

## RESEARCH ARTICLE



# The ceramic vessels of the late antique and early medieval *domus* in the religious complex of San Pietro (*Canusium*, Italy): Clayey geosources, local production and imports in northern Apulia

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## Abstract

This study broadens our knowledge of the relationship between the clayey geosources available in northern *Apulia* and the artisanal production of ceramics. The focus is placed on a collection of 6<sup>th</sup> and 7<sup>th</sup> century A.D. pottery found in the *domus* excavated within the archaeological complex of Canosa San Pietro (ancient *Canusium*) in Italy. The integration of the results obtained from this study with those already available made it possible to outline conscious technological choices in terms of raw materials' exploitation, based on which the alluvial deposits were selected for the production of coarse cooking ware and the marine Subapennine clays for the production of fine common ware. This selective choice undoubtedly had a practical implication since it supplied raw materials that required little processing, being already suitable for the type of ceramic to be produced. Moreover, the compositional comparison of investigated pottery with products distributed along the Carapelle valley, rather than those from *Canusium* previously studied, provides new perspectives for reconstructing the microcirculation of ceramics in northern *Apulia*. Lastly, the imports of Classe-type pottery, probably from the northern Adriatic area, are worth mentioning since they represent the most consistent distribution of this type of ceramic in southern Italy and may reflect the assiduous pilgrimage of the monastery after the death of Bishop *Savinus*.

## KEYWORDS

archaeometry and geoarchaeology, ceramic trade, clayey geosources, Late Antiquity and Middle Ages, pottery production and import

## 1 | INTRODUCTION

In northern *Apulia* (also known as *Daunia*; Figure 1), the alluvial and terraced alluvial deposits (Upper Pleistocene-Holocene) and the Subapennine clays (Lower Pleistocene) are

well suited for the production of different types of ceramics (Gliozzo et al., 2018).

The alluvial and terraced alluvial deposits typically consist of gravels, sands and clays. They frequently contain volcanic rocks and related minerals (e.g., volcanic glass, haüyne, sanidine, leucite and pyroxenes)

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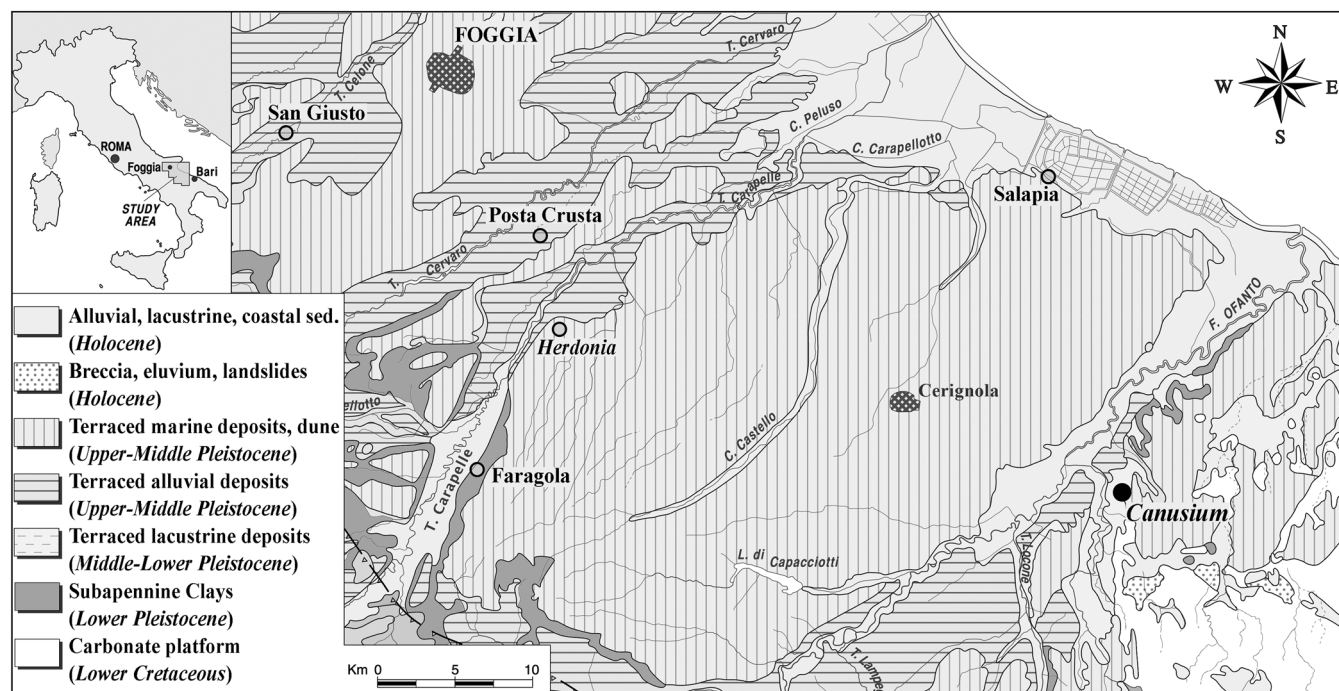


**FIGURE 1** Geographic localisation of the archaeological site of Canusium (within the present town of Canosa di Puglia) and the geological map of the northern Apulian territory (modified after Bonardi et al., 1988).

transported by wind from the Mount Vulture (Roman Province high-potassium and potassium series; Bindi et al., 1999; Caggianelli et al., 1990; Fino et al., 1982) and the Vesuvian areas (Cioni et al., 1999, 2000; Sulpizio et al., 2008). Their composition can widely vary also at a short distance range, especially along the riverbeds.

The Subapennine clays are marine hemipelagic deposits (Balenzano et al., 1977) of marly, sandy and silty clays. In the territory of Canusium (present-day Canosa di Puglia), these clays outcrop where fluvial meandering and erosional phenomena have removed the more recent alluvial deposits. They generally show a grey-blue colour and are rich in fossils; however, they shift to a yellowish colour in the upper sand-enriched layers. The blue clays are characterised by variable contents of phyllosilicates (29%–71%) and quartz (11%–18%). Among clay minerals, illite (25%–72%) prevails over montmorillonite (8%–56%) and kaolinite (5%–20%) (Cherubini et al., 2005).

Other sediments such as carbonates and calcarenites (e.g., 'Calcarenite di Gravina' unit, which accumulated before the formation of the Subapennine clays) are also typical in this area, but they could not represent the primary source for ceramic production.

The wide availability of clayey georesources favoured the development of numerous ceramic workshops throughout the territory. These have been the object of several archaeometric studies, beginning from the late Antique pottery (fourth to seventh centuries A.D.) found within the San Giusto kiln (Gliozzo et al., 2005). The coarse wares and the fine tablewares examined in this seminal study have later guided sampling in the other archaeological sites of the Daunian area. For example, the same or similar types of pottery were sampled at Posta Crusta, Herdonia, Canusium, Faragola and Salapia (Gliozzo et al., 2010, 2013, 2014, 2019).

Besides cooking ware and tableware, building materials were investigated at Faragola and Canusium, where the workshops were found and stratigraphically excavated (Gliozzo et al., 2016).

Further archaeometric studies focused on Late Apulian red-figured pottery from Egnatia (fourth century B.C.; Mangone et al., 2013); 'Gnathia' pottery from Fasano (fourth to third centuries B.C.; Mangone et al., 2009); late Antique oil lamps from the catacombs of Canusium (Eramo et al., 2014); a selection of late Roman cooking ware from Herdonia, Posta Crusta and San Giusto (Eramo et al., 2004); and 'Torre Alemanna type' pottery from the homonym building complex in the province of Foggia (fifteenth to sixteenth centuries A.D.; Fioretti et al., 2022).

The state of the art of the studies can thus be described as 'intermediate' and a substantial bunch of archaeometric data on clayey raw materials, pottery and building materials is available for compositional comparison. Similarly, the potential raw materials available in Daunia were sampled and geochemically investigated (Gliozzo et al., 2018).

The study presented in this paper focuses on a collection of 24 samples, including coarse wares for cooking (henceforth, cooking ware) and finer wares for the table and storage (henceforth, common ware), found in a *domus* within the archaeological complex of 'Canosa San Pietro'. The main objectives of this study can be summarised as follows: (1) to characterise the present collection from a geochemical and mineralogical-petrographic standpoint; (2) to investigate the production technology; (3) to distinguish local and imported products; and (4) to identify consistent trends of raw materials' supply and evaluate the relationship between the availability of clayey georesources and ceramic production.

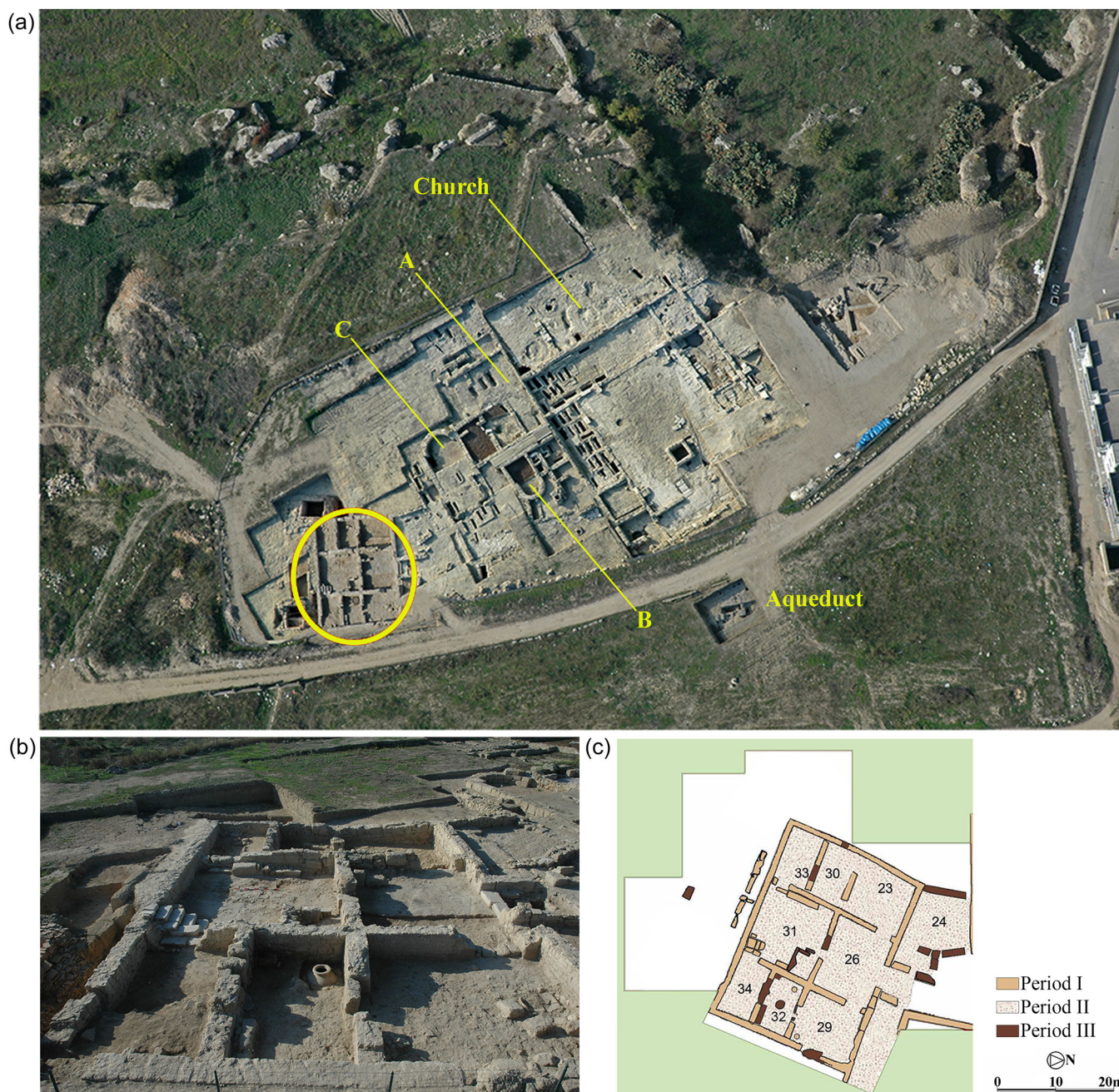


**FIGURE 2** Archaeological site of 'Canosa San Pietro'. (a) Aerial view of the site; (b, c) image and map of the *domus*.

## 2 | ARCHAEOLOGICAL BACKGROUND

Located in the southern periphery of Canosa di Puglia, the area of San Pietro (Figure 2) was the object of archaeological excavations by the Universities of Foggia and Bari from 2001 to 2005 (Volpe et al., 2002, 2003; Volpe, Favia, et al., 2007). In Roman times, the site represented a suburban sector used for artisanal activities. A Republican or late Republican kiln for bricks (perhaps, also terracotta sculptures) and a late Antique ceramic kiln for building materials were identified and archaeologically investigated (Gliozzo et al., 2016). However, the finding of numerous production indicators (e.g., wastes and moulds for oil lamps) and the ground traces localised by recent

geomagnetic prospecting suggest that the artisanal district was wider than the extension of these two kilns. It developed near the Antoninian aqueduct that brought water to the town and was connected to the urban centre by a paved road that ran a few tens of metres further west (parallel to the aqueduct).

In this same place, Justinian coins and numerous bricks stamped by the bishop *Savinus* (who lived between the second quarter and the mid-sixth century A.D.) were found in the collapse layers. These findings testify that the bishop had built an imposing church with three naves and floor mosaics (Volpe et al., 2005), preceded by a narthex and a porticoed *atrium*. The church was further flanked by a building (indicated with 'A' in Figure 2a) used for residential and service functions, where

rooms decorated with floor mosaics and equipped with corner fireplaces were identified. The *atrium* was connected to a small apsidal mausoleum (indicated with 'B' in Figure 2a)—designed organically and contextually with the religious nucleus—probably intended to house the burial of the bishop who commissioned the complex.

The extensive necropolis developed within the religious complex and its immediate vicinity perhaps experienced a further increase following the Saint's burial in the mausoleum. In the southern sector, slightly detached from the religious complex, there was an apsidal building (indicated with 'C' in Figure 2a), which housed some burials, surrounded by a cemetery. The context of San Pietro has been interpreted as a religious funerary complex, wanted by the influential bishop *Savinus* to house his grave. However, it is also possible that the church may have hosted relics (Nuzzo, 2011), perhaps fulfilling the role of a sanctuary.

The ceramics analysed in this contribution were found in the *domus* discovered southeast of the San Pietro church. In the sixth century (Period I in Figure 2c), the *domus* was partially built on the remains of the late Antique kiln, which likely fired the building materials used to construct the church. The building was arranged into three juxtaposed rows of rooms. The central and larger one was divided into two rooms: (1) the main access to the building opened in the northernmost room no. 26, facing the nearby church, and (2) a representative room used for audiences in the southernmost room no. 31. The function of this latter room was identified based on its position inside the house and the presence of peculiar, fixed furnishings (a seat placed in front of a bench, both in masonry). The side wings were divided into three smaller spaces connected to the central sector. The eastern one (rooms nos. 29, 32 and 34) must have been intended for the conservation and transformation of foodstuffs (underground *dolia* and remains of plastered basins were found), while the western one (rooms no. 23, 30 and 33) was perhaps designed to host administrative and fiscal activities (several coins and a balance were found in one of the rooms). The upper floor likely housed the residential areas, as suggested by the recovery of large mosaic fragments and glass lamps in the collapse layers. Given the proximity to the Sabinian cemetery and its characteristics, the building has been interpreted as an episcopal residence, that is, a place for officials belonging to the high ecclesiastical hierarchies (Giuliani & Capacchione, 2011; Giuliani et al., 2011).

The complex of San Pietro retains for a certain period the physiognomy impressed by *Savinus*. During the seventh century (Period II in Figure 2c), the precarious structures found in some liturgical spaces and the northern sector of the *domus* testify to the beginning of a progressive decline. Between the seventh and the eighth centuries (Period III in Figure 2c), the systematic looting of the church led to the accumulation of its furnishings in the *domus*, whose ground floor was reused as a warehouse. The construction of a spiral staircase obliterating the masonry seat shows that, in this phase, the upper floor continued to be in use, probably with the same residential function previously performed. To the north of the house, a new workshop was built, probably used to rework the stone materials taken from the nearby church. This activity was likely

managed by the Canusian Church, which regained control of its assets after the period of crisis recorded by the epistolarity of Pope Gregory the Great (540–604 A.D.), where the absence of ministries in the diocese of *Canusium* at the end of the sixth century is emphasised. This revival by the church is also suggested by other indicators such as the movement of the stone and marble furnishings from the church to the nearby workshop, the recovery and storage of floor mosaic *tesserae* and, lastly, the plugging of the entrances to the cult building to preserve it from abusive occupations.

The ceramic collection investigated here was recovered from the stratigraphy relating to the last phase beginning in the early Middle Ages (seventh to eighth century A.D.); however, it cannot be unquestionably excluded that it belonged to the sixth-century furnishings. It can be hypothesised that, in this period, the building was used by artisans committed to reworking stone building materials for the recycling circuit, which was also most likely under ecclesiastical control (Giuliani, 2022).

The San Pietro area continued to be occupied for residential use until the tenth century.

### 3 | MATERIALS

The 7064 ceramic fragments collected in the stratigraphies of the *domus* are divided into 5173 fragments (=73.2%) of painted and unpainted tableware and storage wares and 1891 fragments (=26.8%) of cooking wares.

An articulate morphological repertoire has been reconstructed through the study of comparable late sixth to seventh and eighth century A.D. typologies in central-northern *Apulia* and southern Italy (Arthur, 2010; Arthur & Patterson, 1998; Arthur et al., 2007; Favia et al., 2015; Turchiano, 2010; Volpe, Annese, et al., 2007).

Among the cooking wares, three types of jars prevail, sometimes with their lids. The quantities of pots and pitchers with trilobate rim are decidedly smaller. Jugs (23.8%), little *amphorae* (17.4%) and bowls (10.5%) are made for use on the table, for kitchen storage and food preparation. Jars with pouring spout, plates, mortars, basins, funnels and large containers are documented in smaller quantities.

Overall, 24 samples have been investigated by archaeometric analysis (Table 1; Figure 3), 14 of which are cooking wares, while 10 samples are vessels used as tableware or for kitchen storage and food preparation. This selection is representative both 'internally', that is, compared to the types found in the *domus*, and 'externally', that is, compared to the types previously investigated in the Daunian archaeological sites. The most representative and well-documented forms in the *domus* stratigraphies were sampled, taking into account the morphological characteristics, functions and decorations. Moreover, the comparability with the vessels was archaeometrically characterised from the other Apulian sites (the references are provided in the Introduction).

A specific sampling concerned the so-called 'Classe type' wares (Gelichi, 1998), that is, vessels without handles, characterised by an everted rim, a flat base and a decoration with a wave motif engraved

**TABLE 1** The ceramic collection. Samples list, findspot information and typology (typology refers to Scrima, 2012).

| Sample | Findspot        | Ceramic type | Shape                | Typological reference |
|--------|-----------------|--------------|----------------------|-----------------------|
| SPV 1  | Room 23-US 3441 | Cooking ware | Jar—Classe type      | II,14 (Tav. LVI. 4)   |
| SPV 2  | Room 33-US 3798 | Cooking ware | Jar—Classe type      | II,15 (Tav. LV.2)     |
| SPV 3  | Room 29-US 3521 | Cooking ware | Jar—Classe type      | II,26 (Tav. LV.3)     |
| SPV 4  | Room 30-US 3754 | Cooking ware | Jar—Classe type      | II,1 (Tav. LV.1)      |
| SPV 5  | Room 29-US 3846 | Cooking ware | Jar                  | II,28 (tav. LVI.6)    |
| SPV 6  | Room na-US 3526 | Cooking ware | Jar                  | II,36 (Tav. LXI.24)   |
| SPV 7  | Room 26-US 3544 | Cooking ware | Jar                  | II,2 (Tav. LVII.8)    |
| SPV 8  | Room 23-US 3458 | Cooking ware | Jar                  | II,20 (Tav. LX.23)    |
| SPV 9  | Room 29-US 3521 | Cooking ware | Jar (double handles) | II,23 (Tav. LIX.17)   |
| SPV 10 | Room na-US 3526 | Cooking ware | Jar                  | II,36 (Tav. LXI.25)   |
| SPV 11 | Room 24-US 3448 | Cooking ware | Pot                  | I,3 (Tav. LXI.26)     |
| SPV 12 | Room 23-US 3422 | Cooking ware | Three-lobed pitcher  | V,1 (Tav. LXIII.36)   |
| SPV 13 | Room 30-US 3452 | Cooking ware | Lid—Classe type      | III,1 (tav. LXII.27)  |
| SPV 14 | Room 23-US 3422 | Cooking ware | Lid                  | III,6 (Tav. LXIII.32) |
| SPV 15 | Room 32-US 3638 | Common ware  | Bowl                 | V,6 (Tav. LXIV.41)    |
| SPV 16 | Room 29-US 3521 | Common ware  | Basin                | IV,8 (Tav. LXX.60)    |
| SPV 17 | Room 32-US 3850 | Common ware  | Basin                | IV,11 (Tav. LXXII.64) |
| SPV 18 | Room 23-US 3458 | Common ware  | Basin                | IV,4 (Tav. LXXI.62)   |
| SPV 19 | Room 26-US 3523 | Common ware  | Mortar               | XI,2 (Tav. LXIX.56)   |
| SPV 20 | Room 24-US 3401 | Common ware  | Small dolium         | X,5 (Tav. LXXV.75)    |
| SPV 21 | Room 29-US 3521 | Common ware  | Small pitcher        | II,11 (Tav. LXVI.47)  |
| SPV 22 | Room 26-US 3557 | Common ware  | Small amphora        | I,10 (Tav. LXXIV.71)  |
| SPV 23 | Room 23-US 3441 | Common ware  | Small amphora        | I,4 (Tav. LXXIII.68)  |
| SPV 24 | Room 33-US 3807 | Common ware  | Funnel               | XIV,1 (Tav. LXXVI.77) |

on the shoulder (SPV 1–5, 7). The associated lids show button grips bearing the same decoration (SPV 13). The amount of 'Classe-type' wares overall found at *Canusium* was remarkable: nearly 170 fragments attributable to 68 vessels were recovered in the *domus*, allowing the morphological evolution to be tracked along the transition between the seventh and eighth centuries. To the latter, other findings from the same complex of San Pietro (Monno, 2018) and a dump excavated in Goldoni Street (current centre of Canosa; archaeometrically characterised in Gliozzo et al., 2013) must be added. Vessels typologically comparable to the 'Classe-type' jars have been reported in sites located in Emilia Romagna (Cavalazzi & Fabbri, 2015; Negrelli, 2021), Veneto (Spagnol, 2007), Marche and Abruzzo (Staffa, 1991) and, on the eastern coast of the Adriatic Sea, in Istria at Parenzo, in Dalmatia at Zara and in Albania at Butrint (Reynolds, 2004), testifying a production destined for commercialisation in the early Middle Ages Adriatic Sea. The jars attested in the seventh-century context of the *Crypta Balbi* in Rome (Ricci, 1998)

represent the only case of circulation of these products in the Tyrrhenian area; however, it is not established that those vessels were the same production. Similar types were recovered from the stratigraphies of the coastal *villa* of Agnuli at Mattinata (Foggia) (Volpe et al., 1998; specifying the attribution is doubtful) and from the early medieval settlement of Faragola (Ascoli Satriano, Foggia), where only one vessel was found in seventh-century layers.

Quantitatively lower are the occurrences of other typologies, such as the two-handled jars with oval section (SPV 9), protruding or extroverted, rounded or moulded rims, generally made without handles (SPV 6, 8, 10), and the pots (SPV 11). Interesting is the presence of a pitcher with a trilobate rim (SPV 12), probably used as a kettle.

The predominance of jars suggests that boiling was the main cooking method for the preparation of liquid and semi-liquid food, based on meat, vegetables and legumes, as also emerged from the analysis of organic residues carried out in other coeval Apulian sites (Giannotta et al., 2018). Among tableware, a small bowl was

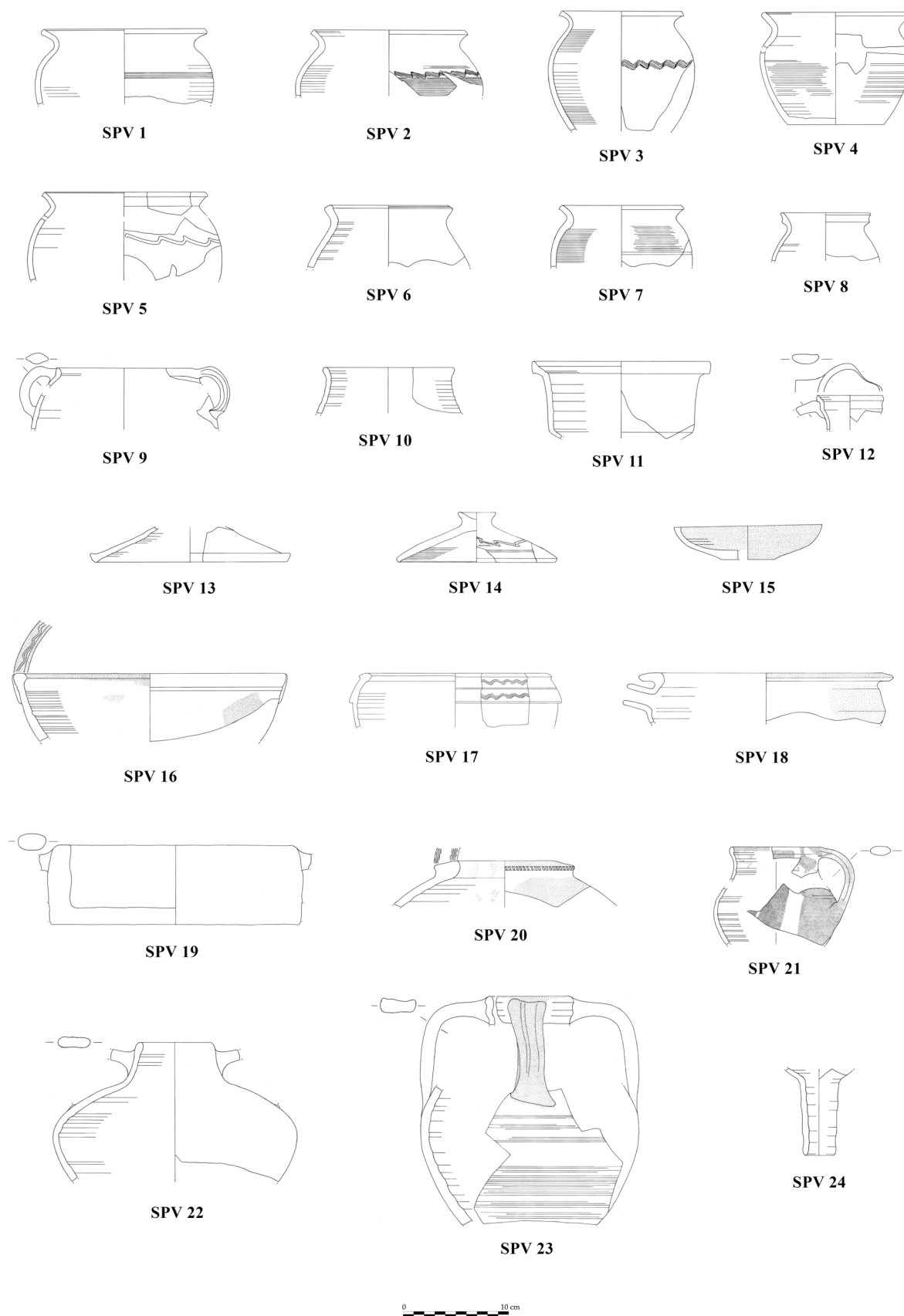


**FIGURE 3** Samples selected for the archaeometric study. Drawings were made by Dr. Gianluca Scrima.

selected (SPV 15). The most attested forms are the jugs and, in particular, the small one analysed here (SPV 21), with a large circular rim and a globular body painted in bands, which shows new morphological features compared to the more frequent models with banded rims.

