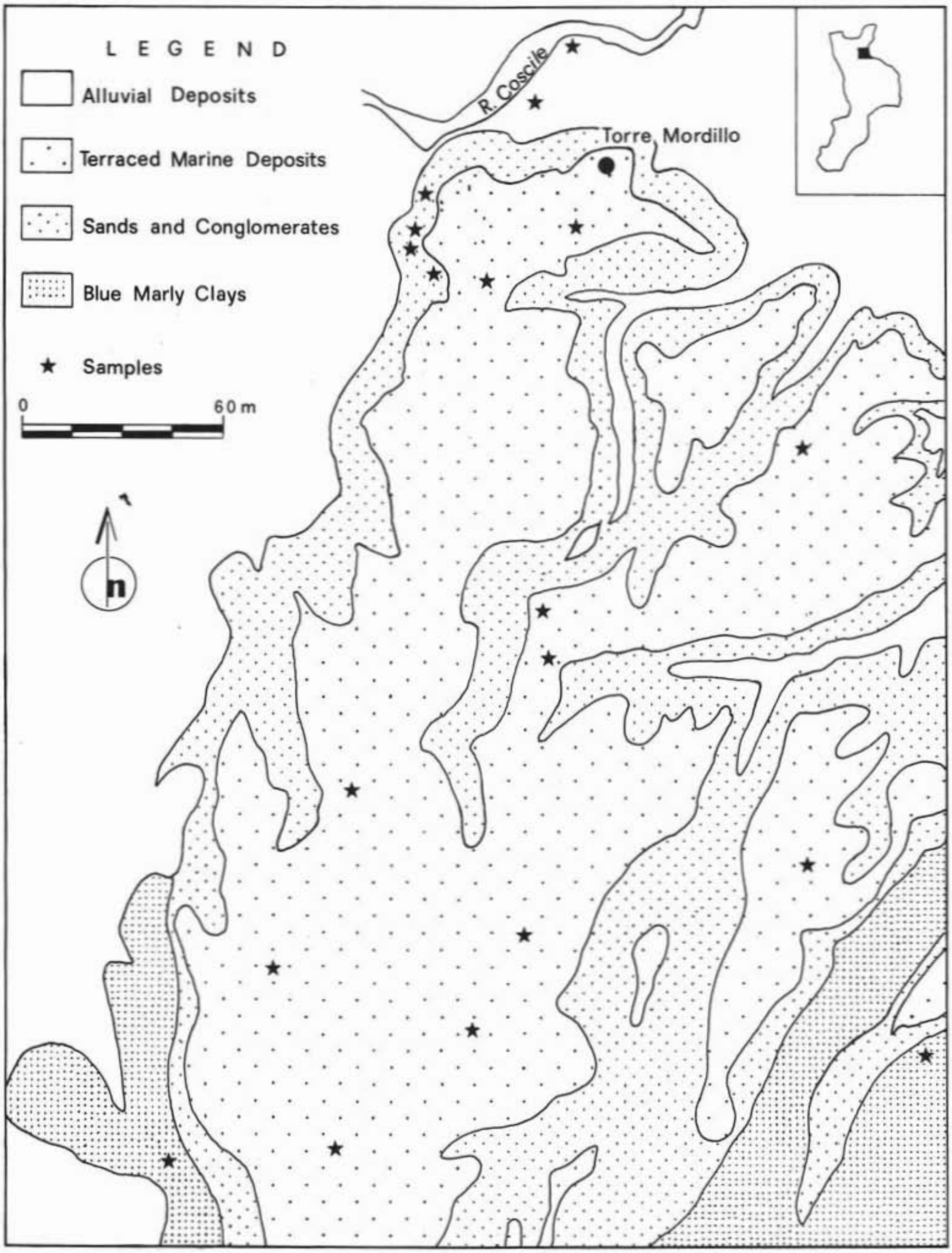



Fig. 2. — Geological sketch map of the study area.

Calabria in the recent past (Vezzani, 1968; Bousquet, 1973; Verstappen, 1977). On the top of the terraced surface of one of these hills, the archaeological site remains are to be found.

The site area, which is about 1000 m long and 300 m wide and which lies 60 m above the adjacent plain, is bounded by very steep slopes on the northen, western and southern sides, whereas it is connected to the foot-hills

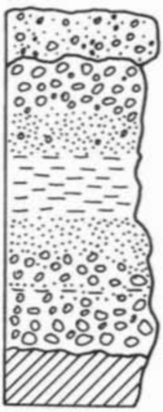



Fig. 3. — Stratigraphic sequence of the rock units outcropping in the study area.

of the Sila to the east.

From a geological point of view, the lower part of the Crati valley is underlain by a thick sequence of Olocene coarse grained sediments (mainly gravels and sands) and by Pliocene-Quaternary sandy-clayey and conglomeratic deposits, which rest unconformably on Paleozoic to Upper Miocene igneous (granites), metamorphic (gneiss, schist, phyllite, metabasite) and sedimentary (limestone, marl, clay, conglomerate) rocks. The latter crop out to the north and to the south, forming the carbonatic sequence of the Pollino mountains and the crystalline rocks of the Sila massif: both of them constitute the source material of the youngest (Pliocene-Quaternary) terranes which, because of their primary interest to the present investigation, are briefly illustrated as follows (fig. 3).

— Middle Pliocene sands and conglomerates: this unit consists of thick bedded conglomerates with a sandy matrix and elements formed by poorly sorted, well-rounded pebbles derived from igneous metamorphic rocks belonging to the Sila massif.
— Middle-Upper Pliocene blue marly clays: the previously described terranes are stratigraphically overlain by a thick sequence of clays, marly clays and sandy clays, all blue in color.
— Upper Pliocene sands and conglomerates: coarse-grained sands, alternating with marly clays and gravels, rest conformably on the blue marly clays deposits. Lenses of conglomerates with elements composed of sedimentary and igneous-metamorphic rocks crop out locally.
— Quaternary terraced sandy and conglomeratic deposits: this unit consists of medium to fine-grained, well-sorted sands and conglomerates with a sandy matrix and generally well-rounded elements derived from igneous metamorphic rocks. These sediments are terraced in various order and frequently covered by terra-rossa produced from the weathering of the conglomerate elements (VERSTAPPEN, 1977). The hill-top, where the archaeological rests are, is underlain by these deposits.

## 3. Data collection and analysis

### 3.1. *Sampling*

To perform sampling, a total of 35 samples has been collected from the two groups of vessels, namely 21 from the first (*A*) and 14 from the second (*B*). It is worth noting that not only the two groups themselves, but also the types within the groups were represented.

So that damage could be avoided or contained, the specimens for mineralogical and geochemical analyses have been taken in the form of powder by drilling in the base, whereas those used in petrographic analysis were small chips from a broken edge.

At the same time, all the rock units outcropping both in the site and adjacent areas have been sampled for a total of 19 samples partitioned as follows: 3 from Middle Pliocene marly clays; 5 from Upper Miocene sands and conglomerates; 9 from terraced Quaternary sandy and conglomerate sediments; 2 from the alluvial deposits in the Coscile river (fig. 2).

Following the previously outlined strategy (see Introduction), to sift the samples for data a multianalytical approach has been adopted as the most productive one, and, among the available techniques, mineralogical, petrographic and geochemical analyses have been selected for the interrelated information they provide.

### 3.2. *Mineralogical analysis*

Within the framework of the present investigation, all the vessels and rock unit samples have been analized by a standard X-ray diffraction procedure in order to establish their mineralogical composition. Such procedure, applied to the study of ceramics by Bimson (1967) and Maggetti (1980), has been discussed by Peacock (1970) and Shepard (1976), to whom the reader is referred for its potential and pitfalls.

For what Group A is concerned, it has proved to be characterized by the occurrence of quartz, illite, plagioclase and K-feldspar. The mineralogical composition of Group B appeared to be nearly the same except that less clay minerals and more calcite and dolomite have been found. The rock samples also showed a rather similar composition as they contained quartz, illite, muscovite, plagioclase and K-feldspar. However, more calcite and dolomite have been detected in the samples of marly clay, Pliocene sands and conglomerates, and alluvial deposits than in the vessel samples; on the other hand, carbonates appeared to be almost absent in the Quaternary sands and conglomerates.

The results of mineralogical analysis are displayed in the triangular diagrams in fig. 4, where quartz, plagioclase and calcite phases for all the available samples are plotted (the quantity of clay minerals was insufficient to enable them to be included in the analysis). From a visual inspection of the above diagram in fig. 4, it is apparent that all the Group A and most of Group B exhibit similar quartz/plagioclase/calcite ratios, with only 5 Group B vessel samples characterized by the presence of more abundant calcite and plagioclase. On the other hand, lithological samples show a much wider variety in composition, which, as clearly illustrated by the below diagram in fig. 4, is by far greater between than within the rock units. Again referring to fig. 4, it is apparent that quartz and plagioclase in the Quaternary sands and conglomerates are in the same ratio as in the vessels of Group A and almost the same of Group B.

### 3.3. *Petrographic analysis*

The value of petrographic approach to ceramic studies has been pointed out by Shepard (1966, 1976), Peacock (1970) and Williams and Jenkins (1976), who have also provided meaningful examples of its

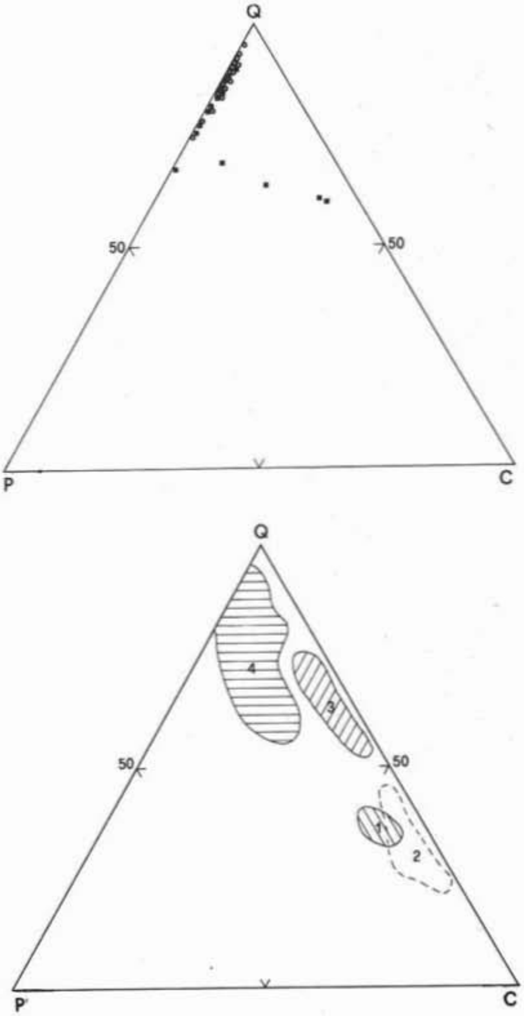



Fig. 4. — Triangular diagrams showing P, Q and C phases for all the samples. Pottery samples above; symbols: *circle* = Group A; *square* = Group B. Rock unit samples below; *fields*: 1 = marly clays; 2 = sands and conglomerates; 3 = Coscile river alluvial deposits; 4 = terraced deposits.

application. Therefore, this analytical procedure has been applied to both rock and vessel samples. As a result, the vessels in the A group have proved to be characterized by a very heterogeneous texture, with crystals varying in size (from 0.25 to 2.0 mm), shape and distribution (fig. 5 left). The most common crystals were quartz, plagioclase (andesine), K-feldspar (microcline), followed by minor biotite, white-mica, garnet, pyroxene (augite), olivine and various other accessory minerals (zircon, apatite, iron oxide, ecc.).