Mortars were widely used in ancient and medieval cooking to prepare, grind and mix foods (Stasolla, 2003). The selected mortar (SPV 19), with a large diameter (30 cm), low body and thick, irregular walls, was created using the 'colombino' technique, likewise a mortar found at the Faragola site (Giannotta et al., 2018). This particular execution technique is clearly legible based on the traces of the clay roll that wrapped in a spiral that was not subsequently well smoothed. Furthermore, the walls are particularly thick and do not bear traces of the potter's wheel lines.

The basins are well documented, either in continuity with the late antique artisanal tradition (SPV 17) or showing innovations with new typologies characterised by rims that tend to narrow and become less deep (SPV 16) or shallow vessels with a projecting pouring spout.

The two-handled amphorae (SPV 22 and 23) are the most attested types of storage kitchen wares since at least 30 examples with a wide typological articulation were found. Alongside the amphorae types with moulded rims, ribbon handles and ovoid bodies (SPV 23) used during the Late Antiquity, different small amphorae are also documented. The latter show an almost indistinct, slightly thickened rim and a flattened body with a biconical profile (SPV 22; height of 20/22 cm). This vessel was sampled because it does not find regional comparisons and shows a macroscopically different paste. The amphorae were storage vessels used for kitchen pantries and oil and wine storage, but were probably also used for retail and local and/or regional trades. In addition, these amphorae are associated with funnels (SPV 24), used to transfer liquids (water, wine and oil) into vessels of different capacities, as also well documented at Faragola (Scrima & Turchiano, 2012; Turchiano & Volpe, 2019).

Lastly, the sample SPV 20 is a large container without handles, very similar to a small *dolium*, which was likely used for wine and oil storage.

## 4 | METHODS

A small slice was cut perpendicular to each artefact's surface to prepare polished thin sections. All thin sections were investigated by polarised light optical microscopy (Axio Imager A2m Zeiss) and scanning electron microscopy (SEM-EDS). Morphological and semi-quantitative microchemical analyses were performed using a SEM-EDS electronic microscope (ZEISS EVO MA 15; M.E.M.A. University of Florence) equipped with an analytical system in dispersion of energy EDS/SDD, Oxford Ultimex 40 (40 mm<sup>2</sup> with resolution 127 eV @5.9 keV). The operative conditions were as follows: acceleration potential of 15 kV, 500 pA beam current, working distance of 9–8.5 mm, 20 s live time as the acquisition rate useful to archive at least 600.000 cts, on Co standard, process time 4 for point analyses. Microanalysis software (Aztec 5.0 SP1) applies the XPP matrix correction scheme developed by Pouchou and Pichoir (1991). This is a Phi-Rho-Z approach that uses

exponentials to describe the shape of the  $\phi$  ( $\rho z$ ) curve. XPP matrix correction was chosen because of its favourable performance in situations of severe absorption, such as the analysis of light elements in a heavy matrix. The quantitative analysis is 'standard-less', that is, using pre-acquired standard materials for calculations and constant analytical conditions (i.e., filament emission) are obtained through repeated analyses of a Co metallic standard. Detection limits and precision were 0.1 wt% and ~2%, respectively. Observations were mainly performed in backscattered electrons on carbon-coated polished surfaces.

For bulk chemistry, around 10–15 g from each sample was finely ground and analysed for major, minor, trace and rare-earth elements at the Bureau Veritas Laboratories, Vancouver (Canada). About 5 g of each sample was subjected to a LiBO<sub>2</sub>/Li<sub>2</sub>B<sub>4</sub>O<sub>7</sub> fusion in a graphite crucible at 980°C, followed by digestion in nitric acid (5 vol.% concentration). The SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, CaO, MgO, Na<sub>2</sub>O, K<sub>2</sub>O, TiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, MnO, Ba and Ni contents were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES) using Spectro Ciros Vision equipment. The trace elements were determined by inductively coupled plasma mass spectrometry (ICP-MS) using a Perkin-Elmer-Elan 6000/9000 instrument and following the same decomposition procedure described above. The precious and base metals<sup>2+</sup> (Mo, Cu, Pb, Zn, Ni, As, Cd, Sb, Bi, Au, Hg and Tl) were digested in *aqua regia* and analysed by ICP-MS. The loss on ignition was calculated after heating the undried sample for 90 min at 1000°C in a LECO furnace. The standards STD SO-19 and STD OREAS30A (ORE Research & Exploration Pty Ltd.) were used for major elements (SiO<sub>2</sub>, TiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, MnO, MgO, CaO, Na<sub>2</sub>O, K<sub>2</sub>O and P<sub>2</sub>O<sub>5</sub>), minor/trace elements (Sc, Be, V, Cr, Co, Ga, Rb, Sr, Y, Zr, Nb, Sn, Cs, Ba, Hf, Ta, W, Th and U) and rare-earth elements (La Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu). Ni, Cu, Zn, As, Mo, Cd, Sb, Au, Tl, Pb and Bi were determined based on STD BVGEO01, STD DS11 and STD OREAS262 standards.

## 5 | RESULTS

The presentation of the results is divided according to the analytical techniques that were used to obtain them. Bulk chemical analyses precede the minero-petrographic and microchemical investigations carried out by optical microscopy and SEM-EDS, respectively.

### 5.1 | Bulk geochemical analyses

The results are provided in Table 2 and shown in Figures 4 and 5.

Based on the ternary diagrams provided by Gliozzo (2020), the ceramic collection from *Canusium* can be divided into three main groups (Figure 4a,b):

1. Ca-poor/non-carbonatic ceramics, including six samples of cooking ware (blue dots; SPV 6, 8–12, 14) and the small amphora SPV 22 (pink dot);

TABLE 2 Major, minor and trace element contents measured by inductively coupled plasma atomic emission spectrometry (ICP-AES) and inductively coupled plasma mass spectrometry (ICP-MS).

| SPV# | SiO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | Fe <sub>2</sub> O <sub>3</sub> | MgO  | CaO   | Na <sub>2</sub> O | K <sub>2</sub> O | TiO <sub>2</sub> | P <sub>2</sub> O <sub>5</sub> | MnO  | LOI  | Be   | Sc   | V   | Co   | Cr  | Ni  | Cu   | Zn | Ga   | As | Rb    | Sr  |     |    |   |      |     |    |     |    |     |
|------|------------------|--------------------------------|--------------------------------|------|-------|-------------------|------------------|------------------|-------------------------------|------|------|------|------|-----|------|-----|-----|------|----|------|----|-------|-----|-----|----|---|------|-----|----|-----|----|-----|
|      | 0.01             | 0.01                           | 0.04                           | 0.01 | 0.01  | 0.01              | 0.01             | 0.01             | 0.01                          | 0.01 |      | 1    | 1    | 8   | 0.2  | 10  | 20  | 0.1  | 1  | 0.5  | 1  | 0.1   | 5   |     |    |   |      |     |    |     |    |     |
| 1    | 46.32            | 14.34                          | 4.57                           | 2.03 | 30.46 | 0.13              | 0.89             | 1.02             | 0.13                          | 0.13 | 20.9 | 1    | 12   | 119 | 16.1 | 172 | 86  | 15.1 | 54 | 10.6 | 4  | 36.5  | 143 |     |    |   |      |     |    |     |    |     |
| 2    | 46.29            | 12.40                          | 4.73                           | 1.28 | 32.23 | 0.26              | 1.66             | 0.90             | 0.13                          | 0.13 | 21.7 | 2    | 11   | 119 | 16.7 | 166 | 88  | 18.8 | 67 | 9.3  | 6  | 52.4  | 168 |     |    |   |      |     |    |     |    |     |
| 3    | 39.02            | 14.63                          | 6.37                           | 1.36 | 35.37 | 0.27              | 1.90             | 0.81             | 0.27                          | 0.00 | 25.9 | <1   | 12   | 146 | 12.6 | 130 | 94  | 16.9 | 63 | 10.0 | 17 | 56.3  | 194 |     |    |   |      |     |    |     |    |     |
| 4    | 45.78            | 13.81                          | 5.75                           | 2.17 | 30.05 | 0.26              | 1.02             | 0.90             | 0.13                          | 0.13 | 21.7 | 1    | 12   | 129 | 17.3 | 166 | 90  | 14.6 | 73 | 10.8 | 7  | 35.1  | 165 |     |    |   |      |     |    |     |    |     |
| 5    | 48.94            | 15.07                          | 6.23                           | 2.62 | 23.66 | 0.37              | 1.87             | 0.87             | 0.25                          | 0.12 | 19.5 | 2    | 13   | 136 | 19.6 | 156 | 103 | 12.0 | 74 | 12.0 | 8  | 65.2  | 183 |     |    |   |      |     |    |     |    |     |
| 6    | 64.14            | 18.65                          | 6.25                           | 1.64 | 3.28  | 1.23              | 3.69             | 0.72             | 0.20                          | 0.20 | 2.2  | 3    | 12   | 108 | 14.1 | 62  | 34  | 12.2 | 31 | 17.2 | 6  | 204.1 | 244 |     |    |   |      |     |    |     |    |     |
| 7    | 46.33            | 16.60                          | 6.18                           | 0.90 | 25.87 | 0.39              | 2.19             | 0.77             | 0.64                          | 0.13 | 22.1 | 4    | 11   | 109 | 9.0  | 78  | 37  | 17.8 | 72 | 12.0 | 23 | 86.9  | 279 |     |    |   |      |     |    |     |    |     |
| 8    | 69.80            | 15.76                          | 5.45                           | 1.31 | 1.82  | 1.31              | 3.74             | 0.61             | 0.10                          | 0.10 | 0.7  | 4    | 11   | 102 | 11.6 | 52  | 30  | 10.2 | 14 | 14.8 | 2  | 171.9 | 145 |     |    |   |      |     |    |     |    |     |
| 9    | 70.43            | 15.76                          | 6.85                           | 0.87 | 2.61  | 0.33              | 2.17             | 0.65             | 0.22                          | 0.11 | 7.8  | 2    | 16   | 115 | 20.2 | 99  | 71  | 34.4 | 82 | 14.8 | 13 | 54.4  | 161 |     |    |   |      |     |    |     |    |     |
| 10   | 69.13            | 16.11                          | 5.61                           | 1.35 | 1.87  | 1.35              | 3.74             | 0.62             | 0.10                          | 0.10 | 3.4  | 2    | 12   | 98  | 12.3 | 62  | 30  | 26.8 | 67 | 14.9 | 10 | 152.3 | 188 |     |    |   |      |     |    |     |    |     |
| 11   | 69.59            | 15.52                          | 5.25                           | 1.61 | 2.25  | 1.28              | 3.64             | 0.64             | 0.11                          | 0.11 | 6.4  | 6    | 10   | 103 | 11.7 | 52  | 30  | 22.2 | 70 | 13.3 | 11 | 132.6 | 263 |     |    |   |      |     |    |     |    |     |
| 12   | 66.91            | 17.26                          | 5.92                           | 1.84 | 2.04  | 1.23              | 3.78             | 0.72             | 0.10                          | 0.20 | 1.9  | 6    | 12   | 102 | 12.1 | 62  | 30  | 11.9 | 19 | 16.4 | 2  | 181.1 | 218 |     |    |   |      |     |    |     |    |     |
| 13   | 47.86            | 16.96                          | 6.16                           | 1.01 | 25.13 | 0.25              | 1.38             | 1.01             | 0.13                          | 0.13 | 20.3 | <1   | 14   | 155 | 15.2 | 182 | 116 | 24.0 | 74 | 12.4 | 9  | 58.7  | 146 |     |    |   |      |     |    |     |    |     |
| 14   | 69.16            | 16.38                          | 5.89                           | 1.28 | 2.36  | 0.86              | 3.21             | 0.64             | 0.11                          | 0.11 | 6.5  | 3    | 11   | 125 | 10.5 | 62  | 31  | 16.3 | 69 | 14.7 | 16 | 134.5 | 163 |     |    |   |      |     |    |     |    |     |
| 15   | 56.27            | 14.46                          | 5.42                           | 2.15 | 16.72 | 1.02              | 2.94             | 0.68             | 0.23                          | 0.11 | 11.2 | 4    | 12   | 97  | 10.9 | 73  | 34  | 21.9 | 77 | 12.5 | 4  | 81.5  | 395 |     |    |   |      |     |    |     |    |     |
| 16   | 57.55            | 14.33                          | 5.51                           | 2.09 | 15.55 | 1.10              | 2.76             | 0.66             | 0.33                          | 0.11 | 9.2  | <1   | 12   | 114 | 12.3 | 68  | 33  | 17.9 | 73 | 12.9 | 14 | 88.8  | 356 |     |    |   |      |     |    |     |    |     |
| 17   | 57.32            | 16.30                          | 5.88                           | 2.33 | 12.75 | 0.89              | 3.44             | 0.78             | 0.22                          | 0.11 | 9.8  | 3    | 13   | 118 | 12.6 | 73  | 33  | 25.9 | 88 | 16.3 | 6  | 104.8 | 370 |     |    |   |      |     |    |     |    |     |
| 18   | 58.16            | 14.68                          | 5.48                           | 2.63 | 14.13 | 1.10              | 2.85             | 0.66             | 0.22                          | 0.11 | 8.6  | <1   | 13   | 101 | 11.4 | 73  | 38  | 21.1 | 64 | 14.4 | 10 | 99.6  | 365 |     |    |   |      |     |    |     |    |     |
| 19   | 56.57            | 13.92                          | 5.35                           | 2.34 | 16.26 | 1.11              | 3.12             | 0.67             | 0.56                          | 0.11 | 10.0 | 1    | 12   | 120 | 10.4 | 73  | 28  | 22.0 | 72 | 11.9 | 22 | 95.3  | 402 |     |    |   |      |     |    |     |    |     |
| 20   | 59.19            | 16.81                          | 6.16                           | 2.82 | 9.71  | 0.94              | 3.34             | 0.73             | 0.21                          | 0.10 | 4.1  | 2    | 15   | 110 | 13.7 | 94  | 38  | 19.8 | 58 | 16.9 | 7  | 113.3 | 329 |     |    |   |      |     |    |     |    |     |
| 21   | 59.22            | 14.75                          | 5.42                           | 2.06 | 13.23 | 1.19              | 3.04             | 0.65             | 0.33                          | 0.11 | 7.7  | <1   | 13   | 92  | 11.5 | 78  | 29  | 22.0 | 68 | 14.0 | 10 | 92.4  | 366 |     |    |   |      |     |    |     |    |     |
| 22   | 65.24            | 18.76                          | 7.65                           | 1.22 | 1.94  | 1.02              | 3.16             | 0.71             | 0.20                          | 0.10 | 1.8  | 4    | 13   | 128 | 11.3 | 78  | 29  | 9.9  | 12 | 19.2 | 2  | 226.8 | 148 |     |    |   |      |     |    |     |    |     |
| 23   | 58.07            | 14.97                          | 5.67                           | 2.14 | 14.12 | 1.18              | 2.67             | 0.75             | 0.32                          | 0.11 | 6.2  | 4    | 13   | 105 | 12.7 | 73  | 39  | 21.3 | 80 | 15.8 | 6  | 97.4  | 352 |     |    |   |      |     |    |     |    |     |
| 24   | 59.05            | 16.21                          | 6.21                           | 2.11 | 11.58 | 0.95              | 2.84             | 0.74             | 0.21                          | 0.11 | 4.5  | 1    | 15   | 117 | 13.7 | 83  | 44  | 28.0 | 87 | 17.2 | 5  | 106.5 | 366 |     |    |   |      |     |    |     |    |     |
| SPV# | Y                | Zr                             | Nb                             | Mo   | Cd    | Sn                | Sb               | Cs               | Ba                            | La   | Ce   | Pr   | Nd   | Sm  | Eu   | Gd  | Tb  | Dy   | Ho | Er   | Tm | Yb    | Lu  | Hf  | Ta | W | Au   | Tl  | Pb | Bi  | Th | U   |
|      | 0.5              | 2                              | 0.1                            | 0.1  | 0.1   | 1                 | 0.1              | 0.1              | 1                             | 0.1  | 0.1  | 0.1  | 0.02 | 1   | 1    | 1   | 1   | 1    | 1  | 1    | 1  | 1     | 0.1 | 0.2 | 1  | 1 | 0.5  | 0.1 | 2  | 0.1 | 1  | 0.1 |
| 1    | 25.5             | 211                            | 13.7                           | 1.1  | 0.3   | 2                 | 0.2              | 4.0              | 219                           | 30.7 | 62.8 | 7.04 | 26   | 5   | 1    | 5   | 1   | 4    | 1  | 3    | -  | 3     | 0.4 | 5.7 | 1  | 2 | 12.5 | 0.3 | 14 | 0.2 | 10 | 2.7 |

(Continues)

TABLE 2 (Continued)

| SPV# | Y    | Zr  | Nb   | Mo  | Cd   | Sn | Sb   | Cs   | Ba  | La   | Ce    | Pr    | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu  | Hf  | Ta | W | Au   | Tl   | Pb | Bi   | Th | U   |
|------|------|-----|------|-----|------|----|------|------|-----|------|-------|-------|----|----|----|----|----|----|----|----|----|----|-----|-----|----|---|------|------|----|------|----|-----|
| 2    | 22.2 | 214 | 11.4 | 0.8 | 0.4  | 2  | 0.2  | 3.7  | 293 | 26.8 | 53.8  | 5.97  | 23 | 4  | 1  | 4  | 1  | 4  | 1  | 2  | -  | 2  | 0.4 | 5.7 | 1  | 2 | 2.2  | 0.2  | 16 | 0.2  | 9  | 2.7 |
| 3    | 18.6 | 101 | 9.2  | 0.9 | 0.2  | 2  | 0.3  | 4.0  | 301 | 21.9 | 43.8  | 5.07  | 19 | 3  | 1  | 3  | 1  | 3  | 1  | 2  | -  | 2  | 0.3 | 2.9 | 1  | 1 | 3.4  | 0.2  | 14 | 0.2  | 7  | 1.8 |
| 4    | 26.1 | 203 | 13.3 | 1   | 0.5  | 2  | 0.3  | 3.5  | 253 | 30.4 | 64.3  | 6.86  | 26 | 5  | 1  | 5  | 1  | 4  | 1  | 3  | -  | 3  | 0.4 | 5.5 | 1  | 2 | 6.2  | 0.3  | 16 | 0.3  | 9  | 2.6 |
| 5    | 21.6 | 143 | 11.9 | 0.7 | 0.4  | 2  | 0.1  | 5.1  | 319 | 26.7 | 52.9  | 5.91  | 23 | 4  | 1  | 4  | 1  | 4  | 1  | 2  | -  | 2  | 0.3 | 4   | 1  | 2 | 1.9  | 0.2  | 15 | 0.2  | 9  | 2.1 |
| 6    | 32.1 | 334 | 35.3 | 0.7 | <0.1 | 4  | 0.2  | 13.5 | 669 | 59.7 | 126.9 | 12.79 | 47 | 8  | 2  | 7  | 1  | 6  | 1  | 3  | -  | 3  | 0.5 | 7.7 | 2  | 4 | 4.6  | 0.4  | 12 | <0.1 | 24 | 2.6 |
| 7    | 44.7 | 202 | 19.8 | 0.7 | 0.4  | 3  | 0.3  | 8.1  | 452 | 64.5 | 99.7  | 13.14 | 49 | 9  | 2  | 8  | 1  | 7  | 1  | 4  | 1  | 3  | 0.5 | 5   | 1  | 2 | 3.4  | 0.5  | 36 | 0.4  | 20 | 4.3 |
| 8    | 26.3 | 245 | 22.3 | 0.7 | <0.1 | 3  | <0.1 | 8.8  | 593 | 43.6 | 86.9  | 9.62  | 36 | 6  | 1  | 6  | 1  | 5  | 1  | 3  | -  | 2  | 0.4 | 6.2 | 1  | 2 | 2.8  | 0.2  | 8  | <0.1 | 16 | 2.1 |
| 9    | 51.0 | 163 | 17.6 | 0.7 | 0.2  | 3  | 0.2  | 4.0  | 427 | 55.8 | 75.6  | 12.03 | 47 | 9  | 2  | 9  | 1  | 8  | 2  | 5  | 1  | 4  | 0.6 | 4.3 | 1  | 2 | 12.4 | 0.3  | 26 | 0.4  | 12 | 1.5 |
| 10   | 25.0 | 246 | 20.8 | 1   | 0.1  | 3  | 0.2  | 6.4  | 589 | 39.4 | 79.9  | 8.94  | 33 | 6  | 1  | 5  | 1  | 4  | 1  | 3  | -  | 3  | 0.4 | 6.3 | 1  | 4 | 7.9  | 0.6  | 25 | 0.3  | 15 | 2.1 |
| 11   | 24.1 | 312 | 25.6 | 0.6 | <0.1 | 3  | 0.1  | 7.0  | 607 | 43.0 | 87.7  | 9.39  | 34 | 6  | 1  | 5  | 1  | 4  | 1  | 2  | -  | 2  | 0.4 | 7.4 | 1  | 3 | 2.9  | 0.6  | 24 | 0.2  | 19 | 2.4 |
| 12   | 25.7 | 283 | 27.6 | 0.8 | <0.1 | 3  | 0.1  | 12.7 | 601 | 48.6 | 94.8  | 10.32 | 36 | 7  | 1  | 5  | 1  | 5  | 1  | 3  | -  | 3  | 0.4 | 6.9 | 2  | 3 | 3.8  | 0.3  | 6  | <0.1 | 21 | 2.6 |
| 13   | 23.2 | 168 | 12.5 | 1.1 | 0.3  | 3  | 0.2  | 4.2  | 242 | 28.6 | 56.6  | 6.65  | 25 | 5  | 1  | 4  | 1  | 4  | 1  | 2  | -  | 2  | 0.4 | 4.6 | 1  | 2 | 3.0  | 0.3  | 71 | 0.3  | 10 | 2.2 |
| 14   | 20.7 | 228 | 22.1 | 0.9 | <0.1 | 3  | 0.2  | 6.8  | 538 | 35.1 | 77.6  | 8.07  | 30 | 5  | 1  | 4  | 1  | 4  | 1  | 2  | -  | 2  | 0.3 | 5.7 | 1  | 3 | 3.0  | 0.6  | 25 | 0.3  | 17 | 2.2 |
| 15   | 20.9 | 143 | 12.1 | 0.8 | 0.1  | 3  | <0.1 | 4.0  | 657 | 27.4 | 53.9  | 6.37  | 24 | 5  | 1  | 4  | 1  | 4  | 1  | 2  | -  | 2  | 0.3 | 3.9 | 1  | 2 | 1.5  | 0.3  | 14 | 0.2  | 9  | 2.5 |
| 16   | 21.6 | 144 | 12.6 | 0.9 | 0.1  | 2  | 0.1  | 4.6  | 371 | 28.4 | 54.4  | 6.51  | 25 | 5  | 1  | 4  | 1  | 4  | 1  | 2  | -  | 2  | 0.3 | 3.9 | 1  | 2 | 7.6  | 0.3  | 14 | <0.1 | 9  | 2.9 |
| 17   | 23.1 | 138 | 12.8 | 0.6 | 0.2  | 3  | <0.1 | 4.9  | 448 | 31.3 | 60.6  | 7.15  | 27 | 5  | 1  | 5  | 1  | 4  | 1  | 2  | -  | 2  | 0.3 | 3.7 | 1  | 2 | 6.2  | 0.3  | 20 | 0.3  | 11 | 3.2 |
| 18   | 21.5 | 151 | 12.2 | 0.8 | <0.1 | 3  | 0.2  | 4.4  | 357 | 28.3 | 56.2  | 6.57  | 25 | 5  | 1  | 4  | 1  | 4  | 1  | 2  | -  | 2  | 0.3 | 4.1 | 1  | 2 | 1.5  | 0.2  | 15 | 0.2  | 10 | 3.8 |
| 19   | 22.7 | 146 | 12.3 | 0.9 | <0.1 | 3  | 0.2  | 4.8  | 453 | 28.6 | 55.9  | 6.54  | 24 | 5  | 1  | 4  | 1  | 4  | 1  | 2  | -  | 2  | 0.3 | 4.2 | 1  | 2 | 3.5  | 0.3  | 17 | <0.1 | 10 | 4.8 |
| 20   | 22.5 | 138 | 14.0 | 0.4 | <0.1 | 3  | 0.2  | 5.9  | 425 | 32.7 | 62.7  | 7.47  | 28 | 5  | 1  | 5  | 1  | 4  | 1  | 2  | -  | 2  | 0.3 | 3.6 | 1  | 2 | 4.5  | <0.1 | 12 | 0.1  | 11 | 2.4 |
| 21   | 21.5 | 151 | 12.1 | 0.5 | <0.1 | 3  | 0.2  | 4.3  | 422 | 28.4 | 54.9  | 6.48  | 25 | 5  | 1  | 4  | 1  | 4  | 1  | 2  | -  | 2  | 0.3 | 4   | 1  | 3 | 29.9 | 0.1  | 32 | 0.2  | 10 | 3   |
| 22   | 26.7 | 256 | 26.1 | 0.8 | <0.1 | 4  | 0.1  | 14.8 | 423 | 50.6 | 95.4  | 10.69 | 38 | 7  | 1  | 5  | 1  | 5  | 1  | 3  | -  | 3  | 0.4 | 6.2 | 2  | 3 | 3.1  | 0.1  | 4  | <0.1 | 22 | 4.3 |
| 23   | 23.1 | 153 | 13.3 | 1.2 | <0.1 | 3  | 0.2  | 4.5  | 300 | 29.9 | 56.8  | 6.81  | 25 | 5  | 1  | 5  | 1  | 4  | 1  | 2  | -  | 2  | 0.3 | 4.1 | 1  | 2 | 5.0  | 0.2  | 14 | 0.2  | 10 | 2.6 |
| 24   | 24.7 | 152 | 14.6 | 1.2 | <0.1 | 3  | 0.2  | 5.1  | 381 | 33.1 | 65.2  | 7.52  | 28 | 5  | 1  | 5  | 1  | 4  | 1  | 2  | -  | 2  | 0.3 | 4.1 | 1  | 2 | 3.4  | 0.3  | 25 | 0.2  | 10 | 3.1 |

Note: Major element contents have been normalised to 100 after the subtraction of loss on ignition (LOI) values. Major oxides and LOI are expressed as wt%; all the other elements are given in ppm. Detection limits are reported in the second row. Se and Hg were measured but not reported as they were constantly below the detection limits.