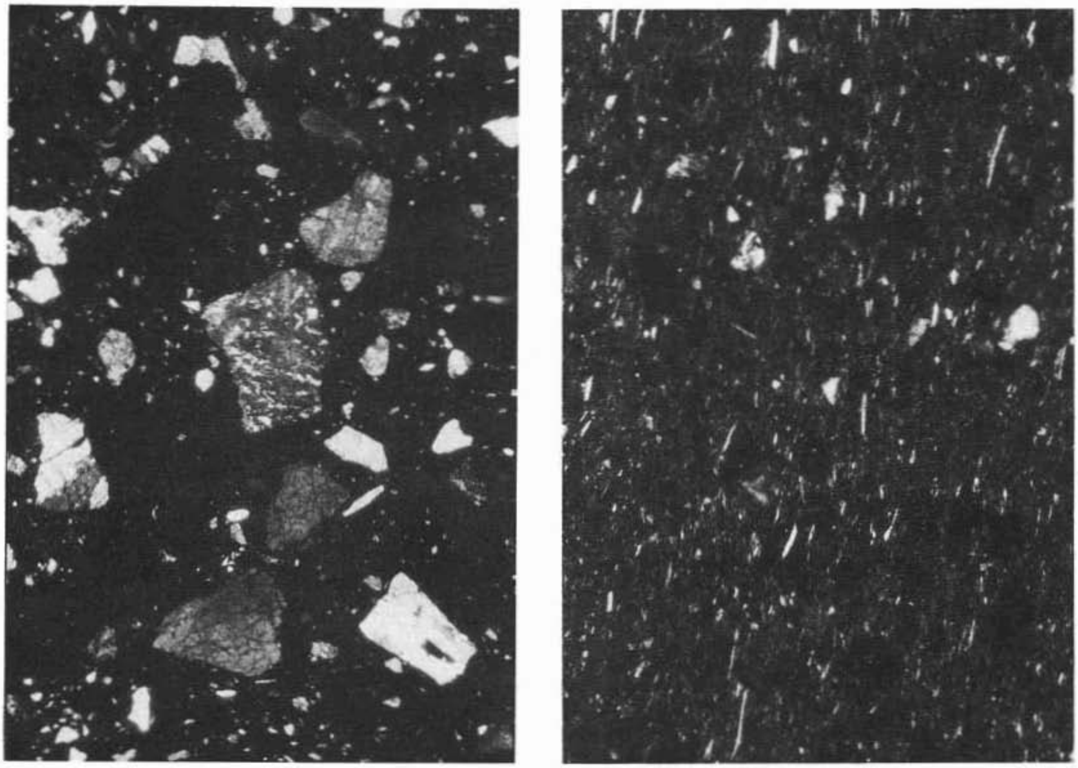


Fig. 5. — Thin sections of Group A (left) and Group B (right) pottery samples, respectively.

Rock fragments from metamorphic (gneiss and schist) or granitic rocks appeared to be fairly frequent. Some metabasite fragments (ophiolite suites) could also be found. All these elements were lying in a matrix optically unresoluble because of its very fine size and oxidation processes undergone during firing.

The second group of pottery has shown a much more homogeneous texture since all the clasts (crystals, crystal or rarely rock fragments) had a nearly equal size (from 0.25 to 0.50 mm) and shape and uniform distribution (fig. 5 right). Quartz, biotite, K-feldspar and plagioclase were the most common constituents of the clasts, while in the matrix many small flakes of white-mica could be detected. The occurrence of rear grog (crushed pottery) should also be mentioned. The matrix, which was very finely crystallized, appeared strongly oriented; structures wrapping around larger clast or grog fragments have been observed in some samples; the same preferred orientation was shown by a series of elongated cavities, probably generated by the release of $CO_2$ from the carbonate present in small amount in the raw material. Lastly, it is worth nothing that different grades of crystallinity could be distinguished in the matrix of the pottery group under study; likewise, two zones sharply defined, corresponding to the previously mentioned outer/darker and inner/lighter layers, could be noticed in the wall of some vessels.

As regards the rock samples, only those collected from the Quaternary terraced sands and conglomerates have proved petrographically similar to the material of Group A pottery. These samples were characterized by the occurrence of rock and crystal fragments of various size and shape, lying in a medium to fine-grained matrix. Crystals were made of quartz, plagioclase, K-feldspar and minor pyroxene and garnet; whereas, rock fragments were derived from granitic rocks and, more rarely, from high to medium grade metamorphosed terranes (gneiss, schist, phyl-

TABLE 1

*Chemical analysis of main elements (wt%) and of some trace elements (ppm) for the pottery samples*

| Sample | 315 | 264 | 329 | 339 | 381 | 145 | 105 | 115 | 119 | 156 | 160 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 58.92 | 58.14 | 57.58 | 54.75 | 61.59 | 54.02 | 55.12 | 54.60 | 54.57 | 53.87 | 50.49 |
| $TiO_2$ | 0.80 | 0.84 | 0.93 | 0.88 | 0.70 | 0.82 | 1.02 | 0.88 | 0.86 | 0.85 | 0.86 |
| $Al_2O_3$ | 17.22 | 17.58 | 18.08 | 18.03 | 16.68 | 16.90 | 18.74 | 17.66 | 17.28 | 18.21 | 17.95 |
| $Fe_2O_3$ | 4.72 | 5.80 | 6.30 | 7.13 | 5.97 | 6.86 | 8.23 | 6.60 | 6.90 | 6.89 | 7.09 |
| FeO | 1.15 | – | 0.0 | 0.0 | – | 0.09 | 0.29 | 0.54 | 0.22 | 0.06 | 0.07 |
| MnO | 0.06 | 0.07 | 0.13 | 0.12 | 0.06 | 0.10 | 0.13 | 0.12 | 0.12 | 0.11 | 0.10 |
| MgO | 0.71 | 1.44 | 0.65 | 0.50 | 1.28 | 2.94 | 1.52 | 1.32 | 1.25 | 2.74 | 3.17 |
| CaO | 1.43 | 1.55 | 1.62 | 1.90 | 1.62 | 5.06 | 5.31 | 4.85 | 6.36 | 3.31 | 7.38 |
| $Na_2O$ | 0.98 | 0.97 | 1.07 | 0.55 | 1.43 | 1.00 | 1.02 | 0.67 | 0.96 | 0.80 | 0.73 |
| $K_2O$ | 1.98 | 1.99 | 2.23 | 1.83 | 1.94 | 2.52 | 2.63 | 2.60 | 2.67 | 2.74 | 2.41 |
| $P_2O_5$ | 0.23 | 0.29 | 0.33 | 0.56 | 0.26 | 0.28 | 0.20 | 0.32 | 0.88 | 0.28 | 0.21 |
| L.O.I. | 11.80 | 11.34 | 11.08 | 13.70 | 8.47 | 9.41 | 5.79 | 9.85 | 7.93 | 10.15 | 9.53 |
| Rb | 105 | 90 | 102 | 108 | 86 | 116 | 130 | 117 | 129 | 121 | 110 |
| Sr | 162 | 159 | 189 | 188 | 172 | 210 | 202 | 241 | 282 | 176 | 317 |
| Y | 24 | 31 | 36 | 22 | 19 | 24 | 29 | 27 | 30 | 25 | 24 |
| Zr | 273 | 282 | 324 | 344 | 217 | 169 | 198 | 183 | 180 | 159 | 148 |
| Nb | 26 | 27 | 37 | 32 | 20 | 16 | 19 | 21 | 18 | 17 | 17 |

The first 5 samples belong to Group A, the others to Group B. — = not determined.

lite and metabasite). In a few samples a small to very small quantity of clasts derived from carbonatic rocks have been found.

## 3.4. *Geochemical analysis*

The theoretical background together with examples of the application of geochemical analyses to ceramic project are provided by the above mentioned authors, to whom WILSON (1978) and MAGGETTI (1980) should be added.

For the present investigation, main and trace elements have been analyzed through the X-ray fluorescence method proposed by FRANZINI and LEONI (1972) and LEONI and SAITTA (1976). MgO content has been determined by atomic absorption; $Fe^{2+}$ has been titrated with $K_2Cr_2O_7$, and weight loss has been determined by heating to 900° C. Precision is equal to 5 % for the main elements, while it ranges from 5 % to 20 % for the trace elements.

The results obtained when the main elements and some of the trace elements (Nb, Sr, Zr, Y, Rb) of vessel and rock samples were investigated are listed in tab. 1 and 2, respectively. In addition, in fig. 6 to 8 these

TABLE 1

*Chemical analyses of main elements (wt%) and of some trace elements (ppm) for the sediment samples*