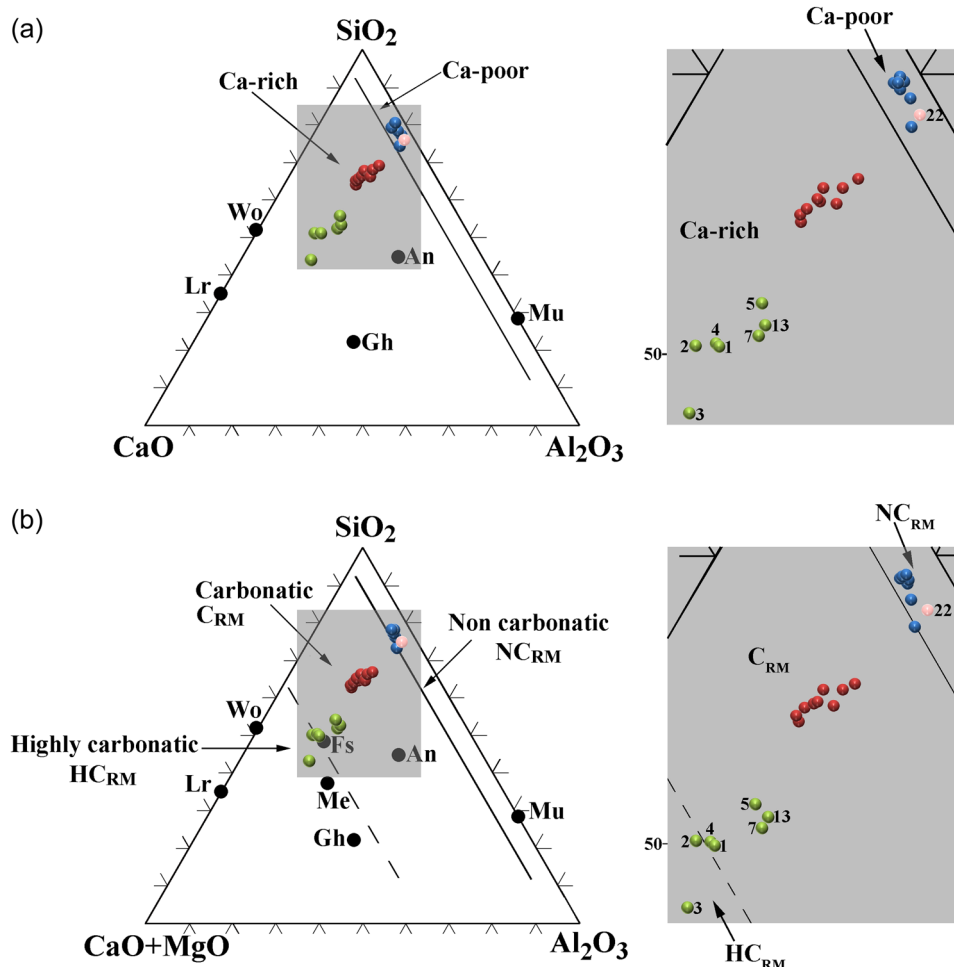


**FIGURE 4** Ternary diagrams showing common ware (red and pink dots) and cooking ware (blue and green dots). In the two ternaries, the classification varies depending on whether CaO alone is considered (a) or the sum of CaO and MgO (b). An, anorthite; Fs, forsterite; Gh, gehlenite; Lr, larnite; Me, melilite; Mu, mullite; Wo, wollastonite.

2. Ca-rich/carbonatic ceramics, including nine samples of common ware (red dots; SPV 15–21, 23–24); and
3. Ca-rich/highly carbonatic ceramics, including seven samples of cooking ware (green dots; SPV 1–5, 7, 13). Only SPV 1–4 approach or fall within the highly carbonatic field; however, 5, 7 and 13 show greater similarities to them rather than to the Ca-rich/carbonatic ceramics.

As shown in Figure 4a,b, the subdivision into Ca-poor and Ca-rich is based on CaO wt% exclusively, while the subdivision into non-carbonatic, carbonatic and highly carbonatic considers both the CaO and the MgO wt%.

Overall, the ternary diagrams unquestionably demonstrate that while all common wares (except SPV 22) are carbonatic, the cooking wares are either non-carbonatic or highly carbonatic.

The binary diagrams provided in Figure 5a reinforce the validity of this grouping and show further details. For example, SiO<sub>2</sub> represents a valid discriminant; conversely, Al<sub>2</sub>O<sub>3</sub> contents show wide variations in all three groups. What can be observed in the diagram translates into a close similarity of the Al<sub>2</sub>O<sub>3</sub> average

values of each group: 16.8 wt% (SD = 1.3) in non-carbonatic, 15.2 wt% (SD = 1) in carbonatic and 14.8 wt% (SD = 1.6) in highly carbonatic ceramics.

In Figure 5b, the amounts of CaO and MgO do not show apparent linear correlations. Moreover, common ware shows more homogeneous MgO levels and a higher average value than cooking ware (av. 2.3 with SD 0.3 vs. 1.5 wt% SD 0.5). Conversely, the highly carbonatic cooking wares show the greatest MgO variations, ranging from 0.9 to 2.6 wt%.

Another observation of interest concerns the amphora SPV 22, which appears to be consistently comparable to the non-carbonatic cooking wares in Figure 5a,b.

Another component particularly useful for discriminating groups is Na<sub>2</sub>O, followed, to a lesser extent, by K<sub>2</sub>O. The Na<sub>2</sub>O–K<sub>2</sub>O binary diagram (Figure 5c) demonstrates that the lowest contents of both elements characterise highly carbonatic cooking wares. In contrast, the carbonatic common ware and the non-carbonatic cooking wares are Na<sub>2</sub>O and K<sub>2</sub>O richer. Moreover, while sample SPV 22 becomes comparable with its typological macro-group, sample SPV 9 moves away from the distribution field of non-carbonatic ceramics to that of highly carbonatic cooking wares.

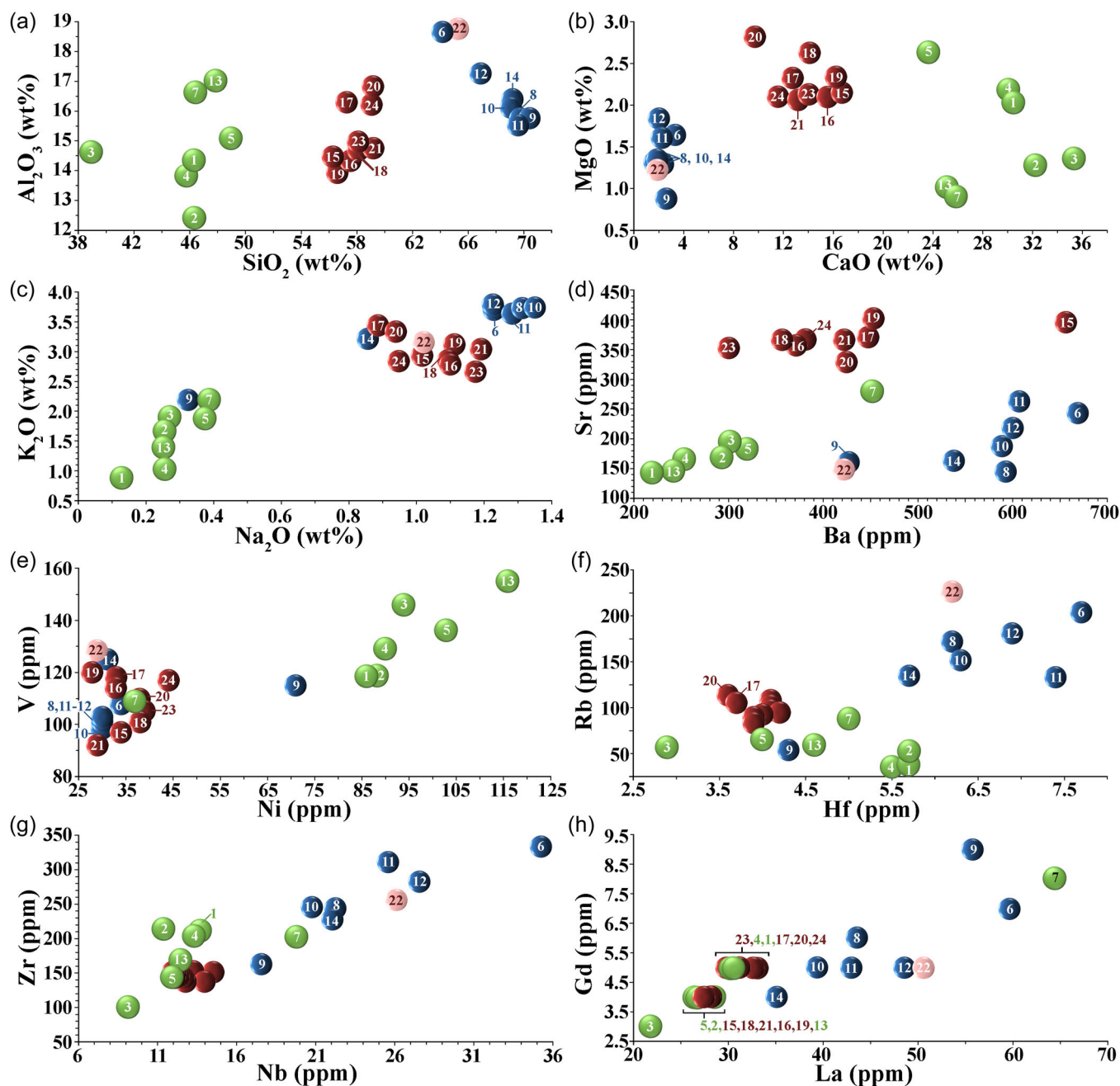


**FIGURE 5** Binary diagrams showing the discrimination parameters distinguishing non-carbonatic wares (pink and blue), highly carbonatic coarse wares (green) and carbonatic fine wares (red). (a)  $\text{SiO}_2$ - $\text{Al}_2\text{O}_3$ , (b)  $\text{CaO}$ - $\text{MgO}$ , (c)  $\text{Na}_2\text{O}$ - $\text{K}_2\text{O}$ , (d)  $\text{Ba}$ - $\text{Sr}$ , (e)  $\text{Ni}$ - $\text{V}$ , (f)  $\text{Hf}$ - $\text{Rb}$ , (g)  $\text{Nb}$ - $\text{Zr}$ , and (h)  $\text{La}$ - $\text{Gd}$ .

Among minor and trace elements, those that perform a discriminating function are Ba and Sr for all three groups, Ni and V for the highly carbonatic cooking wares and the Hf-Rb, Nb-Zr and La-Gd ratios for non-carbonatic cooking wares.

The Ba-Sr ratio outlines three different distribution areas for each group (Figure 5d): low Ba-Sr for highly carbonatic cooking wares, high Ba-low Sr for non-carbonatic cooking wares and intermediate Ba-high Sr for tablewares. However, samples SPV 9 and 22 confirm their anomalous composition, together with samples SPV 7 and 15.

High levels of Ni and partially also of V distinguish the highly carbonatic cooking wares, to which sample SPV 9 tends to

approach in this case (Figure 5e). All the other samples show moderate levels of Ni and variable levels of V. Again, sample SPV 7 stands alone compared to its macro-group, showing low values of both elements.

The last diagrams highlight particular features of non-carbonatic cooking wares, such as the high values of Hf and Rb (Figure 5f), Nb and Zr (Figure 5g) and La and Gd (Figure 5h), as well as the compositional homogeneity of common wares and the singularity of its sample SPV 22. In contrast, the highly carbonatic cooking wares are compositionally heterogeneous, as evidenced by the varying allocation of sample SPV 7.

Overall, the geochemical data consistently distinguish, on the one hand, the three groups represented by (1) non-carbonatic cooking wares, (2) carbonatic tablewares and (3) highly carbonatic cooking wares and, on the other, samples SPV 7, 9 and 22 that often differ from the macro-groups to which they belong.

## 5.2 | Mineralogical–petrographic investigation by OM–microchemical analyses by SEM-EDS

A detailed description of each sample is provided in Supporting Information S1: Table S1, while the main characteristics of each group are discussed below. Images taken by optical microscopy and SEM are provided in Supporting Information S1: Figures S1–S4. The lithic fragments of volcanic origin have been classified following Gliozzo et al. (2014), where

1. Type 1 corresponds to 'aggregates of tabular K-feldspar, showing a trachytic texture and interstitial Fe-oxides' (Figure 6a,b);
2. Type 2 corresponds to clasts 'made of leucite and clinopyroxene, embedded in a glassy groundmass' (Figure 6c,d);
3. Type 3 corresponds to 'strongly vesicular volcanic glass' (Figure 6e,f).

The chemical data obtained by SEM-EDS on the matrices and single crystals are further used to define the groups (Table 3).

The samples can be divided into five groups and three outliers based on their mineralogical–petrographic assemblage and textural and morphological characteristics of the skeleton and the matrix.

### 5.2.1 | Group 1. Calcite temper—Classe type

This group includes six cooking ware samples (SPV 1–5, 13; green dots in Figures 4 and 5) classified as Ca-rich/highly carbonatic through bulk chemical analyses. In all samples, calcite is very abundant and unreacted, quartz is abundant, micas and Mg–Fe chlorites are frequent but very small in size (<30 µm long) and K-feldspar and plagioclase are extremely scarce. Regarding calcite, while SPV 2, 3 and 4 do not contain magnesian calcite, SPV 1 and 5 include abundant magnesian calcite and SPV 13 shows both magnesian calcite and frequent Cr-spinel, along with Mg–Al chlorites. Among the accessory phases, Ti and Fe oxides are typical. Carbonate rocks are the only lithic fragments present (except for a single fragment of mudstone in SPV 4), while minute microfauna is sporadically present and is mainly represented by foraminifera.

The addition of abundant calcite temper homogeneously characterises this group. In support of this statement, mainly based on the angular shape and low sphericity of the calcite crystals and the bimodal texture, the matrix's analysis—representative of the raw clay—further verified that the finer fraction shows a much lower calcium content than that measured by bulk chemistry.

### 5.2.2 | Variant 1a. Calcite temper

This is represented by a single cooking ware sample (SPV 7; green dot in Figures 4 and 5) classified as Ca-rich/highly carbonatic through bulk chemical analyses. Based on major element contents, SPV 7 is very similar to the samples of Group 1; however, minor and trace element contents, along with textural and mineralogical differences, suggest keeping it separate. Recalling bulk chemical data, SPV 7 has comparable contents of SiO<sub>2</sub> and CaO, higher levels of Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, K<sub>2</sub>O, Rb, Sr, Y, Ba, La, Ce, Pb, Th and U and much lower amounts of MgO and Cr than the first group. From a textural and mineralogical standpoint, the sparry calcite has much smaller dimensions (<250 µm), leading to better-sorted grain size. Moreover, although the mineralogical assemblage is the same overall, plagioclase (Ab<sub>92</sub>–Ab<sub>99</sub>) is much more abundant. Conversely, other characteristics, such as the poor sintering of the matrix, the absence of reaction rims around the crystals and the primary porosity, are fully comparable with Group 1.

### 5.2.3 | Group 2. Coarse, non-carbonatic 1

This group includes five cooking ware samples (SPV 6, 8, 10–12; blue dots in Figures 4 and 5) classified as Ca-poor/non-carbonatic through bulk chemical analyses. These samples were grouped because of a similar mineralogical and petrographic assemblage: abundant quartz and orthoclase, plagioclase ranging from albite to bytownite, primary calcite absent, abundant black and white mica, sporadic olivine (Fo<sub>37</sub>–Fo<sub>61</sub>), common to abundant clinopyroxene, rare clin amphibole and, among accessory minerals, frequent garnet (esp. almandine and grossular), iron and/or titanium oxides and epidote. Microfauna is absent, while the numerous lithic inclusions are of volcanic origin.

Despite these similarities, some significant differences are noted. For example, SPV 10 shows a finer grain size and the absence of pervasive elongated voids. Moreover, this is the only sample in which the biotite appears relatively poorer in TiO<sub>2</sub>. As for volcanic clasts, only type 1 is present in SPV 6, 8 and 10, while both type 1 and type 2 are present in SPV 11 and 12. Furthermore, samples SPV 6 and 12 show numerous wads,<sup>1</sup> which are absent in the others.

### 5.2.4 | Group 3. Coarse, non-carbonatic 2

This group includes two cooking ware samples (SPV 9 and 14; blue dots in Figures 4 and 5) classified as Ca-poor/non-carbonatic through bulk chemical analyses. They differ from the previous ones in both textural and compositional characteristics. The average grain size is higher, the degree of sintering is lower, quartz shows previously absent dissolution features, orthoclase bears appreciable amounts of barium, plagioclase is albitic, the primary calcite is rare but present, biotite prevails over muscovite/illite, clinopyroxenes are absent and the rare lithic fragments are represented

<sup>1</sup>The term wad is used to indicate aggregates rich in manganese oxides/hydroxides, characterised by a concentric banding texture.

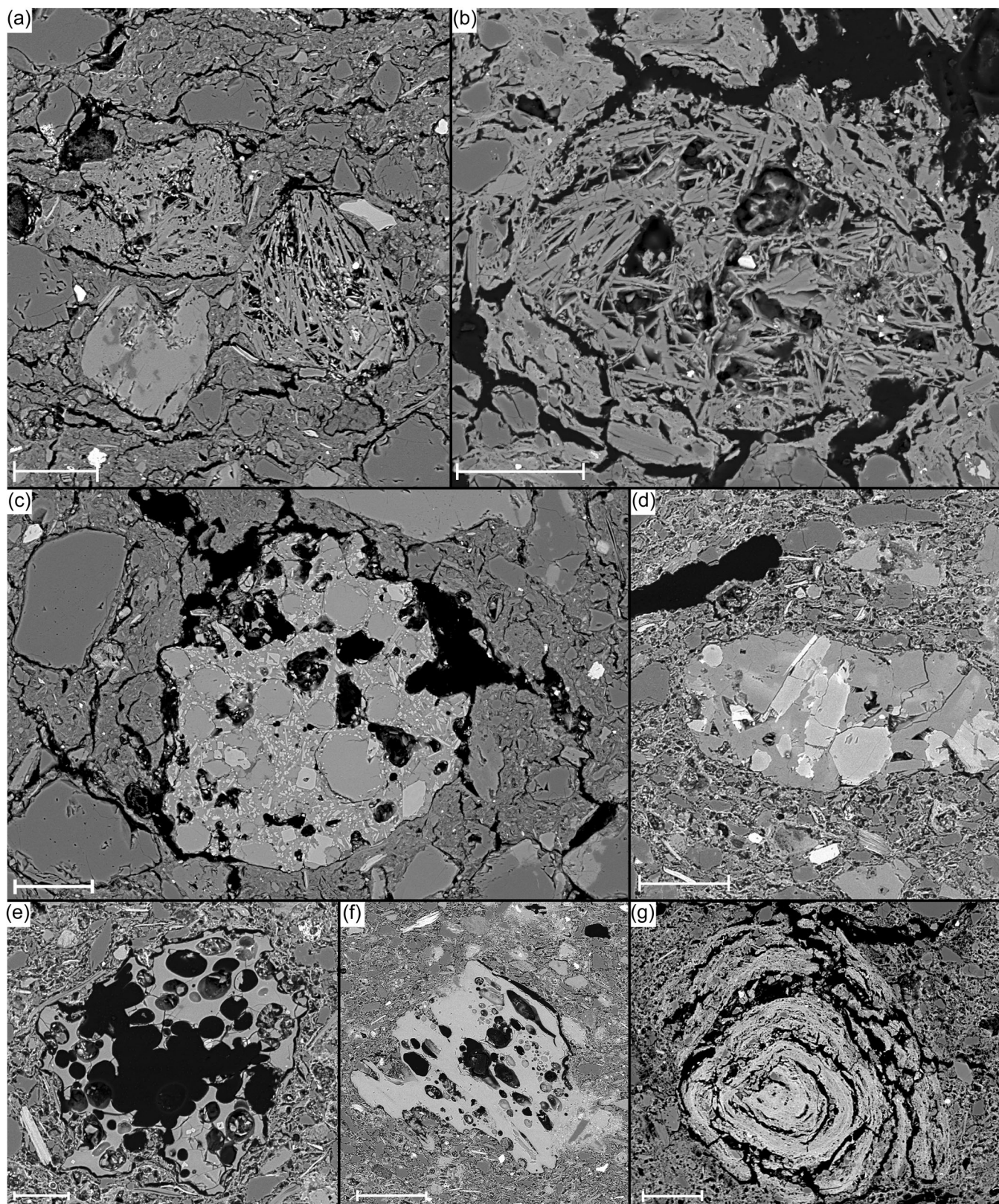


**FIGURE 6** Representative backscattered electron micrographs illustrating the main types of volcanic lithic fragments and WADS in the studied samples. (a) Type 1 in SPV 10; (b) Type 1 in SPV 8; (c) Type 2 in SPV 11; (d) Type 2 in SPV 19; (e) Type 3 in SPV 19; (f) Type 3 in SPV 19; (g) Wads in SPV 6. Scale bars: a–c, e, g = 50  $\mu$ m; d = 100  $\mu$ m; f = 200  $\mu$ m.

**TABLE 3** The composition of the matrix (scanning electron microscopy-EDS). The values are expressed as wt%: average ( $n=$ ) and standard deviation (SD) values.

| Sample |    |          | Na <sub>2</sub> O | MgO  | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> | P <sub>2</sub> O <sub>5</sub> | Cl   | SO <sub>3</sub> | K <sub>2</sub> O | CaO   | TiO <sub>2</sub> | MnO  | FeO   | Total |
|--------|----|----------|-------------------|------|--------------------------------|------------------|-------------------------------|------|-----------------|------------------|-------|------------------|------|-------|-------|
| SPV 1  | HC | $n = 21$ | 0.13              | 1.89 | 23.40                          | 55.00            |                               | 0.05 |                 | 1.57             | 11.11 | 1.26             |      | 5.57  | 100   |
|        |    | SD       | 0.16              | 0.22 | 6.12                           | 3.39             |                               | 0.09 |                 | 0.84             | 6.93  | 0.41             |      | 1.49  |       |
| SPV 2  | HC | $n = 19$ | 0.34              | 1.52 | 17.50                          | 55.21            | 0.10                          | 0.28 | 0.14            | 2.45             | 16.05 | 0.90             | 0.13 | 5.35  | 100   |
|        |    | SD       | 0.06              | 0.11 | 2.12                           | 2.30             | 0.07                          | 0.12 | 0.08            | 0.29             | 2.67  | 0.25             | 0.19 | 1.01  |       |
| SPV 3  | HC | $n = 19$ | 0.43              | 1.63 | 22.60                          | 53.93            | 0.05                          | 2.74 | 0.02            | -                | 9.40  | 1.00             |      | 8.20  | 100   |
|        |    | SD       | 0.09              | 0.08 | 1.81                           | 1.53             | 0.16                          | 0.16 | 0.05            | -                | 2.43  | 0.17             |      | 0.61  |       |
| SPV 4  | HC | $n = 18$ | 0.51              | 1.03 | 26.70                          | 53.73            | -                             | 0.04 | -               | 1.91             | 4.25  | 1.39             | -    | 10.41 | 100   |
|        |    | SD       | 0.07              | 0.19 | 1.79                           | 2.15             | -                             | 0.08 | -               | 0.17             | 1.25  | 0.25             | -    | 1.22  |       |
| SPV 5  | HC | $n = 18$ | 0.53              | 2.25 | 18.89                          | 56.97            | 0.19                          | 0.13 | 0.09            | 2.67             | 11.17 | 0.95             | 0.08 | 6.08  | 100   |
|        |    | SD       | 0.07              | 0.28 | 1.32                           | 2.59             | 0.08                          | 0.10 | 0.07            | 0.18             | 2.32  | 0.12             | 0.05 | 0.30  |       |
| SPV 6  | NC | $n = 22$ | 0.80              | 1.96 | 23.70                          | 58.25            | 0.03                          | 0.01 | -               | 3.56             | 3.13  | 0.92             | 0.03 | 7.61  | 100   |
|        |    | SD       | 0.21              | 0.15 | 0.80                           | 0.91             | 0.13                          | 0.03 | -               | 0.28             | 0.73  | 0.19             | 0.13 | 0.54  |       |
| SPV 7  | HC | $n = 18$ | 0.52              | 1.09 | 22.49                          | 57.73            | 0.80                          | -    | -               | 2.92             | 6.86  | 0.96             | -    | 6.66  | 100   |
|        |    | SD       | 0.13              | 0.10 | 1.59                           | 2.54             | 0.24                          | -    | -               | 0.21             | 2.64  | 0.14             | -    | 1.06  |       |
| SPV 8  | NC | $n = 28$ | 0.91              | 1.86 | 23.30                          | 59.05            | -                             | -    | -               | 3.96             | 2.90  | 0.48             | -    | 7.57  | 100   |
|        |    | SD       | 0.46              | 0.34 | 1.51                           | 2.10             | -                             | -    | -               | 1.13             | 0.77  | 0.51             | -    | 1.23  |       |
| SPV 9  | NC | $n = 20$ | 0.51              | 1.02 | 20.11                          | 64.83            | -                             | 0.01 | -               | 2.56             | 2.18  | 0.90             | 0.03 | 7.85  | 100   |
|        |    | SD       | 0.09              | 0.07 | 0.99                           | 1.85             | -                             | 0.03 | -               | 0.13             | 0.24  | 0.15             | 0.16 | 0.71  |       |
| SPV 10 | NC | $n = 24$ | 0.97              | 1.83 | 20.73                          | 62.25            | -                             | 0.11 | -               | 3.80             | 2.16  | 0.78             | 0.02 | 7.36  | 100   |
|        |    | SD       | 0.26              | 0.37 | 1.07                           | 1.83             | -                             | 0.09 | -               | 0.25             | 0.27  | 0.15             | 0.08 | 0.79  |       |
| SPV 11 | NC | $n = 39$ | 0.85              | 2.00 | 20.46                          | 62.78            | 0.05                          | 0.05 | -               | 3.98             | 2.40  | 0.74             | 0.03 | 6.67  | 100   |
|        |    | SD       | 0.20              | 0.14 | 0.73                           | 1.49             | 0.15                          | 0.08 | -               | 0.26             | 0.21  | 0.14             | 0.11 | 0.53  |       |
| SPV 12 | NC | $n = 27$ | 1.10              | 1.82 | 20.81                          | 60.30            | -                             | 0.02 | -               | 4.96             | 2.86  | 0.82             | 0.02 | 7.29  | 100   |
|        |    | SD       | 0.35              | 0.16 | 0.97                           | 2.33             | -                             | 0.06 | -               | 0.80             | 0.89  | 0.32             | 0.10 | 0.44  |       |
| SPV 13 | HC | $n = 19$ | 0.55              | 3.91 | 24.76                          | 51.37            | 1.85                          | -    | 0.11            | -                | 8.88  | 1.00             | -    | 7.57  | 100   |
|        |    | SD       | 0.13              | 0.48 | 1.95                           | 3.44             | 0.27                          | -    | 0.11            | -                | 3.63  | 0.28             | -    | 1.84  |       |
| SPV 14 | NC | $n = 19$ | 0.70              | 1.68 | 21.60                          | 61.34            | -                             | -    | -               | 3.78             | 2.69  | 0.78             | -    | 7.44  | 100   |
|        |    | SD       | 0.19              | 0.09 | 1.07                           | 2.27             | -                             | -    | -               | 0.21             | 1.82  | 0.25             | -    | 0.64  |       |
| SPV 15 | C  | $n = 21$ | 0.90              | 2.59 | 16.54                          | 51.82            | -                             | 0.04 | -               | 2.68             | 19.04 | 0.68             | -    | 5.76  | 100   |
|        |    | SD       | 0.22              | 0.33 | 1.21                           | 3.64             | -                             | 0.08 | -               | 0.57             | 3.98  | 0.31             | -    | 0.55  |       |
| SPV 16 | C  | $n = 19$ | 0.98              | 2.38 | 16.22                          | 53.94            | 0.02                          | 0.13 | 0.06            | 2.83             | 17.09 | 0.67             | -    | 5.68  | 100   |
|        |    | SD       | 0.23              | 0.16 | 1.46                           | 3.32             | 0.11                          |      | 0.20            | 0.40             | 2.97  | 0.41             | -    | 0.42  |       |
| SPV 17 | C  | $n = 20$ | 0.67              | 2.41 | 18.22                          | 54.94            | 0.05                          | 0.20 | -               | 3.72             | 13.39 | 0.45             | -    | 5.96  | 100   |
|        |    | SD       | 0.37              | 0.19 | 1.11                           | 1.93             | 0.23                          | 0.14 | -               | 0.34             | 1.54  | 0.52             | -    | 0.65  |       |
| SPV 18 | C  | $n = 27$ | 0.93              | 2.84 | 16.06                          | 52.22            | -                             | 0.03 | 0.08            | 2.71             | 18.91 | 0.64             | -    | 5.59  | 100   |
|        |    | SD       | 0.24              | 0.26 | 1.45                           | 3.42             | -                             | 0.07 | 0.19            | 0.34             | 3.87  | 0.30             | -    | 0.56  |       |
| SPV 19 | C  | $n = 34$ | 0.93              | 2.48 | 15.47                          | 47.73            | 0.37                          | 0.03 | 0.18            | 2.76             | 24.73 | 0.31             | 0.03 | 4.91  | 100   |
|        |    | SD       | 0.28              | 0.29 | 1.90                           | 6.44             | 0.36                          | 0.09 | 0.27            | 0.60             | 8.34  | 0.40             | 0.19 | 0.53  |       |
| SPV 20 | C  | $n = 21$ | 1.04              | 3.00 | 18.13                          | 54.85            | -                             | 0.08 | -               | 2.60             | 13.01 | 0.84             | -    | 6.47  | 100   |
|        |    | SD       | 0.10              | 0.33 | 0.92                           | 1.96             | -                             | 0.09 | -               | 0.34             | 1.15  | 0.19             | -    | 0.51  |       |

(Continues)

TABLE 3 (Continued)

| Sample |    |               | Na <sub>2</sub> O | MgO  | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub> | P <sub>2</sub> O <sub>5</sub> | Cl   | SO <sub>3</sub> | K <sub>2</sub> O | CaO   | TiO <sub>2</sub> | MnO  | FeO  | Total |
|--------|----|---------------|-------------------|------|--------------------------------|------------------|-------------------------------|------|-----------------|------------------|-------|------------------|------|------|-------|
| SPV 21 | C  | <i>n</i> = 19 | 0.96              | 2.34 | 15.62                          | 51.85            | -                             | 0.07 | -               | 2.70             | 20.42 | 0.62             | -    | 5.41 | 100   |
|        |    | SD            | 0.18              | 0.20 | 1.60                           | 3.93             | -                             | 0.11 | -               | 0.36             | 6.19  | 0.26             | -    | 0.58 |       |
| SPV 22 | NC | <i>n</i> = 18 | 0.64              | 1.60 | 24.39                          | 58.83            | -                             | -    | -               | 2.82             | 1.55  | 1.01             | -    | 9.17 | 100   |
|        |    | SD            | 0.16              | 0.11 | 0.94                           | 1.50             | -                             | -    | -               | 0.30             | 0.40  | 0.21             | -    | 0.67 |       |
| SPV 23 | C  | <i>n</i> = 21 | 0.99              | 2.36 | 16.19                          | 51.78            | 0.03                          | 0.25 | 0.32            | 2.36             | 18.86 | 0.76             | 0.13 | 5.97 | 100   |
|        |    | SD            | 0.17              | 0.20 | 1.20                           | 2.29             | 0.14                          | 0.15 | 0.26            | 0.44             | 1.74  | 0.15             | 0.59 | 0.49 |       |
| SPV 24 | C  | <i>n</i> = 21 | 0.98              | 2.32 | 18.87                          | 56.04            | -                             | 0.04 | -               | 2.97             | 11.79 | 0.78             | -    | 6.22 | 100   |
|        |    | SD            | 0.23              | 0.20 | 0.80                           | 1.96             | -                             | 0.08 | -               | 0.35             | 1.42  | 0.22             | -    | 0.27 |       |

Note: In the second column: HC, highly carbonatic; C, carbonatic; NC, non-carbonatic (Reliable figures up to the first decimal).

by sandstone. Also, SPV9 has a higher percentage of matrix (compared to the skeleton) and a larger grain size than SPV 14.

### 5.2.5 | Variant 2/3. Coarse, non-carbonatic

This is represented by a single common ware sample (SPV 22; pink dot in Figures 4 and 5) classified as Ca-poor/non-carbonatic through bulk chemical analyses. This small amphora is comparable with coarse cooking wares based on its grain size but is a common ware not used for cooking food. Nevertheless, it cannot be consistently associated with other common wares due to its non-carbonatic composition. The mineralogical assemblage is non-discriminatory. While the absence of primary calcite brings this sample closer to Group 2, the lack of lithic fragments of volcanic origin is comparable with Group 3 and the other common ware samples. A further peculiarity is represented by clinopyroxene crystals, which show considerable dimensions (up to 500 µm) but are rarely observed.

### 5.2.6 | Group 4. Fine, carbonatic

This group includes seven common ware samples (SPV 15-18, 20-21, 23; red dots in Figures 4 and 5) classified as Ca-rich/carbonatic through bulk chemical analyses. The group is homogeneously characterised by a nondiscriminating mineralogical assemblage: quartz, orthoclase, plagioclase (albite/andesine), calcite, muscovite/illite and biotite, Mg-Fe chlorites and extremely rare clinopyroxene. The differences among these samples arise in the following characteristics:

1. homogeneity of the ceramic body—homogeneous in SPV 16-17, 20 and 23; inhomogeneous in SPV 15, 18 and 21;
2. grain size—maximum in SPV 21 and minimum in SPV 20;
3. relative amount of calcite—higher in SPV 16-18 and 23, lower in SPV 21, 15 and 20;
4. absence of MgO-rich calcite in all samples, except SPV 16 and 17;
5. relative percentage of white and black mica; and
6. microfauna destabilisation level—concluded in SPV 17-18, 20-21 and 23, advanced in SPV 15 and 16.

Regarding the lithic fragments, it is essential to note that they are practically absent in all samples. The largest clast (154 µm) was observed in SPV 18 and consisted of quartz, K-feldspar and white mica. In all cases, the lithics are of sedimentary origin, except for a single volcanic clast (type 2) in SPV 21.

### 5.2.7 | Outlier 1 (SPV 19)

In this Ca-rich/carbonatic (bulk chemistry) common ware sample, the marked inhomogeneity of the ceramic paste is due to the variable percentage and grain size of the carbonates. The mineralogical-petrographic composition is distinguished from all the other samples by the presence of sanidine and volcanic glass. Plagioclase is common and generally albitic. Primary calcite shows reaction rims and, sometimes, high percentages of SO<sub>3</sub>. Among the phyllosilicates, in addition to muscovite/illite and biotite, phlogopite has also been identified. Clinopyroxene is frequent both in single crystals and as a constituent of volcanic lithic fragments, whereas apatite is the most recurring accessory mineral.

### 5.2.8 | Outlier 2 (SPV 24)

Although compositionally similar to the other common wares, this Ca-rich/carbonatic (bulk chemistry) funnel is averagely finer and has no lithic fragments. In addition, three peculiarities are noted: (1) a higher level of sintering compared to all the other samples; (2) the prevalence of biotite compared to muscovite/illite; and (3) the presence, albeit rare, of Cr-spinel.

## 6 | DISCUSSION

### 6.1 | Ceramic technology

The seven Ca-rich/highly carbonatic samples included in the mineralogical Group 1 and variant 1a are characterised by the deliberate addition of sparry calcite to a relatively coarse and carbonate raw material. The variability of CaO and MgO contents

in the matrices (their sum ranges from 5 to 18 wt%) suggests that (magnesian-) calcite with different grain sizes—from coarse to very fine—was added to the non-carbonatic sediment. The degree of sintering is low in all samples but slightly higher in SPV1, where reaction rims are observed in crystals of magnesian calcite. Assuming that the destabilisation temperature of magnesian calcite is similar to that of dolomite and considering the absence of reaction edges in the calcite crystals (while taking into account the average size of calcitic grains), samples SPV 1 and 5 do not seem to have reached maximum temperatures higher than 700°C, while for the other samples, it is possible to propose a  $T_{\max}$  of 100°/150°C higher.

Since low firing temperatures and high temper concentrations decrease ceramic strength but give it high toughness and thermal shock resistance (see e.g., Allegretta et al., 2014; Tite et al., 2001), the properties of these samples agree perfectly with their functional destination.

The eight Ca-poor/non-carbonatic samples included in the mineralogical Groups 2–3 and in variant 2/3 are characterised by a serial, unsorted texture that, paired with the absence of temper, suggests that natural non-carbonatic sediments such as those of alluvial and terraced alluvial deposits were used 'as taken'. The low/medium sintering and the sporadic presence of unreacted calcite indicate a maximum firing temperature much below the destabilisation temperature of this phase (max <900°C; see Gliozzo, 2020 and references therein). The suitability of the ceramic pastes for the intended use is lost with the small amphora SPV22. In this latter case, using such a coarse paste for a vessel that was not supposed to go on fire can perhaps be explained by the immediate availability of the raw material.

The seven Ca-rich/carbonatic samples included in the mineralogical Group 4 are characterised by the use of a completely different raw material with respect to the previous groups, supplied within the deposits of Subapennine clays. The composition is carbonatic, the grain size is smaller, the texture appears moderately sorted and the lithic fragments are extremely rare. In this case, the sediments may have been used 'as taken' but may also have undergone sorting via sedimentation (levigation).

Among the outliers, the carbonatic sample SPV19 is characterised by a very inhomogeneous paste, due to the 'colombino' technique.

Lastly, the sample SPV24 is characterised by a very fine carbonate mixture, likely sorted (levigated) before use. It is interesting to note that this is the only vessel fired at higher  $T_{\max}$  (>850/900°C).

## 6.2 | Ceramic provenance: The comparison with the Apulian ceramic repertoire

Principal component analysis (PCA) was performed on the entire ceramic repertoire of northern Apulia ( $n = 288$ ), including fine wares, coarse wares, building materials and structural elements taken from the kilns (Gliozzo et al., 2005, 2010, 2013, 2014, 2016, 2019). The data have been previously normalised (0–1) and the variables used are SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, MgO, CaO, Na<sub>2</sub>O, K<sub>2</sub>O, TiO<sub>2</sub>, MnO, V, Co, Ni,

Zn, Rb, Sr, Y, Zr, Ba, La, Ce, Pb, Th and U, that is, the elements measured for all 288 samples (excluding P<sub>2</sub>O<sub>5</sub> values, which could be affected by the postdepositional environment; see, e.g., Maritan, 2020 with references therein). The results provided by the PCA are illustrated in Figure 7a, while scores and loadings are provided in Supporting Information S1: S1.

The scree plot (Figure 7a1) shows how each principal component explains the variance. A marked drop is observed just after the first PC (39.90%); therefore, this and the second PC (12.57%) are used for the following elaboration since they explain a large proportion of the total variance. The biplot A2 and the associated loadings show that, among variables showing a strong effect on PC1, CaO, MgO and Sr are negatively correlated. In contrast, most other elements (La, Zr, Ce, Th, Rb, Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> and Ba in decreasing order) are positively correlated. Large positive loadings of V and TiO<sub>2</sub> and strong negative loading of SiO<sub>2</sub> and Na<sub>2</sub>O dominate the second PC. The distance biplot A3 shows how samples separate into three main groups: (1) coarse wares spread over a large heterogeneous group; (2) fine wares and building materials separate along PC2; and (3) Classe-type coarse wares' plot in the left-upper portion (area outlined by the circle).

Among Classe-type jars, the new samples (SPV 1–5, 13) plot together with the two Classe-type jars previously analysed (GOLD21 and GOLD32; Gliozzo et al., 2013). Overall, these ceramics can be neatly distinguished from Apulian coarse wares and confirm their typological identification as imported products.

It is also useful to observe in this diagram that two samples of fine wares plot within the coarse wares field. One is the small amphora SPV22 and the other corresponds to sample FARA 27, that is, another small amphora found in Faragola, whose compositional peculiarity was highlighted in Gliozzo et al. (2014).

An in-depth study was conducted on coarse wares and fine wares considered separately. First, the PCA shown in Figure 7b was performed using only the coarse wares and excluding the Classe-type ceramics. The presentation scheme is the same as in Figure 7a and the associated loadings are provided in Supporting Information S1: S2. The variables showing the most substantial effect on PC1—explaining 28.60% of the variance—are negatively (SiO<sub>2</sub>) or positively correlated (Th, Al<sub>2</sub>O<sub>3</sub>, Ce and La). As for PC2 (15.72%), Zr and SiO<sub>2</sub> are negatively correlated, while CaO, Sr and MgO are positively correlated.

In this diagram, it can be observed that SPV 7 cannot be grouped either with the Classe-type ceramics—with which it could be compared based on the addition of sparry calcite and the content in major elements—nor with the cooking wares group mainly due to considerable differences in the CaO content. The SPV 8–11 and 14 cooking wares tend to overlap the distribution area of the Faragola and Posta Crusta products. In contrast, the SPV6, 12 and 22 cooking wares appear more similar to the *Herdonia* and *Canusium* contexts previously investigated. The SPV 6 sample also shows a certain similarity with the products abandoned inside the San Giusto kiln after its last firing.

The PCA shown in Figure 8a includes only the common wares (associated loadings are provided in Supporting Information

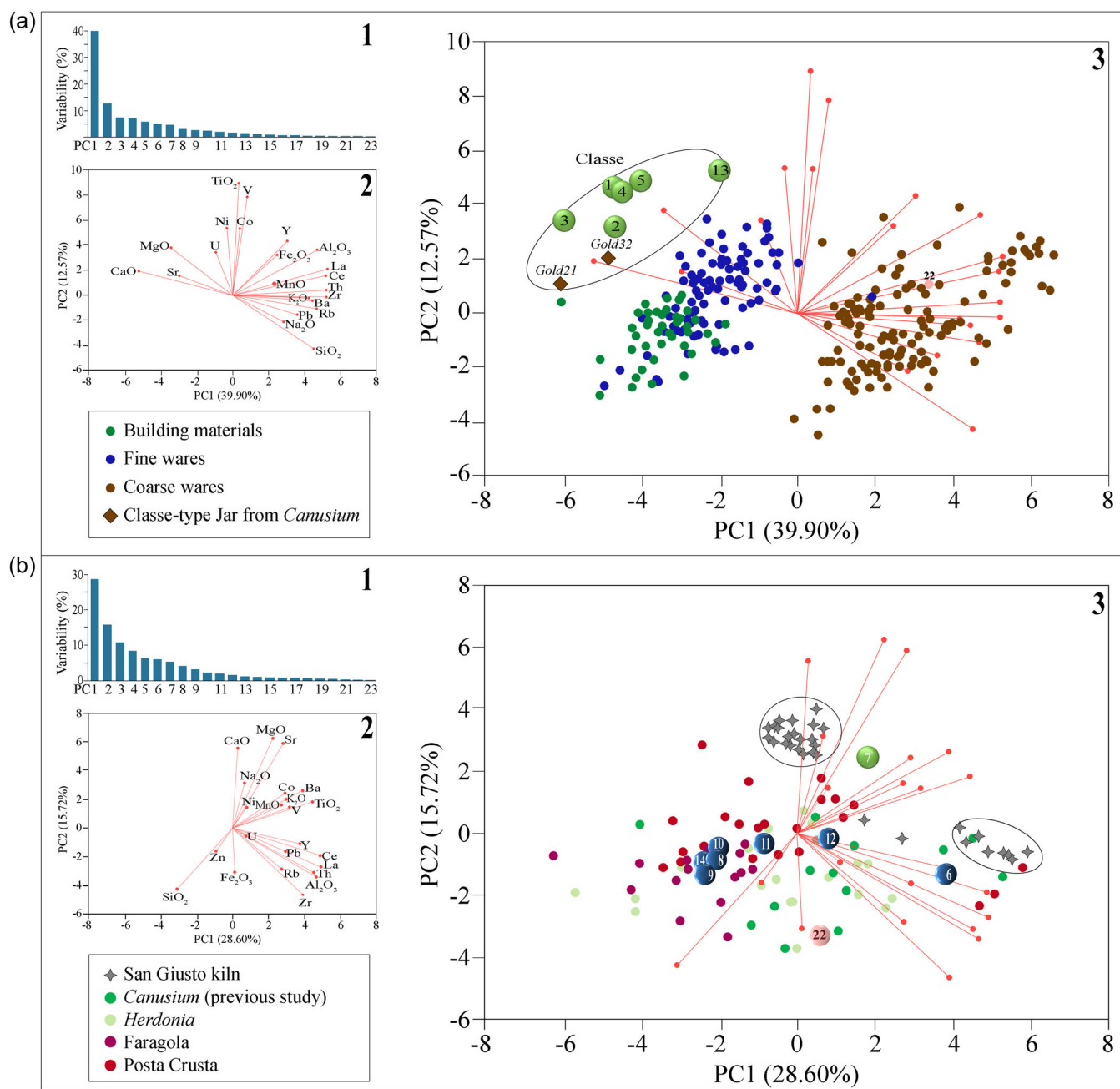


**FIGURE 7** Apulian ceramic samples (present study and previous Gliozzo et al., 2005, 2010, 2013, 2014, 2016, 2019): (a) Principal component analysis (PCA) carried out on all 288 investigated samples. The ellipse indicates the distribution of Classe-type pottery; (b) PCA carried out on 138 cooking ware samples. In (a, b), (1) corresponds to the screen plot showing factors' variability; (2) the active variables on the first and second components; and (3) the distribution of the samples indicated in the legend on the first and second components. The samples investigated in this study are indicated with the same symbols as those used in Figures 4 and 5. The ellipses indicate the production types of San Giusto pottery.

S1: S3). The variables showing the most substantial effect on PC1 (33.70% of the variance) are negatively ( $\text{Al}_2\text{O}_3$ , Co, La) or positively correlated (CaO). As for PC2 (14.66%),  $\text{Na}_2\text{O}$ , Rb and Ce are negatively correlated, while  $\text{TiO}_2$  and Y are positively correlated.

In biplot 3 of Figure 8a, it is interesting to observe how most of the products found in the various sites tend to be distributed rather

homogeneously in the four quadrants: Posta Crusta in the upper right quadrant, San Giusto in the lower right, Faragola in the lower left and the context previously investigated from Canusium top left. However, materials from Herdonia and Canusium show a broader range of distribution in the left quadrants. The finds analysed here tend to overlap the distribution area of San Giusto products, well distanced from those of Posta Crusta and Faragola.

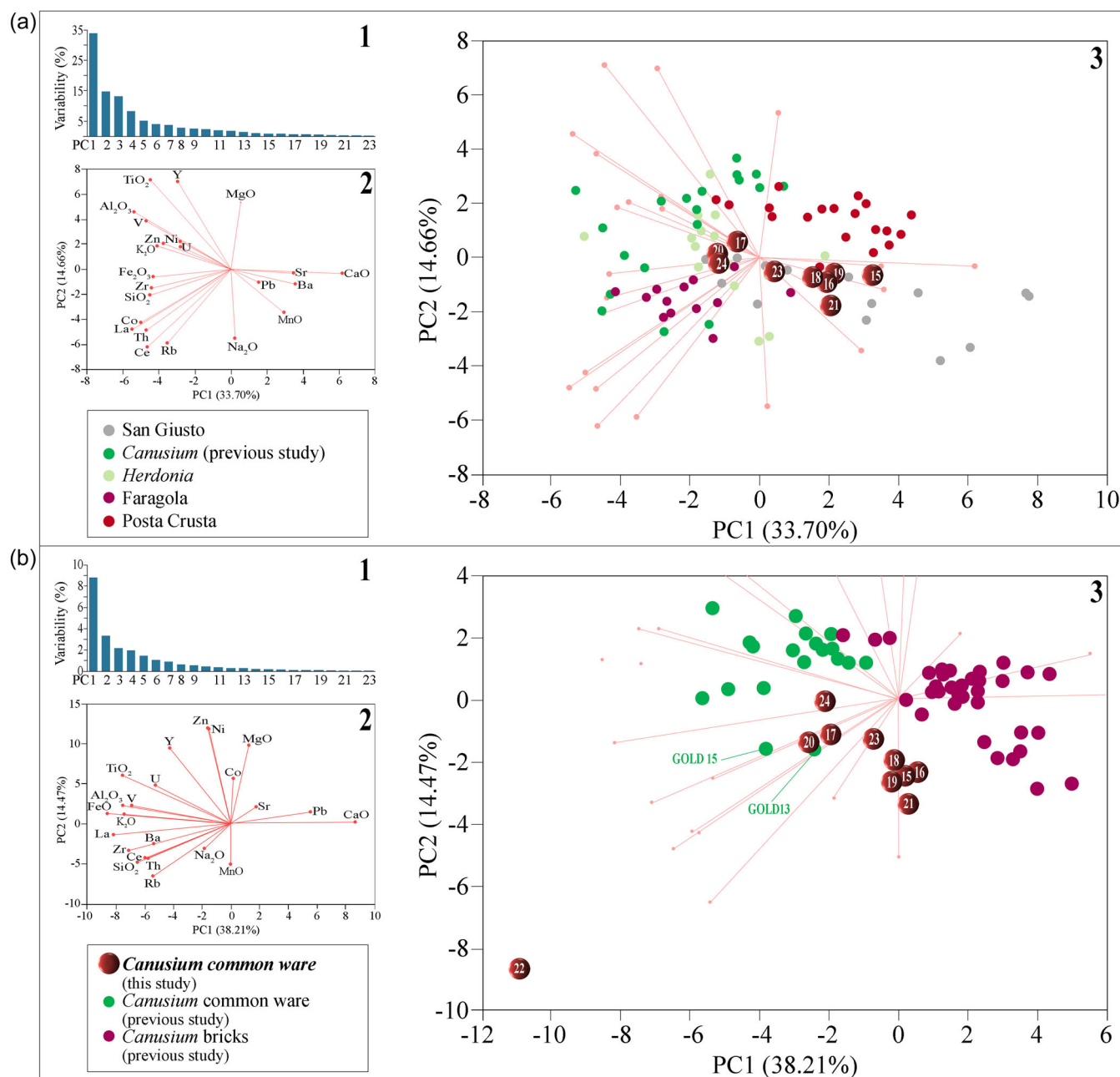


**FIGURE 8** Apulian common wares and building materials: (a) Principal component analysis (PCA) performed on 92 fine common ware samples from northern Apulia (present study and previous Gliozzo et al., 2005, 2010, 2013, 2014, 2016, 2019). (b) PCA performed on 66 common wares (29) and building materials (37) from Canusium (present study and previous Gliozzo et al., 2013, 2016). In (a, b) (1) corresponds to the screen plot showing factors' variability; (2) the active variables on the first and second components; and (3) the distribution of the samples indicated in the legend on the first and second components.

The PCA shown in Figure 8b includes common wares and building materials analysed so far (associated loadings are provided in Supporting Information S1: S4). It offers an almost clear distinction between the materials found at Canusium. The overlaps are minimal and only two samples overlay the distribution field of the common wares analysed in this study: the pitcher GOLD 13 (overlapping the SPV20 *dolium*) and, to a lesser extent, the pitcher GOLD 15.

The series of statistical elaborations provided up to now shows the level of similarity between different ceramics when considering

the entire data set available for northern Apulia, a specific category of products or the single site of Canusium. Conversely, the next and last elaboration intends to probe the discriminating potential of geochemical data, comparing the composition of all ceramics investigated so far with that of the potential supply areas of raw materials.