| Sample | 1 | 10 | 11 | 13 | 14 | 15 | 16 | 19 | 2 | 17 | 18 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 51.17 | 59.18 | 70.13 | 63.79 | 61.01 | 57.70 | 63.10 | 59.13 | 47.58 | 44.50 | 76.94 | 38.19 | 32.99 | 45.26 | 43.15 | 61.84 | 47.27 | 40.45 | 45.34 |
| $TiO_2$ | 0.75 | 0.93 | 1.03 | 0.61 | 0.87 | 0.98 | 0.81 | 0.89 | 0.65 | 0.67 | 0.22 | 0.58 | 0.51 | 0.50 | 0.62 | 0.51 | 0.35 | 0.60 | 0.67 |
| $Al_2O_3$ | 16.09 | 18.92 | 13.41 | 16.61 | 17.57 | 20.09 | 16.69 | 19.38 | 13.15 | 16.68 | 12.29 | 11.62 | 8.55 | 9.49 | 11.95 | 9.57 | 6.85 | 11.40 | 14.04 |
| $Fe_2O_3$ | 4.69 | 5.47 | 3.41 | 3.50 | 5.44 | 6.48 | 4.19 | 6.38 | 5.03 | 5.64 | 1.12 | 4.56 | 4.06 | 3.99 | 4.93 | 4.05 | 3.20 | 4.62 | 5.46 |
| FeO | 0.91 | 0.49 | 1.33 | 1.13 | 0.59 | 0.49 | 0.58 | 0.0 | – | – | 0.97 | – | – | – | – | – | – | – | – |
| MnO | 0.07 | 0.14 | 0.11 | 0.06 | 0.14 | 0.14 | 0.10 | 0.19 | 0.12 | 0.11 | 0.03 | 0.10 | 0.10 | 0.08 | 0.14 | 0.09 | 0.08 | 0.14 | 0.11 |
| MgO | 2.99 | 1.10 | 0.93 | 1.16 | 0.68 | 1.02 | 0.62 | 0.60 | 3.38 | 2.00 | 0.54 | 5.29 | 7.72 | 4.06 | 4.04 | 4.03 | 6.81 | 5.66 | 4.27 |
| CaO | 5.45 | 1.19 | 0.73 | 1.49 | 0.99 | 0.57 | 1.06 | 1.05 | 10.47 | 10.64 | 1.00 | 15.59 | 19.41 | 18.05 | 13.64 | 7.82 | 14.41 | 15.72 | 10.46 |
| $Na_2O$ | 0.71 | 0.66 | 1.15 | 1.83 | 0.72 | 0.50 | 1.42 | 0.65 | 0.51 | 0.43 | 2.69 | 0.53 | 0.25 | 1.33 | 0.45 | 1.30 | 0.57 | 0.39 | 0.81 |
| $K_2O$ | 2.07 | 2.10 | 2.05 | 2.19 | 2.14 | 2.28 | 2.23 | 2.29 | 2.07 | 1.75 | 1.78 | 1.91 | 1.29 | 1.71 | 1.89 | 1.58 | 1.10 | 1.81 | 2.29 |
| $P_2O_5$ | 0.38 | 0.07 | 0.06 | 0.05 | 0.05 | 0.09 | 0.07 | 0.11 | 1.02 | 0.09 | 0.04 | 0.22 | 0.12 | 0.14 | 0.46 | 0.10 | 0.15 | 0.13 | 0.16 |
| L.O.I. | 14.80 | 9.81 | 5.78 | 7.67 | 9.79 | 9.70 | 9.11 | 9.32 | 16.02 | 17.48 | 2.47 | 21.42 | 25.00 | 15.38 | 18.73 | 9.09 | 19.20 | 19.07 | 16.39 |
| Rb | 105 | 129 | 88 | 90 | 138 | 140 | 106 | 144 | 94 | 113 | 59 | 75 | 53 | 64 | 85 | 55 | 45 | 87 | 101 |
| Sr | 135 | 90 | 99 | 151 | 119 | 93 | 171 | 109 | 242 | 125 | 193 | 205 | 325 | 204 | 193 | 180 | 165 | 286 | 249 |
| Y | 24 | 26 | 23 | 14 | 38 | 28 | 28 | 35 | 22 | 24 | 9 | 18 | 17 | 18 | 18 | 14 | 12 | 20 | 23 |
| Zr | 234 | 323 | 406 | 167 | 350 | 326 | 301 | 307 | 208 | 230 | 85 | 181 | 158 | 113 | 171 | 122 | 127 | 148 | 187 |
| Nb | 18 | 30 | 24 | 14 | 29 | 29 | 22 | 31 | 15 | 20 | 5 | 12 | 10 | 7 | 14 | 8 | 7 | 12 | 12 |

Samples 1-18 are from Quaternary terraced deposits; samples 3-6 from Upper Pliocene sands and conglomerates; samples 9 and 12 from blue marly clays; samples 7 and 8 from alluvial deposits. — = not determined.