The PCA shown in Figure 9 includes 42 building materials (bricks and tiles), 119 samples of fine common wares, 137 samples of coarse cooking wares (excluding those of the Classe type), eight structural elements from the Canusium and Faragola kilns, 28

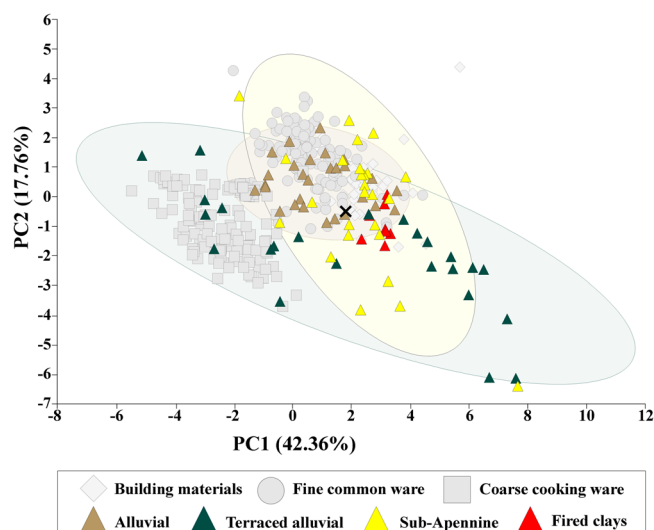


**FIGURE 9** Principal component analysis (PCA) performed for 385 samples of ceramics (298), structural elements of the Faragola and *Canusium* kilns (8) and raw materials (79). The 95% confidence ellipses are drawn around the terraced alluvial (light green), alluvial (light brown) and Subapennine (light yellow) clayey samples. Ceramic samples from Gliozzo et al. (2005), (2010), (2013), (2014), (2016), (2019), structural elements from Gliozzo et al. (2016); raw materials from Gliozzo et al. (2018).

clayey samples taken in the alluvial sediments outcropping along the Carapelle, Celone, Cervaro, Ofanto, Salsola and Vulgano valleys, 24 clayey samples taken in the terraced alluvial sediments outcropping along the Carapelle, Celone and Ofanto valleys and, finally, 27 samples of Subapennine clays (associated loadings are provided in Supporting Information S1: S5).

Despite the apparent limitations of a comparison established between raw materials and artefacts, it is significant that while the coarse cooking ware finds an almost exclusive comparison with the terraced alluvial sediments, the fine common ware is compatible with both the Subapennine marine clays and the alluvial sediments. As for the fine common ware, the chemical analysis seems ineffective in understanding which of the two types of clay was used; conversely, the minero-petrographic research indicates the Subapennine clay as the preferential resource (see also Gliozzo et al., 2018).

Finally, the building materials plot in an area of the diagram in which all the distribution areas of the three types of clayey sediments overlap. However, most bricks and tiles are less compatible with terraced alluvial than the other two types.

## 7 | CONCLUSIONS

### 7.1 | Local products and exploitation of clayey georesources

The collection is mainly made up of Apulian materials (18 out of a total of 24). As in the Daunian ceramics previously analysed, the

exploitation of raw materials mainly focuses on the terraced alluvial deposits outcropping along the river valleys for the production of coarse pottery such as cooking ware and the Subapennine clay deposits for the production of fine common ware.

The greater compatibility of coarse wares with terraced alluvial deposits rather than alluvial deposits outcropping along river banks is significant. Situated at a slightly higher elevation, the terraced deposits are relatively older and less modified by recent fluvial meandering than those deposited along the river banks; therefore, it is likely that they better match the characteristics of the raw materials used in antiquity. Moreover, these deposits are coarser than marine ones (Subapennine), thus lending themselves to be used without adding temper. The supply of raw materials, already in itself suitable for the type of product to be made, inevitably had to reduce production times. The same consideration can be made for the use of Subapennine clays in the manufacture of fine common ware. Also in this case, the sediments are already of the appropriate grain size and composition and do not require lengthy processing.

The overall reconstruction addresses a technically adequate manufacture, perfectly adapted to a conscious exploitation of the territory.

At the moment, it is not possible to precisely locate the production area of these materials; however, the compositional similarities of cooking wares with the products of Faragola and Posta Crusta and of fine common wares with the products of San Giusto and *Herdonia* appear intriguing since they both refer to the Carapelle River's northern valleys and not those of the Ofanto River as would have been imaginable.

Accordingly, it is possible that cooking wares were either made using Ofantine raw materials not investigated so far or imported as finished products from a production site located along the Carapelle Valley. Conversely, the transport to *Canusium* of raw materials from the northern river valleys seems less likely since deposits with similar characteristics are also available near the site.

The import of ceramics from Faragola would be interesting (and possibly suggested by the common presence of wads in the ceramic bodies) since in this *curtis*—probably owned by the Duke/Prince of Benevento—the discovery of kilns and tanks for settling the clay allowed us to hypothesise that the artisanal activity was intended not only to meet the needs of the *curtis* itself but also for transport, sale and/or external exchange. Indeed, the trades would have been favoured by both the settlement position along the *via Aurelia Aeclanensis*, that is, a link road with the *via Traiana*, and the short distance from the Carapelle River. Moreover, the trades departing from the *curtis* may have involved other properties belonging to the Benevento tax authorities or other prominent towns in the Longobard political and administrative geography, such as *Canusium*, which has also been the seat of one of the oldest 'gastaldati'.<sup>2</sup> The trade of nonluxury goods such as ceramics could also have been related to exchanging other primary goods of

<sup>2</sup>Large farm of the Lombard era dependent on the Duke.

higher commercial value, such as foodstuffs, animals, textiles, tools and work tools. In this framework, the periodic markets (the *nundinae*) undoubtedly played an important role.

## 7.2 | The imports

A core of six samples proved to be of likely import. The discovery was not surprising and reinforced the pre-existing picture since Classe-type vessels had already been identified at *Canusium* (GOLD 21 and GOLD 32).

Both the quantities and the typological variety are striking, making San Pietro the most representative case regarding the distribution of 'Classe type' pottery in *Apulia* and, more generally, in southern Italy.

As a matter of fact, the workshops still need to be discovered even though the localisation of at least one production centre in the Ravenna area has been proposed based on the geographic distribution and attestation indices of the exemplars. The production of the 'Classe-type' pottery was intended for local use and the extra-regional market, as evidenced by the numerous finds brought to light in the Adriatic area (the relevant references are provided in the Materials section). Their trade was undoubtedly conveyed by other categories of assets and favoured by the 'privileged' relationship between *Canusium* and Ravenna, the latter being testified by multiple influences in the field of artistic production and the choice of architectural and iconographic models.

The testimony offered by this conspicuous context of the 'Classe-type' pots is also interesting from a chronological standpoint since few data were available regarding the commercial and cultural relations with the central-northern Adriatic area during the Early Middle Ages. Instead, it is now possible to observe a continuous exchange activity from the Late Antiquity, when the port of Siponto (about 40 km north-west of *Canusium* as the crow flies) played a crucial role in the commercialisation of goods traded from both sides of the Adriatic Sea.

As a last consideration regarding the 'Classe-type' pottery, it is worth observing that the large number of materials recovered from the stratigraphy of the *domus* testifies to the presence of a prominent resident community and that, in turn, the testimony handed down by this community may support the hypothesis of the existence of a monastery that, installed near the sanctuary, became a place of pilgrimage following the burial of Bishop *Savinus*.

Still on imports, another sample likely to be of allochthonous provenance is the small amphora SPV22, which does not find significant compositional similarities with the entire set of materials investigated in northern *Apulia*. This amphora is non-carbonatic—already an exception—and its mineralogical assemblage is so common as not to be discriminatory. Hence, a provenance hypothesis cannot be proposed based on archaeometric results.

As a last consideration, the simultaneous presence of ceramics produced locally, in other regional contexts and probably imported from the Ravenna area confirms the importance of *Canusium* in the short- and medium-range trade network up to the Adriatic scale.

From a different perspective, the results obtained so far demonstrate the significant role played by the early medieval Church in promoting local artisanal activity, supporting economic structures and revitalising trade, apart from religious life.

## AUTHOR CONTRIBUTIONS

**Elisabetta Gliozzo:** Conceptualisation; investigation; writing—original draft; writing—review and editing; methodology; visualisation; supervision; formal analysis; project administration. **Corina Ionescu:** Funding acquisition; writing—review and editing; methodology. **Roberta Giuliani:** Writing—original draft. **Maria Turchiano:** Writing—original draft.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

## DATA AVAILABILITY STATEMENT

We certify that the submission is original work and is not under review at any other publication. The authors confirm that the data supporting the findings of this study are available within the article and its Supporting Information.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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## Supplementary materials

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Supporting Information S1: Table [S1](#) (in the text) =

- Supplementary Table 1. Results of the mineralogical-petrographic investigation.

Supporting Information S1: Figures [S1–S4](#) (in the text) =

- Supplementary Figure 1. Representative photomicrographs of the ceramic paste captured through petrographic microscope under plane polarised light and backscattered electron micrographs of the matrix taken by SEM. Samples SPV1-5 and 13.
- Supplementary Figure 2. Representative photomicrographs of the ceramic paste captured through petrographic microscope under plane polarised light and backscattered electron micrographs of the matrix taken by SEM. Samples SPV7, 6, 8, 10, 11-12.
- Supplementary Figure 3. Representative photomicrographs of the ceramic paste captured through petrographic microscope under plane polarised light and backscattered electron micrographs of the matrix taken by SEM. Samples SPV14, 9, 22, 21, 15-16.
- Supplementary Figure 4. Representative photomicrographs of the ceramic paste captured through petrographic microscope under plane polarised light and backscattered electron micrographs of the matrix taken by SEM. Samples SPV17-18, 20, 23, 19, 24.

Supporting Information S1: [S1](#) (in the text) =

- Supplementary Materials 1. PCA loadings. Figure 7A.

Supporting Information S1: [S2](#) (in the text) =

- Supplementary Materials 2. PCA loadings. Figure 7B.

Supporting Information S1: [S3](#) (in the text) =

- Supplementary Materials 3. PCA loadings. Figure 8A.

Supporting Information S1: [S4](#) (in the text) =

- Supplementary Materials 4. PCA loadings. Figure 8B.

Supporting Information S1: [S5](#) (in the text) =

- Supplementary Materials 5. PCA loadings. Figure 9.

Supplementary Table 1. Results of the mineralogical-petrographic investigation. [Abbreviations are explained at the end of the table]

|                         | Sample                              | Ware    | Texture                                                                |
|-------------------------|-------------------------------------|---------|------------------------------------------------------------------------|
| <b>Group 1</b>          | <b>Calcite temper - Classe-type</b> |         |                                                                        |
|                         | SPV1                                | Cooking | Bimodal, homogeneous                                                   |
|                         | SPV2                                | Cooking | Bimodal, homogeneous                                                   |
|                         | SPV3                                | Cooking | Bimodal, inhomogeneous (due to microcrystalline calcite)               |
|                         | SPV4                                | Cooking | Bimodal, inhomogeneous (low % of matrix compared to temper)            |
|                         | SPV5                                | Cooking | Bimodal, inhomogeneous                                                 |
|                         | SPV13                               | Cooking | Bimodal, inhomogeneous (low % of matrix compared to temper)            |
| <b>Variant 1a</b>       | <b>Calcite temper</b>               |         |                                                                        |
|                         | SPV7                                | Cooking | Serial, homogeneous                                                    |
| <b>Group 2</b>          | <b>Coarse - non carbonatic 1</b>    |         |                                                                        |
|                         | SPV6                                | Cooking | Serial, homogeneous, pervasive elongated voids                         |
|                         | SPV8                                | Cooking | Serial, homogeneous, pervasive elongated voids                         |
|                         | SPV10                               | Cooking | Serial, homogeneous                                                    |
|                         | SPV11                               | Cooking | Serial, homogeneous, pervasive elongated voids                         |
|                         | SPV12                               | Cooking | Serial, homogeneous, pervasive elongated voids                         |
| <b>Group 3</b>          | <b>Coarse - non carbonatic 2</b>    |         |                                                                        |
|                         | SPV14                               | Cooking | Serial, homogeneous, pervasive elongated voids                         |
|                         | SPV9                                | Cooking | Serial, inhomogeneous ( $\pm$ carbonatic), pervasive elongated voids   |
| <b>Variant 2/3</b>      | <b>Coarse - non carbonatic</b>      |         |                                                                        |
|                         | SPV22                               | Common  | Serial, homogeneous                                                    |
| <b>Group 4</b>          | <b>Fine - carbonatic</b>            |         |                                                                        |
|                         | SPV21                               | Common  | Serial, inhomogeneous (areas more or less carbonatic)                  |
|                         | SPV15                               | Common  | Serial, inhomogeneous (areas more or less carbonatic)                  |
|                         | SPV16                               | Common  | Serial, homogeneous                                                    |
|                         | SPV17                               | Common  | Serial, homogeneous                                                    |
|                         | SPV18                               | Common  | Serial, inhomogeneous (areas more or less carbonatic)                  |
|                         | SPV20                               | Common  | Serial, homogeneous                                                    |
|                         | SPV23                               | Common  | Serial, homogeneous                                                    |
| <b><u>Outlier 1</u></b> | SPV19                               | Common  | Serial, very inhomogeneous (areas $\pm$ rich in sandy/clayey fraction) |
| <b><u>Outlier 2</u></b> | SPV24                               | Common  | Serial, homogeneous                                                    |

(continued)

|                    | Sample                              | Grain size (max)      | Grain size (av.)                  | Sintering  |
|--------------------|-------------------------------------|-----------------------|-----------------------------------|------------|
| <b>Group 1</b>     | <b>Calcite temper - Classe-type</b> |                       |                                   |            |
|                    | SPV1                                | 1.8 m (calcite)       | 250 µ (temper); 80-120 µ (matrix) | Med.       |
|                    | SPV2                                | 1.5 m (calcite)       | 300 µ (temper); 50-80 µ (matrix)  | Very low   |
|                    | SPV3                                | 2.3 m (calcite)       | 500 µ (temper); 80-120 µ (matrix) | Low        |
|                    | SPV4                                | 1.8 m (calcite)       | 400 µ (temper); 40-80 µ (matrix)  | Low        |
|                    | SPV5                                | 1.6 m (calcite)       | 300 µ (temper); 50-70 µ (matrix)  | Very low   |
|                    | SPV13                               | 2.3 m (calcite)       | 300 µ (temper); 70-90 µ (matrix)  | Low        |
| <b>Variant 1a</b>  | <b>Calcite temper</b>               |                       |                                   |            |
|                    | SPV7                                | 600 µ (calcite)       | 200 µ (temper); 50-70 µ (matrix)  | Very low   |
| <b>Group 2</b>     | <b>Coarse - non carbonatic 1</b>    |                       |                                   |            |
|                    | SPV6                                | 830 m (lithic fr.)    | 180 µ                             | Med.       |
|                    | SPV8                                | 540 µ (quartz)        | 150 µ                             | Med.       |
|                    | SPV10                               | 530 µ (quartz)        | 100/120 µ                         | Med.       |
|                    | SPV11                               | 560 µ (quartz)        | 180 µ                             | Med.       |
|                    | SPV12                               | 415 µ (quartz)        | 180/200 µ                         | Med.       |
| <b>Group 3</b>     | <b>Coarse - non carbonatic 2</b>    |                       |                                   |            |
|                    | SPV14                               | 1.3 m (lithic fr.)    | 200/250 µ                         | Low        |
|                    | SPV9                                | 900 µ (lithic fr.)    | 250/300 µ                         | Low        |
| <b>Variant 2/3</b> | <b>Coarse - non carbonatic</b>      |                       |                                   |            |
|                    | SPV22                               | 1.6 m (quartz)        | 180/200 µ                         | Low        |
| <b>Group 4</b>     | <b>Fine - carbonatic</b>            |                       |                                   |            |
|                    | SPV21                               | 450 µ (lithic fr.)    | 120/150 µ                         | Med. /high |
|                    | SPV15                               | 660 µ (calcite)       | 80/100 µ                          | Med.       |
|                    | SPV16                               | 350 µ (quartz)        | 80/100 µ                          | Med.       |
|                    | SPV17                               | 150 µ (quartz)        | 50/80 µ                           | Med.       |
|                    | SPV18                               | 300 µ (clinopyroxene) | 80/100 µ                          | Med.       |
|                    | SPV20                               | 235 µ (clinopyroxene) | 80 µ                              | Med. /high |
|                    | SPV23                               | 203 µ (muscovite)     | 80/100 µ                          | Med.       |
| <b>Outlier 1</b>   | SPV19                               | 650 µ (lithic fr.)    | 150/200                           | Med.       |
| <b>Outlier 2</b>   | SPV24                               | 200 µ (muscovite)     | 50 µ                              | High       |

(continued)

|                         | Sample                              | Quartz                                                                                           | K-feldspar                                            |
|-------------------------|-------------------------------------|--------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| <b>Group 1</b>          | <b>Calcite temper - Classe-type</b> |                                                                                                  |                                                       |
|                         | SPV1                                | Abund., subroun.; med. spher.; max. 220 $\mu$                                                    | Spor. orthoclase                                      |
|                         | SPV2                                | Abund., subroun.; low spher.; max. 250 $\mu$                                                     | Spor. orthoclase                                      |
|                         | SPV3                                | Abund., subroun.; low spher.; max. 180 $\mu$                                                     | Spor. orthoclase                                      |
|                         | SPV4                                | Abund., subroun.; low spher.; max. 180 $\mu$                                                     | Spor. orthoclase                                      |
|                         | SPV5                                | Abund., subroun.; low spher.; max. 180 $\mu$                                                     | Spor. orthoclase                                      |
|                         | SPV13                               | Abund., subroun.; low spher.; max. 200 $\mu$                                                     | Spor. orthoclase                                      |
| <b>Variant 1a</b>       | <b>Calcite temper</b>               |                                                                                                  |                                                       |
|                         | SPV7                                | Abund.; subroun.; low spher.; max. 450 $\mu$                                                     | Freq. orthoclase                                      |
| <b>Group 2</b>          | <b>Coarse - non carbonatic 1</b>    |                                                                                                  |                                                       |
|                         | SPV6                                | Abund.; subroun.; med. spher.; max. 120 $\mu$                                                    | Abund. orthoclase                                     |
|                         | SPV8                                | Abund.; ang./subroun.; low spher.; max. 540 $\mu$                                                | Abund. orthoclase                                     |
|                         | SPV10                               | Abund.; ang./subroun.; med. spher.; max. 530 $\mu$                                               | Abund. orthoclase                                     |
|                         | SPV11                               | Abund.; subroun.; med./high spher.; max. 560 $\mu$                                               | Abund. orthoclase                                     |
|                         | SPV12                               | Abund.; subroun.; med. spher.; max. 415 $\mu$                                                    | Abund. orthoclase                                     |
| <b>Group 3</b>          | <b>Coarse - non carbonatic 2</b>    |                                                                                                  |                                                       |
|                         | SPV14                               | Abund.; ang./subroun.; low/med. spher.; max. 450 $\mu$ ; frequently showing dissolution features | Freq. Ba-bearing orthoclase                           |
|                         | SPV9                                | Abund.; ang./subroun.; low spher.; max. 700 $\mu$ ; frequently showing dissolution features      | Com. Ba-bearing orthoclase                            |
| <b>Variant 2/3</b>      | <b>Coarse - non carbonatic</b>      |                                                                                                  |                                                       |
|                         | SPV22                               | Abund.; ang./subroun.; low/med. spher.; max. 1.6 mm                                              | Freq. orthoclase                                      |
| <b>Group 4</b>          | <b>Fine - carbonatic</b>            |                                                                                                  |                                                       |
|                         | SPV21                               | Abund.; subroun.; med. spher.; max. 180 $\mu$                                                    | Abund. orthoclase                                     |
|                         | SPV15                               | Abund.; subroun.; med. spher.; max. 120 $\mu$                                                    | Abund. orthoclase                                     |
|                         | SPV16                               | Abund.; subroun.; med. spher.; max. 350 $\mu$                                                    | Com. orthoclase                                       |
|                         | SPV17                               | Abund.; ang./subroun.; low spher.; max. 150 $\mu$                                                | Freq. orthoclase                                      |
|                         | SPV18                               | Abund.; ang./subroun.; med. spher.; max. 150 $\mu$                                               | Freq. orthoclase                                      |
|                         | SPV20                               | Abund.; subroun.; med. spher.; max. 120 $\mu$                                                    | Abund. orthoclase                                     |
|                         | SPV23                               | Abund.; ang./subroun.; low spher.; max. 180 $\mu$                                                | Freq. orthoclase                                      |
| <b><u>Outlier 1</u></b> | SPV19                               | Abund.; ang./subroun.; med. spher.; max. 350 $\mu$                                               | Abund. (highly fractured) orthoclase / Spor. sanidine |
| <b><u>Outlier 2</u></b> | SPV24                               | Abund.; subroun.; med. spher.; max. 100 $\mu$                                                    | Abund. orthoclase                                     |

(continued)

|                         | Sample                              | Plagioclase                 | Primary calcite                                                                                         |
|-------------------------|-------------------------------------|-----------------------------|---------------------------------------------------------------------------------------------------------|
| <b>Group 1</b>          | <b>Calcite temper - Classe-type</b> |                             |                                                                                                         |
|                         | SPV1                                | Rare (albite)               | vAbund., unreacted (ang.; low spher.; max 1.8 m)                                                        |
|                         | SPV2                                | Rare (albite)               | vAbund., unreacted (ang.; low spher.; max. 1.5 m)                                                       |
|                         | SPV3                                | Rare (albite)               | vAbund., unreacted (ang.; low spher.; max. 2.3 m)                                                       |
|                         | SPV4                                | Rare (albite)               | vAbund., unreacted (ang.; low spher.; max. 1.8 m)                                                       |
|                         | SPV5                                | Rare (albite)               | vAbund., unreacted (ang.; low spher.; max. 1.6 m)                                                       |
|                         | SPV13                               | Rare (albite)               | vAbund., unreacted (ang.; low spher.; max. 2.3 m)                                                       |
| <b>Variant 1a</b>       | <b>Calcite temper</b>               |                             |                                                                                                         |
|                         | SPV7                                | Com. (albite/andesine)      | vAbund., unreacted (ang.; low spher.; max. 600 µ)                                                       |
| <b>Group 2</b>          | <b>Coarse - non carbonatic 1</b>    |                             |                                                                                                         |
|                         | SPV6                                | Abund. (All)                | -                                                                                                       |
|                         | SPV8                                | Abund. (All, esp. albite)   | -                                                                                                       |
|                         | SPV10                               | Abund. (albite/labradorite) | -                                                                                                       |
|                         | SPV11                               | Abund. (All, esp. andesine) | -                                                                                                       |
|                         | SPV12                               | Com. (All)                  | -                                                                                                       |
| <b>Group 3</b>          | <b>Coarse - non carbonatic 2</b>    |                             |                                                                                                         |
|                         | SPV14                               | Com. (albite)               | Very rare, unreacted (subroun.; med. spher.; max. 120 µ)                                                |
|                         | SPV9                                | Spor. (albite)              | Very rare, unreacted (subroun.; med. spher.; max. 250 µ)                                                |
| <b>Variant 2/3</b>      | <b>Coarse - non carbonatic</b>      |                             |                                                                                                         |
|                         | SPV22                               | Com. (albite/oligoclase)    | -                                                                                                       |
| <b>Group 4</b>          | <b>Fine - carbonatic</b>            |                             |                                                                                                         |
|                         | SPV21                               | Spor. (albite/oligoclase)   | Freq., reacted (close to complete destabilisation)                                                      |
|                         | SPV15                               | Com. (albite/andesine)      | Com., reacting (subang.; low spher.; max. 70 µ)                                                         |
|                         | SPV16                               | Com. (albite/andesine)      | Abund., reacting (subang.; low spher.; max. 70 µ)                                                       |
|                         | SPV17                               | Com. (albite/andesine)      | Abund., reacting (subang.; low spher.; max. 70 µ)                                                       |
|                         | SPV18                               | Com. (albite)               | Abund., reacting (subang.; low spher.; max. 160 µ)                                                      |
|                         | SPV20                               | Spor. (albite/andesine)     | Rare, reacted (close to complete destabilisation)                                                       |
|                         | SPV23                               | Com. (albite/oligoclase)    | Abund., reacting (subang.; low spher.; max. 60 µ)                                                       |
| <b><u>Outlier 1</u></b> | SPV19                               | Com. (All)                  | Com., reacting (subroun.; low spher.; max. 300 µ)<br>Sometimes high SO <sub>3</sub> wt% (up to 2.8 wt%) |
| <b><u>Outlier 2</u></b> | SPV24                               | Com. (albite)               | Reacted                                                                                                 |

(continued)

|                    | Sample                              | MgO (wt%) in calcite           | Mg-rich calcite                                     |
|--------------------|-------------------------------------|--------------------------------|-----------------------------------------------------|
| <b>Group 1</b>     | <b>Calcite temper - Classe-type</b> |                                |                                                     |
|                    | SPV1                                | av 0.9, sd 0.9, mx. 1.8 (n=12) | vAbund., reacting (MgO 12.5-19.8; av. 15.4, sd 1.7) |
|                    | SPV2                                | av 0.4, sd 0.4, mx. 1.4 (n=13) | -                                                   |
|                    | SPV3                                | av 1.7, sd 2.1, mx. 8.9 (n=32) | -                                                   |
|                    | SPV4                                | av 0.5, sd 0.1, mx. 0.6 (n=19) | -                                                   |
|                    | SPV5                                | av 0.6, sd 1.8, mx. 1.2 (n=9)  | Abund., unreacted (MgO 6.3-11.5; av. 8.6, sd 1.8)   |
|                    | SPV13                               | av 1.0, sd 1.1, mx. 1.5 (n=15) | Abund., unreacted (MgO 5.7-19; av. 11.7, sd 4.9)    |
| <b>Variant 1a</b>  | <b>Calcite temper</b>               |                                |                                                     |
|                    | SPV7                                | av 0.1, sd 0.1, mx. 0.5 (n=23) | -                                                   |
| <b>Group 2</b>     | <b>Coarse - non carbonatic 1</b>    |                                |                                                     |
|                    | SPV6                                | -                              | -                                                   |
|                    | SPV8                                | -                              | -                                                   |
|                    | SPV10                               | -                              | -                                                   |
|                    | SPV11                               | -                              | -                                                   |
|                    | SPV12                               | -                              | -                                                   |
| <b>Group 3</b>     | <b>Coarse - non carbonatic 2</b>    |                                |                                                     |
|                    | SPV14                               | av 0.7, sd 0.1, mx. 0.8 (n=2)  | -                                                   |
|                    | SPV9                                | av 0.2, sd 0.6, mx. 2.0 (n=5)  | -                                                   |
| <b>Variant 2/3</b> | <b>Coarse - non carbonatic</b>      |                                |                                                     |
|                    | SPV22                               | -                              | -                                                   |
| <b>Group 4</b>     | <b>Fine - carbonatic</b>            |                                |                                                     |
|                    | SPV21                               | -                              | -                                                   |
|                    | SPV15                               | av 1.8, sd 1.6, mx. 5.1 (n=13) | -                                                   |
|                    | SPV16                               | av 1.3, sd 2.3, mx. 2.4 (n=25) | Spor. (MgO ↑ 12 wt%)                                |
|                    | SPV17                               | av 3.5, sd 7.0, mx. 2.7 (n=8)  | Spor. (MgO ↑ 20 wt%)                                |
|                    | SPV18                               | av 1.6, sd 0.9, mx. 3.7 (n=8)  | -                                                   |
|                    | SPV20                               | av 1.6, sd 0.9, mx. 3.2 (n=7)  | -                                                   |
|                    | SPV23                               | av 3.2, sd 0.6, mx. 3.7 (n=6)  | -                                                   |
| <b>Outlier 1</b>   | SPV19                               | av 0.7, sd 0.4, mx. 1.1 (n=19) | -                                                   |
| <b>Outlier 2</b>   | SPV24                               | -                              | -                                                   |