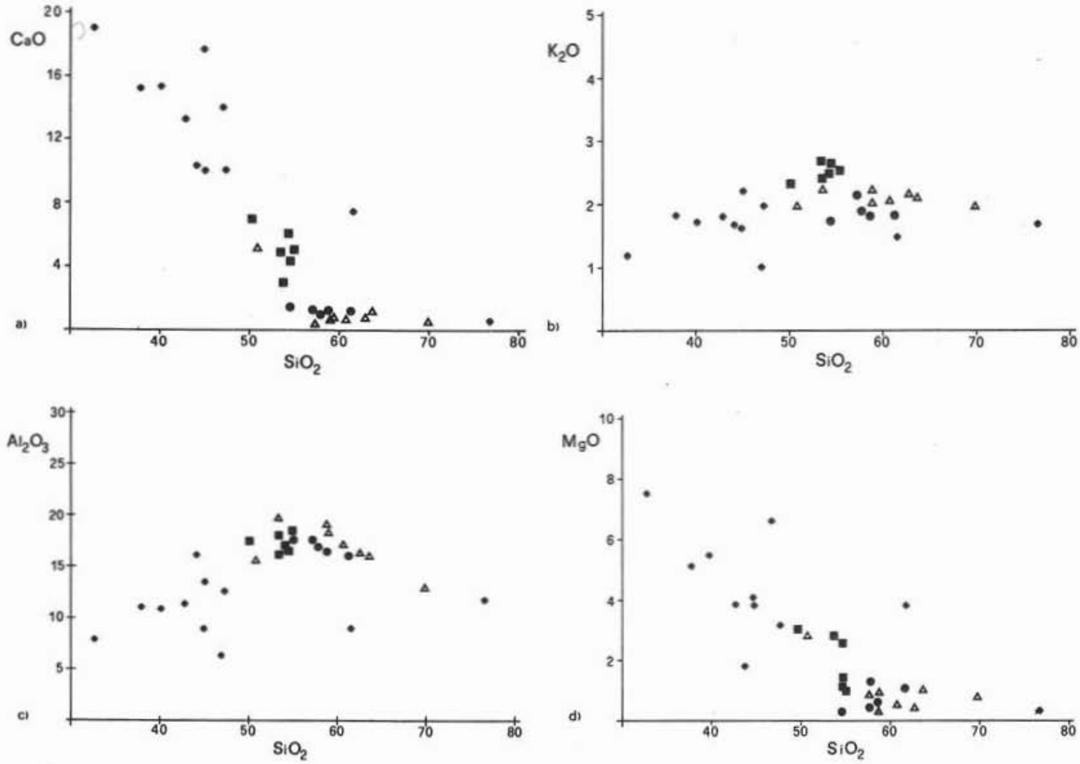


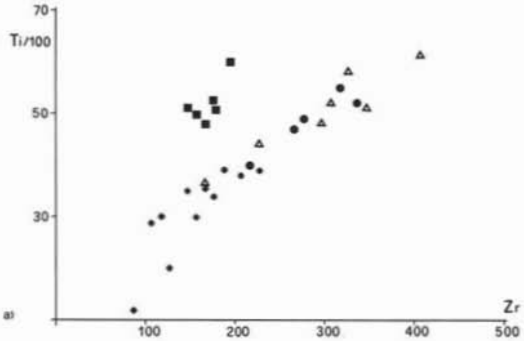

Fig. 6. — CaO, $K_2O$, $Al_2O_3$, MgO versus $SiO_2$ plots for all the pottery and rock unit samples. Symbols: *circle* = Group A pottery; *square* = Group B pottery; *triangular* = terraced deposits; *asterisk* = other rock units.

data are displayed after their grouping according to vessel (Group A and B) or lithologic (Pliocene sands, conglomerates and marly clays, and Quaternary terraced sands and conglomerates) classes. The latter grouping is based on the outcomes of the previously described mineralogical and petrographic analyses. Within each vessel group, the samples show a good similarity of their main elements; conversely, between the two groups they greatly differ: in the case of $SiO_2$/CaO and $SiO_2/K_2O$ plots, for example, they fall into two completely distinct fields, and in the case of $SiO_2/Al_2O_3$ and $SiO_2$/MgO plots they are still remarkably differenciated (fig. 6). Likewise, whereas the other lithologic unit samples scatter throughout the diagram field, the Quaternary sand and conglomerate specimens form a relatively narrow cluster, which lies near the Group A vessels (fig. 6). This result deserves to be further stressed: the Group A is generally separated from the Group B and almost systematically associated with the Quaternary sediments, whilst the Group B does not coincide either with the latter or with any other sampled rock unit.

What has been observed for the main elements also holds true for the trace elements. As shown in fig. 7-8, the chemical composition of the two groups of vessels differ to an equal or even greater extent (see e.g. the diagrams of Ti/Zr and Zr/Y (fig. 7 *a* and *b*), and the diagrams Zr-Y-Nb and Ti-Zr-Y (fig. 8). In fact Group A exhibits higher values of Zr and Nb, lower values of Rb and Sr and comparable values of Ti with respect to Group B, and once again Group A and Quaternary sediments fields virtually overlap, while Group B lies apart.

## 4. Discussion

As mentioned in the introduction, the occurrence of wares characterized by two sets of macroscopically different features led to arrange them in two classes. However, the




validity of this classification had still to be proved.

A first step in this direction is represented by the teechnological examination, which has enabled the differences observed to be related to two distinct manufacture processes, thus giving them an objective dimension.

The mineralogical analysis that has been carried out to further substantiate the previous results, has failed in her aim. On the positive side, however, it allowed to discriminate between the Pliocene and the Quaternary rock unit samples and to ascertain the similarity between the latter and the ware samples.

The petrographic analysis, on the other hand, has made a major contribution to the characterization of both vessels and lithologic units as well as to the localization of the source material of the former. In fact, firstly this analysis has helped to establish the composition of each pottery group samples, then pointing out — to stress the most relevant divergence — that garnet, pyroxene and metamorphic rock fragments present in the first group (A), are totally lacking in the second (B). In addition, it has provided evidence that the size, degree of sorting and distribution of the clastic components drastically differ in the two groups: these differences depending on the composition and elaboration of the raw material, clearly witness diverse manufacture processes. The petrographic analysis has also enabled finer distinctions to be made within the second group (B) on the ground of the degree of orientation of the phyllosilicatic fraction and grade of crystallinity of the matrix. If the

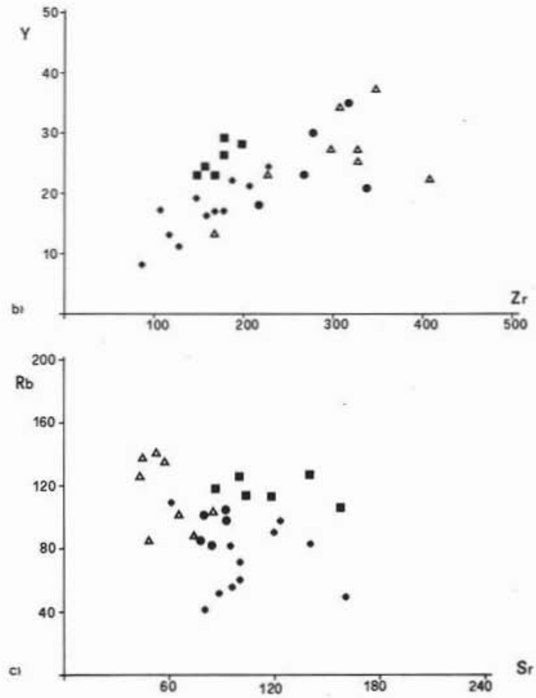



Fig. 7. — Y and Ti versus Zr (*a* and *b*) and Rb versus Sr (*c*) plots for all the pottery and rock unit samples. Simbols as in fig. 6. Ratios in ppm.