(continued)

|                         | Sample                              | Micas                                                                    | TiO <sub>2</sub> in<br>Bt (wt%) | Chlorites                |
|-------------------------|-------------------------------------|--------------------------------------------------------------------------|---------------------------------|--------------------------|
| <b>Group 1</b>          | <b>Calcite temper - Classe-type</b> |                                                                          |                                 |                          |
|                         | SPV1                                | Freq. Mu/Ill, rare Bt                                                    | 2.6                             | Com. Mg-Fe               |
|                         | SPV2                                | Com. Mu/Ill and Bt                                                       | 2.8                             | Com. Mg-Fe               |
|                         | SPV3                                | Com. Mu/Ill and Bt but of very small size                                | 1.9                             | Freq. Mg-Fe              |
|                         | SPV4                                | Abund. Mu/Ill, rare Bt                                                   | 1.7                             | Freq. Mg-Fe              |
|                         | SPV5                                | Com. Mu/Ill and Bt                                                       | 0.2                             | Com. Mg-Fe               |
|                         | SPV13                               | Abund. Mu/Ill, sporadic Bt                                               | 1.1                             | Freq. Mg-Fe and Mg-Al    |
| <b>Variant 1a</b>       | <b>Calcite temper</b>               |                                                                          |                                 |                          |
|                         | SPV7                                | Spor. Bt                                                                 | 2.4                             | Spor. Mg-Fe              |
| <b>Group 2</b>          | <b>Coarse - non carbonatic 1</b>    |                                                                          |                                 |                          |
|                         | SPV6                                | Abund. Mu/Ill and Bt                                                     | 5.3                             | Abund. Mg-Fe             |
|                         | SPV8                                | Abund. Mu/Ill and Bt (fr. chloritised)                                   | 6.6                             | Com. Mg-Fe               |
|                         | SPV10                               | Abund. Mu/Ill and Bt                                                     | 1.4                             | Freq. Mg-Fe              |
|                         | SPV11                               | Abund. Bt, com. Mu/Ill                                                   | 7.6                             | Spor. Fe and Mg-Fe       |
|                         | SPV12                               | Abund. Mu/Ill and Bt                                                     | 5.0                             | Spor. Mg-Fe              |
| <b>Group 3</b>          | <b>Coarse - non carbonatic 2</b>    |                                                                          |                                 |                          |
|                         | SPV14                               | Freq. esp. Bt (very small)                                               | 2.7                             | Spor. Mg-Fe (very small) |
|                         | SPV9                                | Spor. Bt (small)                                                         | NA                              | -                        |
| <b>Variant 2/3</b>      | <b>Coarse - non carbonatic</b>      |                                                                          |                                 |                          |
|                         | SPV22                               | Abund. Bt (fr. chloritised), freq. Mu/Ill                                | 6.1                             | Abund. Mg-Fe             |
| <b>Group 4</b>          | <b>Fine - carbonatic</b>            |                                                                          |                                 |                          |
|                         | SPV21                               | Abund. Bt, common Mu/Ill                                                 | 3.0                             | Abund. Mg-Fe             |
|                         | SPV15                               | Abund. Bt, freq. Mu/Ill                                                  | 3.3                             | Abund. Mg-Fe             |
|                         | SPV16                               | Abund. Mu/Ill and Bt (↑ 180 μm)                                          | 4.4                             | Abund. Mg-Fe             |
|                         | SPV17                               | Abund. Mu/Ill and Bt (fr. chloritised) ↑ 120 μ                           | 3.6                             | Abund. Mg-Fe             |
|                         | SPV18                               | Abund. Mu/Ill and Bt (↑ 220 μ)                                           | 3.0                             | Abund. Mg-Fe             |
|                         | SPV20                               | Abund. Bt, freq. Mu/Ill                                                  | 3.7                             | Abund. Mg-Fe             |
|                         | SPV23                               | Abund. Mu/Ill and Bt (↑ 203 μ)                                           | 2.0                             | Abund. Mg-Fe             |
| <b><u>Outlier 1</u></b> | SPV19                               | Abund. Mu/Ill and Bt (rarely chloritised), spor. phengite and phlogopite | 3.9                             | Abund. Mg-Fe             |
| <b><u>Outlier 2</u></b> | SPV24                               | Abund. Bt (sometimes chloritised), spor. Mu/Ill                          | 4.1                             | Spor. Mg-Fe              |

(continued)

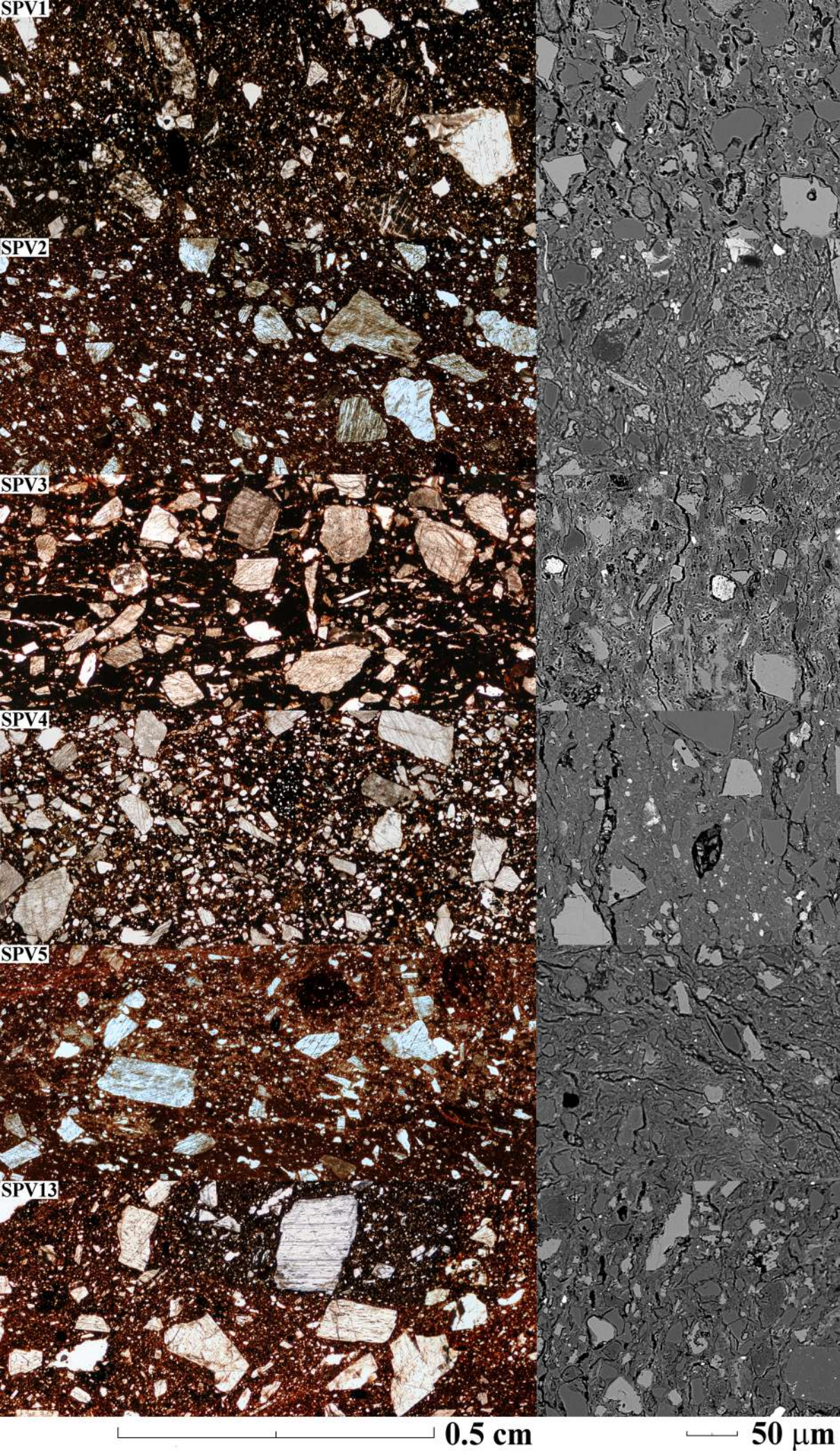
|                    | Sample                              | Clinopyroxene                                 | Lithics                                          |
|--------------------|-------------------------------------|-----------------------------------------------|--------------------------------------------------|
| <b>Group 1</b>     | <b>Calcite temper - Classe-type</b> |                                               |                                                  |
|                    | SPV1                                | Extr. rare (only 1 example)                   | Abund. carbonates                                |
|                    | SPV2                                | -                                             | Abund. carbonates                                |
|                    | SPV3                                | -                                             | Abund. carbonates                                |
|                    | SPV4                                | -                                             | Abund. carbonates, spor. mudstones               |
|                    | SPV5                                | -                                             | Abund. carbonates                                |
|                    | SPV13                               | -                                             | Abund. carbonates                                |
| <b>Variant 1a</b>  | <b>Calcite temper</b>               |                                               |                                                  |
|                    | SPV7                                | -                                             | Sporadic carbonates                              |
| <b>Group 2</b>     | <b>Coarse - non carbonatic 1</b>    |                                               |                                                  |
|                    | SPV6                                | Freq.                                         | Freq. volcanic type 1 (small) and freq. WADS     |
|                    | SPV8                                | Freq.                                         | Freq. volcanic type 1 (small)                    |
|                    | SPV10                               | Com.                                          | Freq. volcanic type 1 (possibly 1 sandstone)     |
|                    | SPV11                               | Abund.                                        | Freq. volcanic types 1 and 2                     |
|                    | SPV12                               | Com.                                          | Freq. volcanic type 1 and 2 and WADS             |
| <b>Group 3</b>     | <b>Coarse - non carbonatic 2</b>    |                                               |                                                  |
|                    | SPV14                               | Traces                                        | Very rare metarenite (small)                     |
|                    | SPV9                                | Traces                                        | Spor. metarenite                                 |
| <b>Variant 2/3</b> | <b>Coarse - non carbonatic</b>      |                                               |                                                  |
|                    | SPV22                               | Very rare but large ( $\uparrow$ 500 $\mu$ m) | Rare metarenite                                  |
| <b>Group 4</b>     | <b>Fine - carbonatic</b>            |                                               |                                                  |
|                    | SPV21                               | In a lithic fragment only                     | Very rare volcanic type 2 (only 1 example)       |
|                    | SPV15                               | Extr. rare (only 1 found)                     | -                                                |
|                    | SPV16                               | Rare and small (<150 $\mu$ m)                 | -                                                |
|                    | SPV17                               | -                                             | -                                                |
|                    | SPV18                               | Extr. rare (only 1 found)                     | Very rare sedimentary rocks (small-Qz+Kfs+Mu/Il) |
|                    | SPV20                               | Extr. rare                                    | Very rare sedimentary rocks (small-Qz+Kfs+Mu/Il) |
|                    | SPV23                               | -                                             | -                                                |
| <b>Outlier 1</b>   | SPV19                               | Freq.                                         | Freq. volcanic type 3                            |
| <b>Outlier 2</b>   | SPV24                               | Extr. rare (only 1 found)                     | -                                                |

(continued)

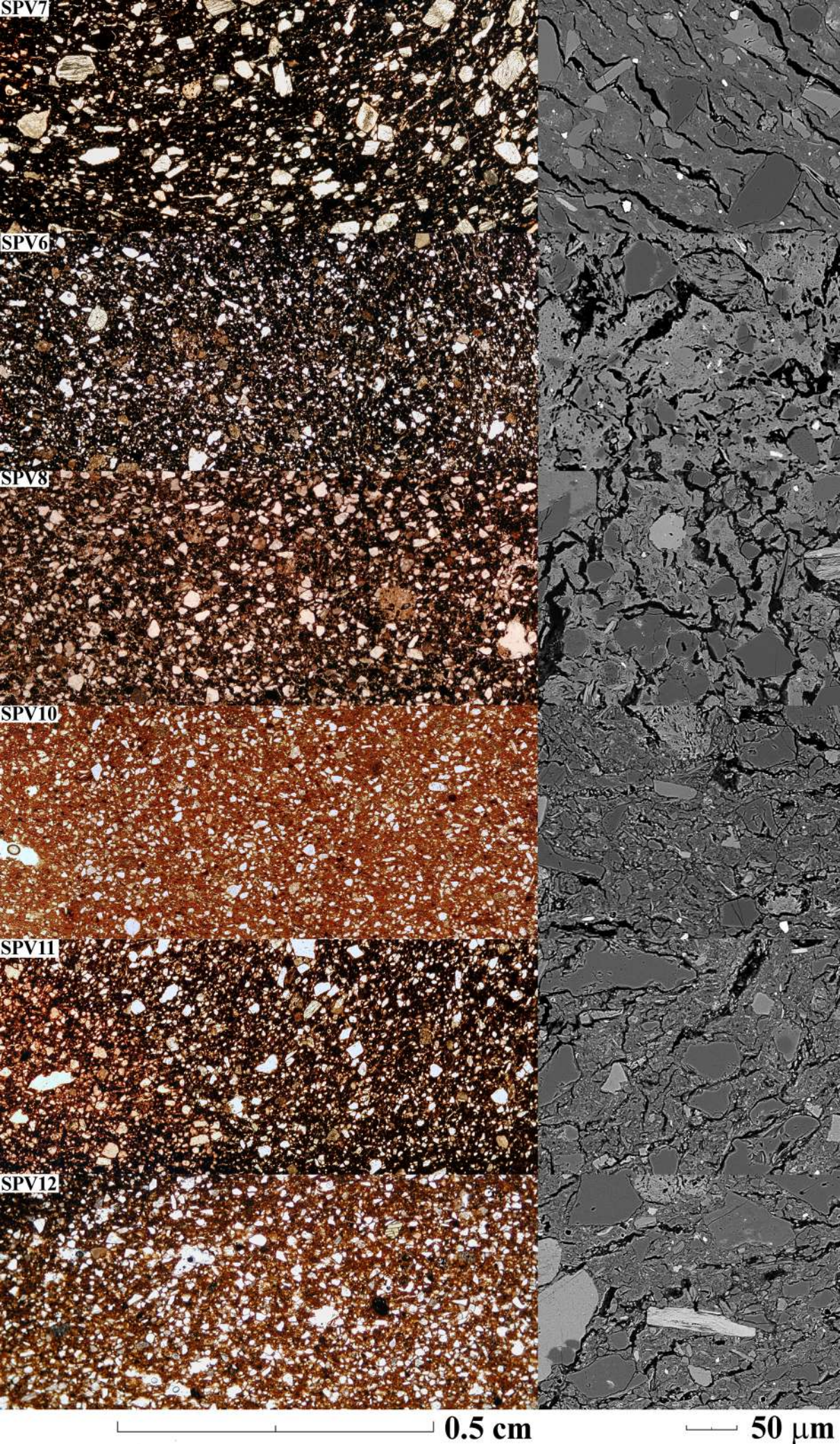
|                    | Sample                              | CaO<br>(matrix) | CaO<br>(bulk) | Other phases or features                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------|-------------------------------------|-----------------|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Group 1</b>     | <b>Calcite temper - Classe-type</b> |                 |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                    | SPV1                                | 11.1            | 30.46         | Calcite temper, extr. rare clino-amphibole                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|                    | SPV2                                | 16.0            | 32.23         | Calcite temper                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|                    | SPV3                                | 9.4             | 35.37         | Calcite temper                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|                    | SPV4                                | 4.2             | 30.05         | Calcite temper                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|                    | SPV5                                | 11.2            | 23.66         | Calcite temper (sometimes with high MgO content)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                    | SPV13                               | 8.9             | 25.13         | Calcite temper; freq. Cr-spinel                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Variant 1a</b>  | <b>Calcite temper</b>               |                 |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                    | SPV7                                | 15.9            | 25.87         | Calcite temper (averagely smaller with respect to SPV1-5)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Group 2</b>     | <b>Coarse - non carbonatic 1</b>    |                 |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                    | SPV6                                | 3.1             | 3.28          | One crystal of olivine (Fo <sub>61</sub> ) and one of garnet (Py <sub>1</sub> Gr <sub>64</sub> Al <sub>35</sub> ).<br>Abund. epidote                                                                                                                                                                                                                                                                                                                                                                                                        |
|                    | SPV8                                | 2.5             | 1.82          | Freq. garnet, esp. almandine-type (Py <sub>6</sub> Gr <sub>22</sub> Al <sub>72</sub> , Py <sub>7</sub> Gr <sub>17</sub> Sp <sub>3</sub> Al <sub>72</sub> ,<br>Py <sub>6</sub> Gr <sub>8</sub> Sp <sub>9</sub> Al <sub>77</sub> , Py <sub>23</sub> Gr <sub>3</sub> Al <sub>74</sub> , Py <sub>4</sub> Gr <sub>27</sub> Sp <sub>3</sub> Al <sub>66</sub> , Py <sub>10</sub> Al <sub>90</sub> ,<br>Py <sub>11</sub> Gr <sub>25</sub> Al <sub>64</sub> ); spor. olivine (Fo <sub>37-60</sub> ) with iddingsitic corona, rare<br>clino-amphibole |
|                    | SPV10                               | 2.2             | 1.87          | Rare garnet (Gr <sub>85</sub> Al <sub>15</sub> ); freq. epidote                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                    | SPV11                               | 2.4             | 2.25          | Freq. garnet, esp. almandine and grossular (Py <sub>15</sub> Gr <sub>29</sub> Al <sub>56</sub> ,<br>Py <sub>15</sub> Gr <sub>29</sub> Sp <sub>2</sub> Al <sub>54</sub> , Py <sub>5</sub> Gr <sub>82</sub> Al <sub>13</sub> , Py <sub>4</sub> Gr <sub>80</sub> Sp <sub>2</sub> Al <sub>14</sub> , Py <sub>13</sub> Gr <sub>3</sub> Al <sub>84</sub> ,<br>Py <sub>5</sub> Gr <sub>2</sub> Sp <sub>15</sub> Al <sub>78</sub> , Py <sub>19</sub> Gr <sub>1</sub> Al <sub>79</sub> )                                                             |
|                    | SPV12                               | 2.8             | 2.04          | Very rare olivine (Fo <sub>47</sub> ); freq. garnet, from grossular to<br>spessartine (Py <sub>3</sub> Gr <sub>33</sub> Sp <sub>65</sub> , Gr <sub>60</sub> Sp <sub>40</sub> , Py <sub>2</sub> Gr <sub>30</sub> Sp <sub>68</sub> , Py <sub>7</sub> Gr <sub>7</sub> Sp <sub>3</sub> Al <sub>84</sub> )                                                                                                                                                                                                                                       |
| <b>Group 3</b>     | <b>Coarse - non carbonatic 2</b>    |                 |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                    | SPV14                               | 2.7             | 2.36          | Garnet ranging from almandine (Py <sub>7</sub> Gr <sub>7</sub> Sp <sub>3</sub> Al <sub>83</sub> ; Py <sub>12</sub> Gr <sub>11</sub> Sp <sub>2</sub> Al <sub>74</sub> )<br>to andradite (Gr <sub>59</sub> Sp <sub>2</sub> Al <sub>39</sub> ), epidote                                                                                                                                                                                                                                                                                        |
|                    | SPV9                                | 2.1             | 2.61          | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Variant 2/3</b> | <b>Coarse - non carbonatic</b>      |                 |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                    | SPV22                               | 1.6             | 1.94          | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Group 4</b>     | <b>Fine - carbonatic</b>            |                 |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                    | SPV21                               | 20.4            | 13.23         | Garnet type almandine (Py <sub>6</sub> Gr <sub>6</sub> Sp <sub>11</sub> Al <sub>77</sub> )                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|                    | SPV15                               | 19.0            | 16.72         | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                    | SPV16                               | 17.1            | 15.55         | Spor. garnet [andradite (Py <sub>1</sub> Gr <sub>59</sub> Sp <sub>2</sub> Al <sub>38</sub> ), almandine (Gr <sub>17</sub> Sp <sub>3</sub> Al <sub>80</sub> ),<br>grossular (Gr <sub>78</sub> Al <sub>22</sub> )], freq. apatite, spor. epidote                                                                                                                                                                                                                                                                                              |
|                    | SPV17                               | 13.4            | 12.75         | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                    | SPV18                               | 18.8            | 14.13         | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                    | SPV20                               | 13.0            | 9.71          | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                    | SPV23                               | 18.9            | 14.12         | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Outlier 1</b>   | SPV19                               | 24.73           | 16.26         | Rare almandine garnet (Gr <sub>22</sub> Sp <sub>2</sub> Al <sub>75</sub> ), abund. apatite                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Outlier 2</b>   | SPV24                               | 11.8            | 11.58         | One crystal of Cr-spinel, freq. garnet (Py <sub>13</sub> Gr <sub>4</sub> Sp <sub>3</sub> Al <sub>80</sub> ;<br>Py <sub>8</sub> Gr <sub>9</sub> Sp <sub>11</sub> Al <sub>72</sub> ; Py <sub>4</sub> Gr <sub>17</sub> Sp <sub>2</sub> Al <sub>77</sub> ), epidote and apatite                                                                                                                                                                                                                                                                 |

Abbreviations :

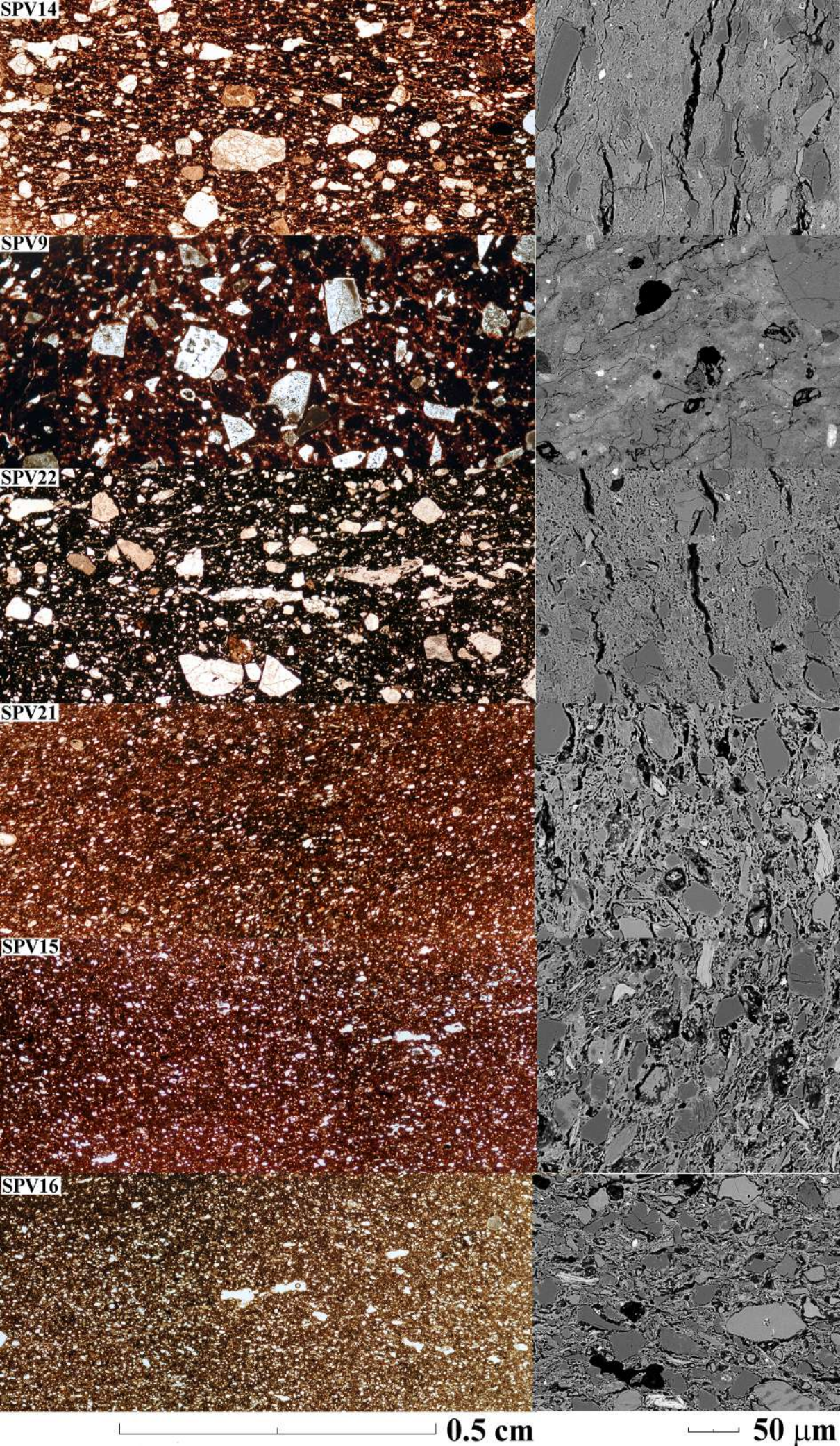
|                  |                             |
|------------------|-----------------------------|
| ↑                | up to                       |
| Abund.           | Abundant                    |
| All              | All range                   |
| ang.             | angular                     |
| av               | average                     |
| Bt               | Biotite                     |
| Com.             | Common                      |
| esp.             | especially                  |
| Extr.            | Extremely                   |
| fr.              | frequently                  |
| Freq.            | Frequent                    |
| Kfs              | K-feldspar                  |
| m                | mm                          |
| med.             | medium                      |
| Mu/Ill           | muscovite/illite            |
| mx               | maximum                     |
| Qz               | Quartz                      |
| sd               | standard deviation          |
| small/very small | small/very small dimensions |
| spher.           | sphericity                  |
| Spor.            | Sporadic                    |
| subroun.         | subrounded                  |
| vAbund.          | Very abundant               |
| μ                | μm                          |



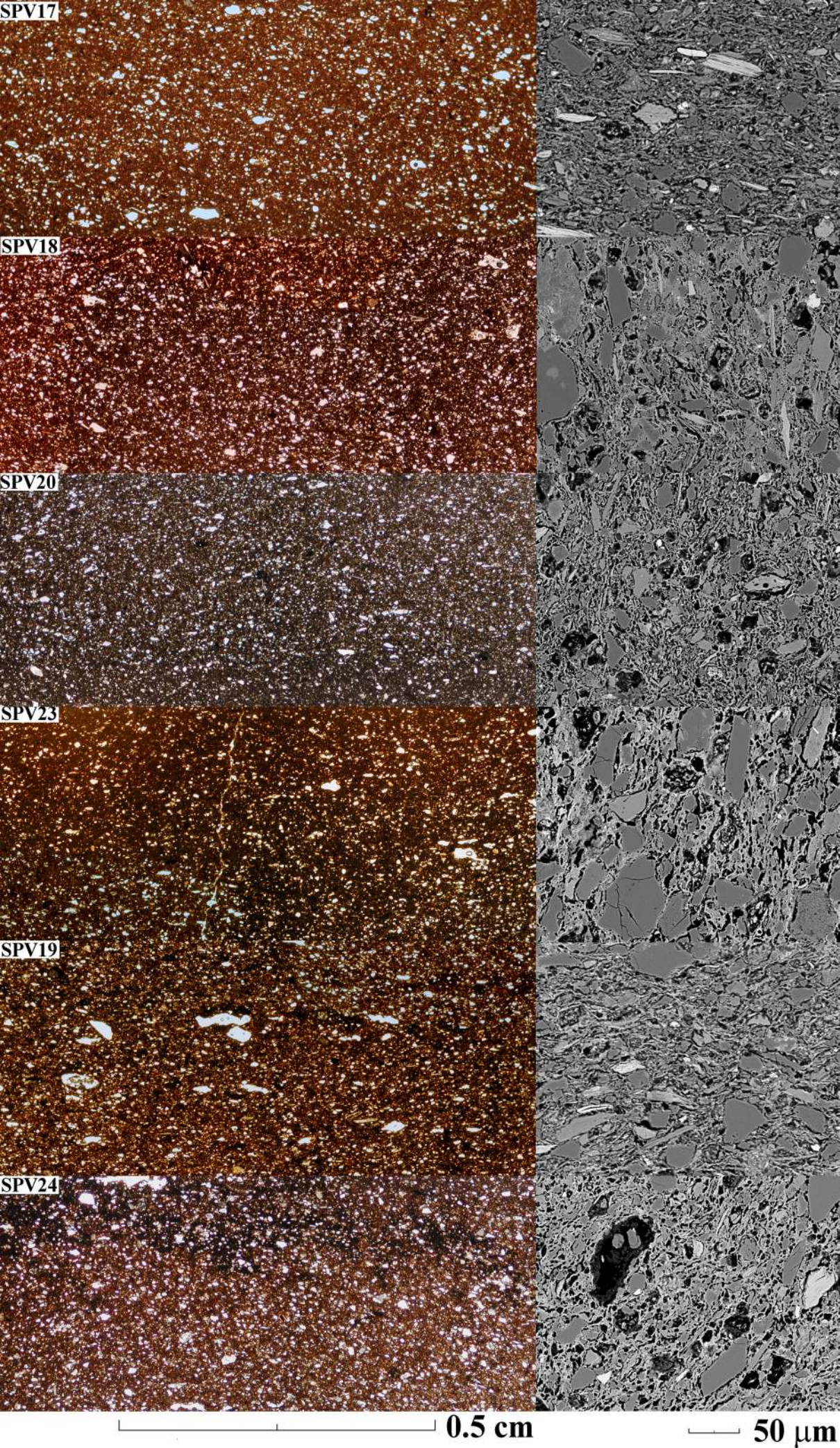
Supplementary Figure 1. Representative images of the ceramic paste taken by optical microscopy (parallel nicols) and images of the matrix taken by SEM. Samples SPV1-5 and 13.