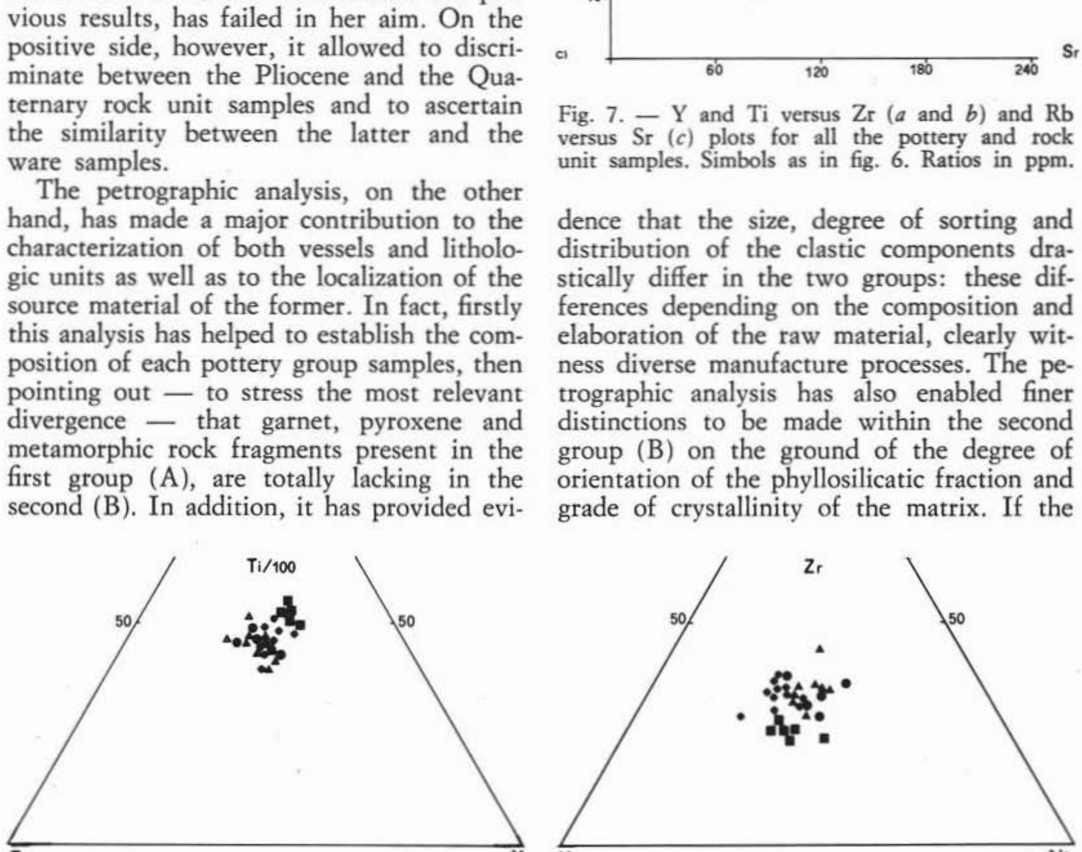



Fig. 8. — Triangular diagrams showing Zr, Ti, Y and Y, Zr, Nb for all the pottery and rock unit samples. Ratios in ppm. Simbols as in fig. 6.

former must be related to varied methods of manufacturing and the latter to diverse temperature gradient during firing, together tery material of the A group reflect the co-existence of more than one workshop. Lastly, this analysis has pointed out that the rock fragments and the minerals in the pottery material of the A group reflect the geology of the area covered by the survey in that they can be associated with the Quaternary terraced deposits.

The geochemical analysis has shown that a remarkable difference occurs in the composition of the two groups of wares for the main as well as for the trace elements and, again, an equally remarkable similarity can be noticed between the first group of vessels and the Quaternary lithologic units. This result requires a more detailed discussion. The above mentioned difference cannot find its explanation in the changes undergone by the raw material during the pottery manufacturing. In fact, where the material used in making the first group was the same of the second modified, such modification would have involved either elimination or addition of raw material. Should the elimination have occurred, then the component eliminated has to be identified — to take the extreme possibilities — either with the coarser portion (quartz) or with the finer one (clay minerals). Now, a subtraction of quartz would have brought apart a reduction of $SiO_2$ and then a relative increase in the other elements, but would not account for the decrease in such elements as Zr and Nb. Likewise, an elimination of the phyllosilicatic fraction would have involved a drastic decrease of the Al and K values, that has not been observed. In addition, the different Nb, Y, Zr and Ti contents and values of the first and second groups of pottery, respectively, rule out the hypothesis that the same source material was used for both. On the other hand, if modification was obtained by adding some other material to that used in manufacturing the A group, again two possibilities can be considered: first, the added material was drawn from the necropolis area or from its environs; second, the material was derived from outside. The first case can be excluded in that all the terranes, with the exception of the Quaternary terraced deposits (used for the Group A), bear a fairly large amount of calcite, whose release during firing notoriously (Caruso, 1979) produces cracking. The second hypothesis cannot be accepted or rejected on the ground of the available geochemical data. However, from an archaeological point of view, the trading of vessels or of raw material rises very similar socio-economic questions. In addition, examples of imported raw material for the production of ceramics are very poorly witnessed in the litterature (Schneider et al., 1978).