Supplementary Figure 2. Representative images of the ceramic paste taken by optical microscopy (parallel nicols) and images of the matrix taken by SEM. Samples SPV7, 6, 8, 10, 11-12.



Supplementary Figure 3. Representative images of the ceramic paste taken by optical microscopy (parallel nicols) and images of the matrix taken by SEM. Samples SPV14, 9, 22, 21, 15-16.



Supplementary Figure 4. Representative images of the ceramic paste taken by optical microscopy (parallel nicols) and images of the matrix taken by SEM. Samples SPV17-18, 20, 23, 19, 24.

## Supplementary Material no. 1

### Principal Component Analysis

Eigenvalues:

|                 | F1    | F2    | F3    | F4    | F5    | F6    | F7    | F8    | F9    | F10   | F11   | F12   |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Eigenvalue      | 9.18  | 2.89  | 1.67  | 1.61  | 1.30  | 1.11  | 1.05  | 0.77  | 0.58  | 0.53  | 0.45  | 0.37  |
| Variability (%) | 39.90 | 12.57 | 7.26  | 7.00  | 5.65  | 4.82  | 4.56  | 3.34  | 2.50  | 2.31  | 1.97  | 1.60  |
| Cumulative %    | 39.90 | 52.47 | 59.73 | 66.74 | 72.39 | 77.21 | 81.77 | 85.11 | 87.62 | 89.93 | 91.90 | 93.50 |

|                 | F13   | F14   | F15   | F16   | F17   | F18   | F19   | F20   | F21   | F22    | F23    |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|
| Eigenvalue      | 0.32  | 0.24  | 0.19  | 0.16  | 0.16  | 0.13  | 0.11  | 0.08  | 0.06  | 0.04   | 0.00   |
| Variability (%) | 1.38  | 1.06  | 0.81  | 0.72  | 0.71  | 0.55  | 0.49  | 0.33  | 0.27  | 0.18   | 0.00   |
| Cumulative %    | 94.88 | 95.94 | 96.75 | 97.47 | 98.18 | 98.73 | 99.21 | 99.54 | 99.82 | 100.00 | 100.00 |

Factor loadings:

|                                | F1     | F2     | F3     | F4     | F5     |
|--------------------------------|--------|--------|--------|--------|--------|
| SiO <sub>2</sub>               | 0.786  | -0.421 | -0.031 | 0.170  | -0.151 |
| Al <sub>2</sub> O <sub>3</sub> | 0.822  | 0.350  | 0.053  | 0.119  | -0.070 |
| Fe <sub>2</sub> O <sub>3</sub> | 0.433  | 0.310  | 0.242  | 0.523  | 0.353  |
| MgO                            | -0.583 | 0.359  | 0.481  | -0.306 | 0.008  |
| CaO                            | -0.895 | 0.183  | -0.125 | -0.203 | 0.118  |
| Na <sub>2</sub> O              | 0.493  | -0.214 | 0.438  | -0.226 | -0.259 |
| K <sub>2</sub> O               | 0.742  | -0.023 | 0.472  | 0.014  | -0.233 |
| TiO <sub>2</sub>               | 0.065  | 0.869  | -0.131 | 0.004  | -0.232 |
| MnO                            | 0.410  | 0.086  | 0.260  | -0.377 | 0.599  |
| V                              | 0.143  | 0.761  | 0.177  | 0.282  | -0.129 |
| Co                             | 0.074  | 0.517  | -0.049 | -0.297 | 0.328  |
| Ni                             | -0.045 | 0.522  | -0.398 | -0.084 | 0.006  |
| Zn                             | 0.104  | -0.017 | 0.228  | 0.525  | 0.498  |
| Rb                             | 0.837  | -0.106 | 0.136  | -0.022 | -0.021 |
| Sr                             | -0.504 | 0.146  | 0.512  | -0.386 | -0.023 |
| Y                              | 0.528  | 0.415  | -0.286 | -0.262 | -0.130 |
| Zr                             | 0.915  | -0.017 | -0.228 | -0.033 | 0.002  |
| Ba                             | 0.775  | -0.051 | 0.222  | -0.315 | -0.139 |
| La                             | 0.917  | 0.197  | -0.015 | -0.009 | 0.064  |
| Ce                             | 0.900  | 0.144  | -0.007 | -0.087 | 0.183  |
| Pb                             | 0.633  | -0.160 | -0.327 | -0.238 | 0.094  |
| Th                             | 0.898  | 0.034  | -0.106 | -0.124 | -0.016 |
| U                              | -0.155 | 0.333  | 0.187  | 0.343  | -0.378 |

Correlations between variables and factors:

|                                | F1     | F2     | F3     | F4     | F5     |
|--------------------------------|--------|--------|--------|--------|--------|
| SiO <sub>2</sub>               | 0.786  | -0.421 | -0.031 | 0.170  | -0.151 |
| Al <sub>2</sub> O <sub>3</sub> | 0.822  | 0.350  | 0.053  | 0.119  | -0.070 |
| Fe <sub>2</sub> O <sub>3</sub> | 0.433  | 0.310  | 0.242  | 0.523  | 0.353  |
| MgO                            | -0.583 | 0.359  | 0.481  | -0.306 | 0.008  |
| CaO                            | -0.895 | 0.183  | -0.125 | -0.203 | 0.118  |
| Na <sub>2</sub> O              | 0.493  | -0.214 | 0.438  | -0.226 | -0.259 |
| K <sub>2</sub> O               | 0.742  | -0.023 | 0.472  | 0.014  | -0.233 |
| TiO <sub>2</sub>               | 0.065  | 0.869  | -0.131 | 0.004  | -0.232 |
| MnO                            | 0.410  | 0.086  | 0.260  | -0.377 | 0.599  |
| V                              | 0.143  | 0.761  | 0.177  | 0.282  | -0.129 |
| Co                             | 0.074  | 0.517  | -0.049 | -0.297 | 0.328  |

|    |        |        |        |        |        |
|----|--------|--------|--------|--------|--------|
| Ni | -0.045 | 0.522  | -0.398 | -0.084 | 0.006  |
| Zn | 0.104  | -0.017 | 0.228  | 0.525  | 0.498  |
| Rb | 0.837  | -0.106 | 0.136  | -0.022 | -0.021 |
| Sr | -0.504 | 0.146  | 0.512  | -0.386 | -0.023 |
| Y  | 0.528  | 0.415  | -0.286 | -0.262 | -0.130 |
| Zr | 0.915  | -0.017 | -0.228 | -0.033 | 0.002  |
| Ba | 0.775  | -0.051 | 0.222  | -0.315 | -0.139 |
| La | 0.917  | 0.197  | -0.015 | -0.009 | 0.064  |
| Ce | 0.900  | 0.144  | -0.007 | -0.087 | 0.183  |
| Pb | 0.633  | -0.160 | -0.327 | -0.238 | 0.094  |
| Th | 0.898  | 0.034  | -0.106 | -0.124 | -0.016 |
| U  | -0.155 | 0.333  | 0.187  | 0.343  | -0.378 |

Contribution of the variables (%):

|                                | F1    | F2     | F3     | F4     | F5     |
|--------------------------------|-------|--------|--------|--------|--------|
| SiO <sub>2</sub>               | 6.739 | 6.129  | 0.058  | 1.792  | 1.762  |
| Al <sub>2</sub> O <sub>3</sub> | 7.355 | 4.241  | 0.168  | 0.882  | 0.375  |
| Fe <sub>2</sub> O <sub>3</sub> | 2.047 | 3.322  | 3.510  | 16.964 | 9.606  |
| MgO                            | 3.704 | 4.450  | 13.882 | 5.800  | 0.006  |
| CaO                            | 8.724 | 1.158  | 0.936  | 2.559  | 1.078  |
| Na <sub>2</sub> O              | 2.648 | 1.579  | 11.469 | 3.159  | 5.153  |
| K <sub>2</sub> O               | 5.998 | 0.018  | 13.364 | 0.012  | 4.187  |
| TiO <sub>2</sub>               | 0.046 | 26.144 | 1.033  | 0.001  | 4.136  |
| MnO                            | 1.831 | 0.257  | 4.055  | 8.842  | 27.616 |
| V                              | 0.221 | 20.018 | 1.877  | 4.934  | 1.281  |
| Co                             | 0.060 | 9.231  | 0.141  | 5.485  | 8.261  |
| Ni                             | 0.022 | 9.419  | 9.462  | 0.436  | 0.003  |
| Zn                             | 0.117 | 0.009  | 3.118  | 17.086 | 19.106 |
| Rb                             | 7.633 | 0.392  | 1.115  | 0.031  | 0.033  |
| Sr                             | 2.770 | 0.735  | 15.677 | 9.270  | 0.040  |
| Y                              | 3.040 | 5.963  | 4.888  | 4.271  | 1.290  |
| Zr                             | 9.118 | 0.010  | 3.109  | 0.068  | 0.000  |
| Ba                             | 6.536 | 0.090  | 2.942  | 6.161  | 1.494  |
| La                             | 9.155 | 1.345  | 0.013  | 0.005  | 0.316  |
| Ce                             | 8.824 | 0.719  | 0.003  | 0.474  | 2.577  |
| Pb                             | 4.365 | 0.883  | 6.401  | 3.505  | 0.684  |
| Th                             | 8.786 | 0.041  | 0.672  | 0.960  | 0.019  |
| U                              | 0.261 | 3.847  | 2.105  | 7.302  | 10.975 |

Squared cosines of the variables:

|                                | F1           | F2           | F3           | F4           | F5           |
|--------------------------------|--------------|--------------|--------------|--------------|--------------|
| SiO <sub>2</sub>               | <b>0.619</b> | 0.177        | 0.001        | 0.029        | 0.023        |
| Al <sub>2</sub> O <sub>3</sub> | <b>0.675</b> | 0.123        | 0.003        | 0.014        | 0.005        |
| Fe <sub>2</sub> O <sub>3</sub> | 0.188        | 0.096        | 0.059        | <b>0.273</b> | 0.125        |
| MgO                            | <b>0.340</b> | 0.129        | 0.232        | 0.093        | 0.000        |
| CaO                            | <b>0.801</b> | 0.033        | 0.016        | 0.041        | 0.014        |
| Na <sub>2</sub> O              | <b>0.243</b> | 0.046        | 0.192        | 0.051        | 0.067        |
| K <sub>2</sub> O               | <b>0.550</b> | 0.001        | 0.223        | 0.000        | 0.054        |
| TiO <sub>2</sub>               | 0.004        | <b>0.756</b> | 0.017        | 0.000        | 0.054        |
| MnO                            | 0.168        | 0.007        | 0.068        | 0.142        | <b>0.359</b> |
| V                              | 0.020        | <b>0.579</b> | 0.031        | 0.079        | 0.017        |
| Co                             | 0.006        | <b>0.267</b> | 0.002        | 0.088        | 0.107        |
| Ni                             | 0.002        | <b>0.272</b> | 0.158        | 0.007        | 0.000        |
| Zn                             | 0.011        | 0.000        | 0.052        | <b>0.275</b> | 0.248        |
| Rb                             | <b>0.701</b> | 0.011        | 0.019        | 0.001        | 0.000        |
| Sr                             | 0.254        | 0.021        | <b>0.262</b> | 0.149        | 0.001        |
| Y                              | <b>0.279</b> | 0.172        | 0.082        | 0.069        | 0.017        |

|    |              |       |       |       |              |
|----|--------------|-------|-------|-------|--------------|
| Zr | <b>0.837</b> | 0.000 | 0.052 | 0.001 | 0.000        |
| Ba | <b>0.600</b> | 0.003 | 0.049 | 0.099 | 0.019        |
| La | <b>0.840</b> | 0.039 | 0.000 | 0.000 | 0.004        |
| Ce | <b>0.810</b> | 0.021 | 0.000 | 0.008 | 0.034        |
| Pb | <b>0.401</b> | 0.026 | 0.107 | 0.056 | 0.009        |
| Th | <b>0.806</b> | 0.001 | 0.011 | 0.015 | 0.000        |
| U  | 0.024        | 0.111 | 0.035 | 0.118 | <b>0.143</b> |

*Values in bold correspond for each variable to the factor for which the squared cosine is the largest*

Factor scores:

|  | F1     | F2     | F3     | F4     | F5     |
|-----------------------------------------------------------------------------------|--------|--------|--------|--------|--------|
| FAR 1                                                                             | -2.650 | -0.426 | -0.515 | -0.882 | 0.324  |
| FAR 2                                                                             | -2.761 | -0.503 | -0.619 | -0.878 | 0.429  |
| FAR 3                                                                             | -1.800 | -0.431 | -0.367 | -0.573 | -0.198 |
| FAR 4                                                                             | -3.117 | -0.695 | -0.840 | -0.330 | 0.624  |
| FAR 5                                                                             | -2.773 | -0.509 | -0.781 | -0.481 | 0.166  |
| FAR 6                                                                             | -2.036 | -1.152 | -0.036 | -1.467 | 0.243  |
| FAR 7                                                                             | -2.273 | -0.855 | 0.032  | -1.388 | 0.153  |
| FAR 8                                                                             | -4.010 | -0.035 | 1.628  | -2.647 | 0.324  |
| FAR 9                                                                             | -2.989 | -0.373 | -0.815 | -1.435 | 1.163  |
| FAR 10                                                                            | -2.679 | 0.333  | 0.128  | -1.369 | 0.427  |
| FAR 11                                                                            | -2.869 | -2.346 | -0.846 | -1.026 | 0.017  |
| FAR 12                                                                            | -2.661 | -1.568 | -1.516 | -1.045 | 1.202  |
| FAR 13                                                                            | -3.930 | -2.129 | -1.509 | -0.965 | 0.939  |
| FARA 1                                                                            | 0.538  | -3.590 | 2.235  | 2.923  | 4.847  |
| FARA 2                                                                            | 1.829  | -2.219 | 0.362  | 1.635  | 4.023  |
| FARA 3                                                                            | 2.379  | -0.894 | 0.275  | 0.976  | -0.014 |
| FARA 4                                                                            | 1.575  | -0.831 | 0.108  | 1.587  | 3.777  |
| FARA 5                                                                            | 2.043  | -2.193 | -0.083 | 0.861  | 2.004  |
| FARA 6                                                                            | 1.567  | -2.527 | -0.342 | 1.097  | 2.037  |
| FARA 7                                                                            | 2.452  | -1.008 | -0.246 | 2.251  | 2.773  |
| FARA 8                                                                            | 3.297  | -1.797 | 0.575  | 1.071  | 3.742  |
| FARA 9                                                                            | 1.430  | -2.190 | -0.178 | 2.367  | 1.740  |
| FARA 10                                                                           | 2.393  | -1.628 | 0.150  | 1.808  | 1.718  |
| FARA 11                                                                           | 1.662  | -0.554 | -0.323 | 2.264  | 1.749  |
| FARA 12                                                                           | 1.329  | -2.596 | 0.455  | 4.453  | 2.139  |
| FARA 13                                                                           | 3.031  | -1.784 | -0.631 | 2.656  | 2.570  |
| FARA 14                                                                           | 1.401  | -2.737 | 0.698  | 2.984  | 0.528  |
| FARA 15                                                                           | 2.366  | -2.777 | 0.799  | 5.685  | 5.596  |
| FARA 16                                                                           | 2.736  | -0.810 | 1.653  | 4.421  | 3.459  |
| FARA 17                                                                           | -1.386 | 0.990  | 1.102  | 1.519  | 0.974  |
| FARA 18                                                                           | -1.246 | 2.149  | 1.244  | 0.732  | 1.435  |
| FARA 19                                                                           | -2.201 | 1.161  | 1.207  | 0.398  | 0.288  |
| FARA 20                                                                           | -1.486 | 1.659  | 0.990  | 0.841  | 0.727  |
| FARA 21                                                                           | -0.962 | 0.387  | 1.642  | 1.401  | 2.503  |
| FARA 22                                                                           | -0.464 | 0.845  | 1.158  | 0.838  | -0.176 |
| FARA 23                                                                           | -0.486 | 1.732  | 1.703  | 2.318  | 1.457  |
| FARA 24                                                                           | -0.567 | 2.139  | 1.663  | 1.684  | 0.278  |
| FARA 25                                                                           | -2.479 | 0.591  | 1.260  | 0.708  | 0.508  |
| FARA 26                                                                           | -1.519 | 1.069  | 1.567  | 0.760  | 0.692  |
| FARA 27                                                                           | 1.944  | 0.553  | 1.633  | 1.252  | 0.450  |
| FARA 28                                                                           | -0.525 | 0.790  | 1.740  | 1.415  | 0.858  |
| FARA 29                                                                           | -1.341 | 1.802  | 1.804  | 1.281  | 0.908  |
| FARA 30                                                                           | -0.929 | 1.772  | 2.051  | 1.711  | 1.855  |
| GOLD 01                                                                           | -1.962 | 1.867  | 1.444  | 0.753  | -0.589 |
| GOLD 02                                                                           | -2.963 | 2.102  | 1.136  | 2.261  | -2.128 |
| GOLD 03                                                                           | -2.660 | 1.351  | 0.231  | 2.289  | -2.468 |
| GOLD 04                                                                           | -2.390 | 1.469  | 0.628  | 2.716  | -2.458 |
| GOLD 05                                                                           | -0.712 | 3.160  | 0.208  | 2.358  | -1.288 |
| GOLD 06                                                                           | -2.170 | 0.934  | 0.900  | 1.359  | -0.769 |

|         |        |        |        |        |        |
|---------|--------|--------|--------|--------|--------|
| GOLD 07 | -2.807 | 1.689  | 0.811  | 1.378  | -1.114 |
| GOLD 08 | -1.851 | 2.333  | 0.937  | 0.868  | -0.150 |
| GOLD 09 | -1.875 | 1.926  | 0.237  | 2.142  | -1.947 |
| GOLD 10 | -2.101 | 1.818  | 0.962  | 0.768  | -0.500 |
| GOLD 11 | -1.765 | 1.848  | 0.457  | 1.367  | -1.184 |
| GOLD 12 | -0.696 | 2.743  | 1.282  | 0.465  | -0.118 |
| GOLD 13 | -1.365 | 0.145  | 0.887  | 0.390  | -0.382 |
| GOLD 14 | 0.078  | 1.784  | 2.319  | 1.052  | -1.121 |
| GOLD 15 | -0.725 | 1.048  | 1.453  | 0.350  | -1.119 |
| GOLD 16 | -0.763 | 2.597  | 1.378  | 0.693  | -0.268 |
| GOLD 17 | -1.254 | 3.147  | 0.605  | 2.351  | -2.043 |
| GOLD 18 | -0.431 | 2.184  | 1.144  | 1.341  | -1.186 |
| GOLD 20 | -2.245 | 3.414  | 1.189  | 2.291  | -2.378 |
| GOLD 21 | -6.011 | 1.046  | -4.353 | 0.918  | 0.592  |
| GOLD 22 | 3.114  | -0.903 | -1.403 | 0.754  | 0.225  |
| GOLD 23 | 4.866  | 1.541  | 0.114  | -0.499 | -0.300 |
| GOLD 24 | 3.197  | -0.343 | 0.282  | -0.098 | -0.928 |
| GOLD 26 | 3.331  | 0.604  | -4.364 | 1.272  | -1.142 |
| GOLD 27 | 0.874  | -3.638 | -0.197 | 0.810  | -1.500 |
| GOLD 28 | 2.609  | 0.661  | -3.871 | 1.742  | -0.254 |
| GOLD 29 | 3.809  | -0.626 | -0.517 | 0.192  | -0.324 |
| GOLD 30 | 6.323  | 0.931  | 0.003  | -1.203 | 0.143  |
| GOLD 31 | 5.519  | 1.437  | 0.691  | -0.841 | -0.285 |
| GOLD 32 | -4.783 | 1.980  | -4.107 | 1.293  | 0.522  |
| GOLD 33 | 3.884  | -0.646 | -0.366 | -0.705 | -0.098 |
| GOLD 34 | 3.703  | -0.926 | 0.295  | -0.453 | -0.547 |
| GOLD 36 | 4.331  | 0.358  | -0.984 | -0.009 | -0.158 |
| GOLD 37 | 4.027  | -0.545 | -0.705 | -0.203 | -0.047 |
| GOLD 38 | 4.699  | -0.994 | -1.745 | -0.284 | -0.324 |
| ORD 01  | -2.333 | 1.064  | 0.291  | 0.344  | -0.232 |
| ORD 02  | -1.713 | 1.561  | 0.695  | 0.942  | -0.797 |
| ORD 03  | -1.680 | 1.239  | 0.763  | 0.828  | -0.751 |
| ORD 04  | -3.118 | -0.506 | 0.512  | 0.516  | -0.094 |
| ORD 05  | -2.207 | 2.559  | 2.253  | 0.637  | -0.632 |
| ORD 06  | -1.890 | 2.853  | 1.916  | 0.681  | -0.719 |
| ORD 07  | -1.197 | -1.271 | -0.374 | 1.288  | -1.310 |
| ORD 08  | -1.946 | 1.121  | 0.828  | 1.545  | -0.367 |
| ORD 09  | -1.981 | -1.233 | 0.273  | -0.081 | -0.620 |
| ORD 10  | -1.118 | 0.376  | 0.544  | -0.345 | -0.582 |
| ORD 11  | -1.912 | 1.709  | 1.146  | 1.290  | -1.056 |
| ORD 12  | -2.036 | 0.893  | 0.469  | 1.143  | -0.186 |
| ORD 13  | -2.577 | 0.075  | 0.273  | 1.061  | -0.550 |
| ORD 14  | -0.744 | 3.017  | 0.634  | 1.478  | -0.137 |
| ORD 15  | -1.538 | -1.416 | 0.037  | 0.232  | -1.179 |
| ORD 16  | 2.952  | -1.213 | -0.619 | 1.068  | -1.098 |
| ORD 18  | 1.880  | -2.813 | -0.562 | 1.159  | -1.615 |
| ORD 19  | 4.243  | -0.389 | -0.028 | -0.252 | -0.592 |
| ORD 20  | 2.509  | -1.032 | -0.179 | 0.075  | -0.697 |
| ORD 21  | 4.212  | -0.403 | 0.019  | 0.092  | -1.344 |
| ORD 22  | 0.594  | -4.528 | -1.477 | 1.430  | -0.271 |
| ORD 23  | 3.250  | -0.516 | -0.499 | 0.427  | 0.212  |
| ORD 24  | 4.810  | 0.626  | -0.702 | 0.143  | 0.558  |
| ORD 25  | 3.851  | -0.525 | -0.772 | -0.004 | 1.143  |
| ORD 26  | 3.382  | 0.000  | 0.088  | -0.164 | -0.510 |
| ORD 27  | 3.541  | -2.197 | -0.661 | 0.902  | -2.618 |
| ORD 28  | 5.431  | -0.692 | -0.391 | -0.773 | -0.141 |
| ORD 29  | 0.927  | -1.878 | -1.475 | 2.967  | -2.356 |
| ORD 30  | 1.157  | -1.874 | -1.641 | 3.175  | -2.226 |
| ORD 31  | 4.903  | -1.184 | -0.726 | -0.763 | -0.401 |
| ORD 32  | 4.023  | -0.404 | -2.426 | 0.825  | 0.373  |
| ORD 33  | 2.700  | -1.432 | -0.224 | 0.068  | -0.616 |
| ORD 34  | 4.577  | -1.824 | -0.328 | -0.718 | -0.077 |