## 5. Conclusions

All the investigations previously illustrated lead to considerations of various orders and degrees. Firstly, the technological examination together with the scientific analyses have enabled an objective classification to be settled, which is indipendent of, even if coinciding with the traditional one. Besides, the petrographic and especially the geochemical analyses have helped provide information concerning the source material used for the pottery. From this, apart from the obvious methodological inferencese, meaningful archaeological deductions can be drawn. It can be stated in fact that the first group of pottery is made of heterogeneous, coarse material corresponding to that of the Quateernary deposits of the necropolis area. Though other parts of Calabria may have a comparable geology, there is no reason to doubt that this group (which represents the greatest proportion of the Torre Mordillo production) was manufactured locally. The fact that the raw material used is apparently the least suitable to the purpose, can be explained by recalling that all the terranes outcropping in the necropolis area and its environs, except for the Quaternary sediments, are rich in calcium. In other words, the material used was not only the easiest to be obtained, but practically the only one utilizable within a range of almost 50 km. Where the second group of pottery is concerned, it was found that the raw material used cannot be related to any local source. Such a result would therefore support the hypothesis that the vessels in Group B were imported, with all the implications that this involves. The occurrence of a large scale trade of wares, hitherto unsuspected, throws in fact a new light on the socio-economic organisation of that time. The final goal of the present investigation is therefore a better understanding of the pottery in relationship to the local culture of the First Iron Age as a whole.

*Acknowledgments.* — We are grateful to Prof. R. Compagnoni for the critical review of the paper; we also thank F. Gagliardi and U. Lanzafame for their technical contribution.

## REFERENCES


Barra Bagnasco M., Branca M.E., Conforto L., Nicoletti M., Palmieri A.M. and Taddeucci A. (1981) - *Imported and locally produced ceramics at Locri Epizephiri: results of petrochemical analyses. Chemical considerations on the thermal treatment of raw material and weathering of ceramics.* Supplém. Révue d'Archéometrie, 3, 19-27.

Bimson R. (1969) - *The examination of ceramics by X-ray powder diffraction.* Studies in Conservation, 14, 83-89.

Bousquet M. - *La tectonique récente de l'Appennin Calabro-Lucanien dans son cadre géologique et géophisique.* Geol. Rom., 12, 1-104.

Caruso N. (1979) - *Ceramica viva,* Milano.

De Angelis A. (1961) - *Ricerche mineralogiche su ceramiche preistoriche italiane.* Sibrium, 5, 178-205.

Franzini M. and Leoni L. (1972) - *A full matrix correction in X-ray fluorescence analysis of rock samples.* Atti Soc. Tosc. Sc. Nat., Mem., A, 79, 7-22.

Guerreschi G. (1966) - *Ceramica preistorica al microscopio.* Sibrium, 8, 151-159.

Guerreschi G. (1969) - *Tecnologia e decorazione della ceramica pre e protostorica.* Sibrium, 9, 339-375.

Hackens T., Mook W.G. and Claus G. (1979) - *Répertoire professionel des laboratoires européens appliquant des méthodes physiques, chimiques ou matématiques au service de l'archéologie.* PACT, 4.

Hodges H.W.M. (1966) - *Aspects of pottery in temperate Europe before the Roman Empire,* in « Ceramics and Man », ed. Matson, F.T., London.

Leoni L. and Saitta M. (1976) - *X-ray fluorescence analysis of 29 trace elements in rocks and mineral standards.* Rend. Soc. It. Miner. Petrol., 32, 497-510.

Maggetti M. (1980) - *Recherches minéralogiques, chimiques et technologiques sur la terre sigilée de l'atelier de la Péniche (Vidy/Lausanne).* Cahiers Romands d'Archéol., 20, 2, 183-188.

Mannoni T. (1980) - *Analisi delle ceramiche dipinte neolitiche di Lipari.* In Meligunìs Lipàra, Palermo, 4, 871-875.

Mariani E., Peco G., Storti G. (1960) - *Caratteristiche chimico-fisiche e ricerche della tecnica di cottura di ceramiche preistoriche italiane.* Sibrium, 5, 188-205.

Ogniben L. (1973) - *Schema geologico della Calabria in base ai dati odierni.* Geol. Rom., 12, 243-585.

Peacock D.P.S. (1970) - *The scientific analysis of ancient ceramics: a review.* World Archaeology, 1, 375-388.

Schneider G., Hoffmann B. and Wirz E. (1978) - *Significance and despensability of provenance of ceramics artifacts.* Archeophisica, 10, 269-285.

Shepard A.O. (1976) - *Ceramics for the Archaeologist.* Washington D.C., 9th ed.

Veraeghe F. (1979) - *Archaeology, Natural Sciences and Technology: The European Situation.* Rapport of the European Science Foundation.

Verstappen H.T. (1977) - *Sulla geomorfologia della parte sud-occidentale della provincia di Cosenza.* Boll. Soc. Geol. It., 10, 6, 541-562.

Vezzani L. (1968) - *I terreni Plio-pleistocenici del basso Crati (Cosenza).* Atti Acc. Gioenia Sc. Nat. Catania, 6, 20, 24-28.

Widemann S. (1980) - *Etudes analitiques de provenance pour la cerámique.* L'Archéologie, 42, 28-39.

Williams J.Ll.W. and Jenkins D. (1976) - *The use of petrographic, heavy mineral and arc spectrographic techniques in assessing the provenance of sediments used in ceramics.* In: Davidson D.A. (Ed), Geoarchaeology, London.

Williams J.Ll.W. (1980) - *A petrological examination of the prehistoric pottery from the excavation in the Castello and Diana plain of Lipari.* In Meligunìs Lipàra, Palermo, 4, 846-868.

Wilson A.L. (1978) - *Elemental analysis of pottery in the study of its provenance: a review.* Journ. of Arch. Science, 5, 219-236.