|        |        |        |        |        |        |
|--------|--------|--------|--------|--------|--------|
| ORD 35 | 2.669  | 1.570  | -2.206 | -0.654 | -1.805 |
| ORD 36 | 2.692  | 2.104  | -1.998 | 0.048  | -1.470 |
| POS 01 | 2.423  | -1.503 | -0.379 | 1.347  | -2.261 |
| POS 02 | 0.842  | -2.562 | 0.357  | -1.451 | -0.222 |
| POS 03 | 1.926  | -1.940 | -1.685 | 0.145  | -1.029 |
| POS 04 | 1.394  | -0.465 | -0.254 | -0.599 | 0.115  |
| POS 05 | 2.190  | -1.023 | -0.569 | -0.590 | 0.907  |
| POS 07 | 0.817  | -1.844 | -0.590 | 1.358  | -1.237 |
| POS 08 | 2.637  | -1.999 | -0.091 | 0.230  | -2.011 |
| POS 09 | 2.536  | 1.344  | -0.246 | 0.893  | -0.246 |
| POS 11 | 2.814  | 0.850  | -0.064 | 0.097  | 0.778  |
| POS 13 | 6.595  | 2.084  | -0.752 | -0.836 | 1.659  |
| POS 14 | 3.420  | -0.766 | 0.428  | -0.972 | -0.147 |
| POS 15 | 2.229  | 3.455  | -2.445 | -0.831 | -0.403 |
| POS 17 | 3.227  | 0.853  | -0.353 | -1.067 | -0.371 |
| POS 18 | 6.244  | 2.647  | -1.082 | -2.015 | 2.133  |
| POS 19 | 3.384  | -1.831 | 1.451  | 0.720  | -1.051 |
| POS 20 | 2.519  | -0.718 | -0.055 | 0.395  | -0.479 |
| POS 21 | -2.035 | -1.407 | -0.491 | -0.648 | -0.519 |
| POS 22 | 1.341  | -0.263 | -0.606 | 0.954  | -0.356 |
| POS 23 | -2.550 | 0.819  | 1.443  | 0.121  | -0.473 |
| POS 24 | -2.403 | 2.165  | 1.585  | 0.362  | -0.207 |
| POS 25 | -3.022 | -0.682 | 0.250  | 0.030  | -0.248 |
| POS 26 | -3.945 | -0.262 | 0.613  | -0.212 | -0.496 |
| POS 27 | -3.056 | 0.159  | 1.222  | -0.426 | -0.535 |
| POS 28 | -3.046 | -0.691 | 1.340  | -0.032 | -0.772 |
| POS 29 | -1.982 | 0.872  | 0.283  | 0.404  | -0.130 |
| POS 30 | -2.905 | -0.720 | 0.719  | -0.707 | -0.674 |
| POS 31 | -3.219 | -0.167 | 0.690  | 0.656  | -0.785 |
| POS 32 | -2.405 | -0.340 | 1.427  | -0.677 | -0.421 |
| POS 33 | -2.270 | 0.772  | 1.146  | 0.569  | -0.108 |
| POS 34 | -1.348 | 2.362  | 1.400  | 0.110  | 0.344  |
| POS 35 | -2.864 | 1.141  | 2.159  | -0.382 | -0.135 |
| POS 36 | -2.769 | -1.552 | -0.685 | -0.653 | 0.147  |
| POS 37 | -3.380 | -0.750 | 0.951  | -0.272 | -0.259 |
| POS 38 | -2.500 | 1.231  | 1.699  | -0.481 | 0.914  |
| POS 39 | -2.670 | 0.339  | 0.531  | 0.306  | -0.206 |
| POS 40 | -1.398 | 1.987  | 1.013  | 0.762  | -0.622 |
| POS 41 | -3.293 | 0.555  | 2.174  | -1.037 | -0.094 |
| POS 42 | 0.846  | -0.547 | -0.429 | 2.498  | -1.827 |
| POS 43 | 1.076  | -1.443 | -1.482 | 0.822  | -1.186 |
| POS 44 | 2.272  | -0.927 | 0.499  | 1.433  | -2.010 |
| POS 45 | 5.747  | 2.734  | -0.202 | -0.137 | 0.333  |
| POS 46 | 2.977  | 0.970  | 0.292  | -0.393 | -1.162 |
| POS 47 | 2.836  | 0.083  | 0.371  | 1.229  | -1.431 |
| POS 48 | 1.773  | -2.044 | -0.186 | 0.879  | -1.600 |
| SAB 1  | -1.926 | 1.444  | 0.645  | -0.598 | 0.292  |
| SAB 2  | -3.167 | -0.919 | -0.381 | -0.928 | -0.054 |
| SG 10  | 5.960  | 2.197  | 0.505  | -1.254 | 1.067  |
| SG 12  | 1.601  | 0.524  | 1.168  | -1.169 | 0.419  |
| SG 13  | 4.178  | 3.878  | -2.396 | -1.339 | -0.347 |
| SG 14  | 2.094  | -2.025 | -0.662 | -0.109 | 0.528  |
| SG 15  | -2.511 | 0.606  | 1.669  | -1.475 | 0.050  |
| SG 16  | -3.503 | -2.564 | 0.875  | -1.471 | 0.607  |
| SG 21  | 2.128  | 0.200  | 1.373  | -1.435 | 0.376  |
| SG 22  | 1.325  | -0.380 | 1.668  | -1.135 | -0.238 |
| SG 23  | 1.908  | 0.514  | 0.603  | -0.950 | 0.528  |
| SG 24  | 1.355  | 0.265  | 1.130  | -1.073 | 0.227  |
| SG 25  | 1.692  | 0.075  | 0.700  | -1.085 | 0.422  |
| SG 26  | 1.196  | -0.110 | 1.348  | -1.450 | -0.063 |
| SG 27  | 1.892  | 0.174  | 0.789  | -1.132 | 0.554  |
| SG 28  | 1.556  | -0.094 | 0.873  | -1.096 | 0.370  |

|       |        |        |        |        |        |
|-------|--------|--------|--------|--------|--------|
| SG 29 | 1.265  | 0.001  | 0.650  | -1.087 | 0.345  |
| SG 30 | 1.148  | -0.135 | 0.744  | -0.855 | 0.556  |
| SG 31 | 0.979  | 0.165  | 0.878  | -1.074 | 0.298  |
| SG 32 | 1.599  | -0.007 | 0.883  | -1.074 | 0.246  |
| SG 33 | 6.138  | 2.366  | 0.143  | -1.596 | 0.993  |
| SG 34 | 1.324  | -0.165 | 1.371  | -1.514 | -0.038 |
| SG 35 | 2.037  | 0.764  | 0.555  | -1.261 | 0.669  |
| SG 36 | 1.858  | -0.033 | 0.535  | -1.101 | 0.452  |
| SG 37 | 1.942  | 0.153  | 1.763  | -1.214 | 0.044  |
| SG 38 | 5.850  | 2.347  | 0.137  | -1.378 | 0.730  |
| SG 39 | 1.890  | -0.143 | 1.663  | -1.900 | 0.149  |
| SG 40 | 5.280  | 1.767  | 0.048  | -1.649 | 0.952  |
| SG 41 | 1.469  | 0.070  | 1.258  | -1.282 | 0.360  |
| SG 42 | 5.546  | 2.246  | 0.314  | -1.281 | 0.778  |
| SG 43 | 1.957  | 0.482  | 0.666  | -1.493 | 0.396  |
| SG 44 | 3.617  | 2.485  | -1.957 | -1.340 | -0.832 |
| SG 45 | 1.308  | -0.369 | 1.357  | -1.427 | 0.200  |
| SG 46 | 1.425  | 0.262  | 0.954  | -1.000 | -0.005 |
| SG 47 | 1.576  | 0.151  | 1.066  | -1.081 | 0.167  |
| SG 48 | 4.926  | 2.038  | 0.162  | -1.407 | 0.789  |
| SG 49 | 5.482  | 1.792  | 0.392  | -1.532 | 0.552  |
| SG 50 | 4.958  | 1.879  | 0.485  | -1.318 | 0.729  |
| SG 51 | -4.872 | -2.723 | 0.626  | -1.859 | 0.337  |
| SG 52 | -3.560 | -2.537 | 0.403  | -1.550 | 0.581  |
| SG 53 | -3.791 | -1.627 | 0.420  | -0.882 | 0.142  |
| SG 54 | -4.497 | -2.163 | 1.410  | -2.068 | 0.107  |
| SG 55 | -2.604 | 1.041  | 1.242  | 0.685  | -0.578 |
| SG 56 | -2.436 | -0.809 | 0.618  | -0.962 | 0.119  |
| SG 57 | -0.972 | 0.838  | 0.946  | 0.091  | -0.389 |
| SG 58 | -2.843 | -0.664 | 0.880  | -1.008 | 0.671  |
| SG 59 | -1.406 | 0.927  | 1.063  | 0.438  | 0.059  |
| SG 6  | 6.208  | 2.192  | 0.569  | -1.209 | 0.794  |
| SG 60 | -1.269 | 1.507  | 1.681  | 0.047  | -0.810 |
| SG 61 | -1.960 | -0.462 | 0.243  | -0.384 | 0.188  |
| SG 62 | -2.375 | -0.485 | 0.632  | -1.023 | 0.621  |
| SG 63 | -1.803 | 0.392  | 0.519  | -0.626 | 0.547  |
| SG 64 | 1.700  | -1.897 | -0.732 | -0.001 | -1.139 |
| SG 65 | 0.679  | -1.881 | 0.378  | -0.507 | -0.701 |
| SG 66 | 1.913  | -1.322 | -0.219 | 0.205  | -1.016 |
| SG 67 | 3.231  | -1.890 | -0.403 | -0.179 | -1.379 |
| SG 68 | -0.002 | -3.976 | -0.622 | -0.463 | -0.313 |
| SG 69 | 3.157  | -0.901 | -0.080 | -0.341 | -1.544 |
| SG 7  | 1.467  | 0.258  | 0.857  | -1.513 | 0.926  |
| SG 70 | 2.257  | -1.621 | -0.230 | 0.900  | -1.905 |
| SG 71 | 3.229  | -1.473 | -0.749 | -0.811 | -0.373 |
| SG 72 | 0.605  | 0.598  | -0.887 | -1.715 | -1.221 |
| SG 73 | 6.522  | 0.814  | -0.390 | -1.646 | 0.824  |
| SG 74 | 2.183  | -2.438 | -1.495 | -1.711 | -2.180 |
| SG 75 | 2.205  | 1.619  | -1.396 | -1.196 | -1.943 |
| SG 76 | 2.977  | -1.989 | -0.314 | 0.184  | -1.552 |
| SG 77 | 3.689  | 1.002  | 0.588  | -1.127 | -0.516 |
| SG 78 | 1.483  | -2.940 | -1.468 | 0.874  | -0.373 |
| SG 79 | 3.436  | -2.831 | -0.321 | -0.964 | -1.174 |
| SG 8  | 6.269  | 2.545  | 0.970  | -1.398 | 0.650  |
| SG 80 | 2.721  | -1.555 | -0.499 | 1.736  | -2.742 |
| SG 9  | 5.990  | 2.078  | 0.387  | -1.665 | 1.126  |
| SP 1  | -2.961 | 0.508  | -0.359 | -0.370 | 0.085  |
| SP 2  | -3.248 | 0.474  | -0.741 | -0.197 | 0.247  |
| SP 3  | -3.791 | -0.347 | 0.050  | -1.345 | 0.278  |
| SP 4  | -2.895 | 0.601  | -0.638 | -0.482 | 0.481  |
| SP 5  | -3.784 | -0.046 | -0.886 | -0.507 | 0.549  |
| SP 6  | -3.324 | 0.051  | -0.856 | -0.126 | -0.127 |

|       |        |        |        |        |        |
|-------|--------|--------|--------|--------|--------|
| SP 7  | -2.765 | -0.726 | -0.604 | 0.010  | -0.003 |
| SP 8  | -3.815 | -1.246 | 0.200  | -0.965 | 0.190  |
| SP 9  | -4.990 | -1.796 | -0.529 | -1.342 | 0.594  |
| SP 10 | -3.508 | -0.775 | -1.222 | -0.886 | 0.756  |
| SP 11 | -3.800 | 0.273  | -0.833 | -0.083 | 0.298  |
| SP 12 | -3.784 | -0.489 | -1.203 | -0.928 | 0.644  |
| SP 13 | -2.752 | 0.078  | -0.519 | -0.504 | 0.006  |
| SP 14 | -2.202 | 1.482  | 0.493  | -0.621 | 0.015  |
| SP 15 | -4.998 | -3.092 | -1.163 | -1.379 | -0.089 |
| SP 16 | -5.977 | 0.340  | 2.790  | -4.908 | -0.084 |
| SP 18 | -4.188 | -2.792 | -1.341 | -1.442 | 0.027  |
| SP 19 | -2.856 | -1.272 | -1.089 | -1.101 | 0.315  |
| SP 20 | -3.410 | -1.161 | -1.308 | -0.275 | 0.276  |
| SP 21 | -4.067 | -2.464 | -0.726 | -0.505 | -0.057 |
| SP 22 | -3.659 | -2.687 | -0.984 | -1.395 | 0.424  |
| SP 23 | -3.061 | -0.668 | -1.069 | -0.565 | -0.013 |
| SP 24 | -4.188 | -0.595 | -0.769 | -1.221 | 0.565  |
| SP 25 | -3.343 | -0.040 | -1.024 | -0.385 | 0.414  |
| SP 26 | -3.415 | -0.510 | -0.995 | -0.564 | 0.369  |
| SP 27 | -2.920 | -0.209 | -0.804 | -0.863 | 0.836  |
| SP 28 | -2.714 | 1.544  | 0.059  | -0.615 | 0.678  |
| SP 29 | -3.434 | -0.131 | -0.665 | -0.939 | 0.170  |
| SP 30 | -3.502 | -0.046 | -0.471 | -0.549 | 0.158  |
| SP 31 | -2.578 | -0.333 | -0.843 | -0.955 | 0.579  |
| SP 32 | -3.049 | -0.136 | -0.922 | -0.207 | 0.468  |
| SP 33 | -3.292 | -0.833 | -1.010 | -0.875 | 0.454  |
| SP 34 | -3.614 | -1.786 | -1.676 | -0.428 | 0.397  |
| SP 35 | -4.193 | -1.423 | -1.084 | -0.221 | 0.020  |
| SP 36 | -4.053 | -0.866 | -1.318 | 0.296  | 0.229  |
| SPV1  | -4.633 | 4.588  | -4.783 | -0.482 | 1.070  |
| SPV2  | -4.584 | 3.076  | -4.196 | -0.238 | 1.362  |
| SPV3  | -5.943 | 3.409  | -3.413 | 2.130  | -0.318 |
| SPV4  | -4.484 | 4.495  | -3.918 | -0.057 | 1.966  |
| SPV5  | -3.993 | 4.701  | -2.381 | 0.171  | 1.720  |
| SPV6  | 5.402  | 1.082  | 0.276  | -1.517 | 0.109  |
| SPV7  | 0.701  | 2.537  | -3.464 | -0.378 | 0.451  |
| SPV8  | 2.376  | -1.946 | -0.269 | -0.049 | -1.952 |
| SPV9  | 1.455  | 2.162  | -4.349 | 0.259  | 1.485  |
| SPV10 | 2.340  | -2.076 | -0.166 | 0.269  | -0.960 |
| SPV11 | 2.615  | -1.721 | -0.069 | -0.135 | -0.939 |
| SPV12 | 3.422  | -0.204 | 0.791  | -1.014 | -0.525 |
| SPV13 | -1.976 | 5.262  | -5.742 | 0.581  | 1.562  |
| SPV14 | 1.651  | -1.230 | -0.656 | 1.553  | -0.549 |
| SPV15 | -2.590 | -0.864 | 0.838  | -0.453 | -0.297 |
| SPV16 | -2.742 | -0.314 | 0.545  | 0.276  | -0.181 |
| SPV17 | -1.438 | 1.170  | 0.979  | 0.539  | -0.416 |
| SPV18 | -2.658 | -0.444 | 0.808  | -0.036 | -0.579 |
| SPV19 | -2.599 | 0.005  | 1.346  | 0.297  | -1.124 |
| SPV20 | -1.399 | 0.871  | 1.051  | 0.137  | -0.525 |
| SPV21 | -1.849 | -1.512 | 0.269  | -0.454 | -0.335 |
| SPV22 | 3.441  | 1.009  | -0.233 | 2.063  | -1.799 |
| SPV23 | -2.333 | 0.235  | 0.198  | 0.217  | -0.119 |
| SPV24 | -1.231 | 1.098  | 0.126  | 0.540  | 0.136  |

## Supplementary Material no. 2

### Principal Component Analysis

Eigenvalues:

|             | F1    | F2    | F3    | F4    | F5    | F6    | F7    | F8    | F9    | F10   | F11   | F12   |
|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Eigenvalue  | 6.58  | 3.62  | 2.41  | 1.89  | 1.56  | 1.38  | 1.17  | 0.89  | 0.75  | 0.50  | 0.45  | 0.34  |
| Variability | 28.60 | 15.72 | 10.50 | 8.20  | 6.77  | 5.99  | 5.11  | 3.85  | 3.26  | 2.18  | 1.95  | 1.46  |
| Cumulative  | 28.60 | 44.32 | 54.82 | 63.02 | 69.79 | 75.79 | 80.89 | 84.74 | 88.01 | 90.19 | 92.14 | 93.61 |

|             | F13   | F14   | F15   | F16   | F17   | F18   | F19   | F20   | F21   | F22    | F23    |
|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|
| Eigenvalue  | 0.25  | 0.22  | 0.19  | 0.17  | 0.16  | 0.15  | 0.11  | 0.10  | 0.07  | 0.06   | 0.00   |
| Variability | 1.10  | 0.94  | 0.82  | 0.74  | 0.68  | 0.64  | 0.48  | 0.42  | 0.29  | 0.27   | 0.00   |
| Cumulative  | 94.71 | 95.65 | 96.47 | 97.21 | 97.89 | 98.53 | 99.01 | 99.43 | 99.73 | 100.00 | 100.00 |

Factor loadings:

|                                | F1     | F2     | F3     | F4     | F5     |
|--------------------------------|--------|--------|--------|--------|--------|
| SiO <sub>2</sub>               | -0.549 | -0.458 | 0.522  | 0.014  | 0.102  |
| Al <sub>2</sub> O <sub>3</sub> | 0.774  | -0.458 | 0.053  | -0.076 | -0.065 |
| Fe <sub>2</sub> O <sub>3</sub> | 0.027  | -0.437 | -0.554 | -0.077 | 0.043  |
| MgO                            | 0.398  | 0.744  | -0.047 | -0.207 | -0.187 |
| CaO                            | 0.087  | 0.636  | -0.527 | 0.135  | -0.097 |
| Na <sub>2</sub> O              | 0.106  | 0.458  | 0.655  | 0.005  | 0.185  |
| K <sub>2</sub> O               | 0.508  | 0.310  | 0.468  | -0.518 | 0.057  |
| TiO <sub>2</sub>               | 0.758  | 0.171  | 0.199  | 0.396  | -0.130 |
| MnO                            | 0.469  | 0.185  | -0.506 | -0.453 | 0.097  |
| V                              | 0.542  | 0.078  | -0.056 | 0.090  | -0.506 |
| Co                             | 0.496  | 0.288  | -0.114 | 0.232  | -0.087 |
| Ni                             | 0.148  | 0.193  | 0.135  | 0.737  | 0.207  |
| Zn                             | -0.156 | -0.166 | -0.320 | -0.163 | 0.286  |
| Rb                             | 0.446  | -0.363 | 0.274  | -0.424 | -0.394 |
| Sr                             | 0.509  | 0.714  | -0.084 | -0.066 | 0.188  |
| Y                              | 0.633  | -0.160 | -0.145 | 0.493  | 0.158  |
| Zr                             | 0.650  | -0.565 | 0.145  | -0.044 | 0.215  |
| Ba                             | 0.643  | 0.389  | 0.366  | -0.157 | 0.181  |
| La                             | 0.828  | -0.355 | -0.192 | 0.116  | 0.076  |
| Ce                             | 0.818  | -0.256 | -0.298 | -0.115 | 0.095  |
| Pb                             | 0.452  | -0.114 | 0.158  | 0.028  | 0.615  |
| Th                             | 0.754  | -0.389 | 0.122  | -0.015 | -0.070 |
| U                              | 0.199  | -0.176 | 0.219  | 0.263  | -0.594 |

Correlations between variables and factors:

|                                | F1     | F2     | F3     | F4     | F5     |
|--------------------------------|--------|--------|--------|--------|--------|
| SiO <sub>2</sub>               | -0.549 | -0.458 | 0.522  | 0.014  | 0.102  |
| Al <sub>2</sub> O <sub>3</sub> | 0.774  | -0.458 | 0.053  | -0.076 | -0.065 |
| Fe <sub>2</sub> O <sub>3</sub> | 0.027  | -0.437 | -0.554 | -0.077 | 0.043  |
| MgO                            | 0.398  | 0.744  | -0.047 | -0.207 | -0.187 |
| CaO                            | 0.087  | 0.636  | -0.527 | 0.135  | -0.097 |
| Na <sub>2</sub> O              | 0.106  | 0.458  | 0.655  | 0.005  | 0.185  |
| K <sub>2</sub> O               | 0.508  | 0.310  | 0.468  | -0.518 | 0.057  |
| TiO <sub>2</sub>               | 0.758  | 0.171  | 0.199  | 0.396  | -0.130 |
| MnO                            | 0.469  | 0.185  | -0.506 | -0.453 | 0.097  |
| V                              | 0.542  | 0.078  | -0.056 | 0.090  | -0.506 |

|    |        |        |        |        |        |
|----|--------|--------|--------|--------|--------|
| Co | 0.496  | 0.288  | -0.114 | 0.232  | -0.087 |
| Ni | 0.148  | 0.193  | 0.135  | 0.737  | 0.207  |
| Zn | -0.156 | -0.166 | -0.320 | -0.163 | 0.286  |
| Rb | 0.446  | -0.363 | 0.274  | -0.424 | -0.394 |
| Sr | 0.509  | 0.714  | -0.084 | -0.066 | 0.188  |
| Y  | 0.633  | -0.160 | -0.145 | 0.493  | 0.158  |
| Zr | 0.650  | -0.565 | 0.145  | -0.044 | 0.215  |
| Ba | 0.643  | 0.389  | 0.366  | -0.157 | 0.181  |
| La | 0.828  | -0.355 | -0.192 | 0.116  | 0.076  |
| Ce | 0.818  | -0.256 | -0.298 | -0.115 | 0.095  |
| Pb | 0.452  | -0.114 | 0.158  | 0.028  | 0.615  |
| Th | 0.754  | -0.389 | 0.122  | -0.015 | -0.070 |
| U  | 0.199  | -0.176 | 0.219  | 0.263  | -0.594 |

Contribution of the variables (%):

|                                | F1     | F2     | F3     | F4     | F5     |
|--------------------------------|--------|--------|--------|--------|--------|
| SiO <sub>2</sub>               | 4.578  | 5.808  | 11.302 | 0.011  | 0.667  |
| Al <sub>2</sub> O <sub>3</sub> | 9.109  | 5.794  | 0.114  | 0.306  | 0.273  |
| Fe <sub>2</sub> O <sub>3</sub> | 0.011  | 5.276  | 12.708 | 0.316  | 0.121  |
| MgO                            | 2.414  | 15.303 | 0.093  | 2.265  | 2.244  |
| CaO                            | 0.116  | 11.191 | 11.496 | 0.967  | 0.609  |
| Na <sub>2</sub> O              | 0.172  | 5.791  | 17.778 | 0.001  | 2.206  |
| K <sub>2</sub> O               | 3.920  | 2.658  | 9.059  | 14.226 | 0.207  |
| TiO <sub>2</sub>               | 8.727  | 0.813  | 1.636  | 8.329  | 1.078  |
| MnO                            | 3.340  | 0.948  | 10.601 | 10.889 | 0.601  |
| V                              | 4.473  | 0.169  | 0.131  | 0.426  | 16.431 |
| Co                             | 3.736  | 2.297  | 0.536  | 2.863  | 0.482  |
| Ni                             | 0.333  | 1.035  | 0.755  | 28.820 | 2.739  |
| Zn                             | 0.371  | 0.765  | 4.244  | 1.406  | 5.262  |
| Rb                             | 3.027  | 3.645  | 3.110  | 9.520  | 9.964  |
| Sr                             | 3.938  | 14.097 | 0.292  | 0.230  | 2.272  |
| Y                              | 6.084  | 0.704  | 0.872  | 12.869 | 1.611  |
| Zr                             | 6.420  | 8.828  | 0.872  | 0.104  | 2.954  |
| Ba                             | 6.287  | 4.178  | 5.558  | 1.315  | 2.103  |
| La                             | 10.427 | 3.490  | 1.531  | 0.719  | 0.373  |
| Ce                             | 10.181 | 1.815  | 3.666  | 0.703  | 0.581  |
| Pb                             | 3.100  | 0.359  | 1.033  | 0.043  | 24.284 |
| Th                             | 8.633  | 4.185  | 0.620  | 0.011  | 0.311  |
| U                              | 0.602  | 0.852  | 1.992  | 3.662  | 22.628 |

Squared cosines of the variables:

|                                | F1           | F2           | F3           | F4           | F5    |
|--------------------------------|--------------|--------------|--------------|--------------|-------|
| SiO <sub>2</sub>               | <b>0.301</b> | 0.210        | 0.273        | 0.000        | 0.010 |
| Al <sub>2</sub> O <sub>3</sub> | <b>0.599</b> | 0.210        | 0.003        | 0.006        | 0.004 |
| Fe <sub>2</sub> O <sub>3</sub> | 0.001        | 0.191        | <b>0.307</b> | 0.006        | 0.002 |
| MgO                            | 0.159        | <b>0.553</b> | 0.002        | 0.043        | 0.035 |
| CaO                            | 0.008        | <b>0.405</b> | 0.278        | 0.018        | 0.009 |
| Na <sub>2</sub> O              | 0.011        | 0.209        | <b>0.429</b> | 0.000        | 0.034 |
| K <sub>2</sub> O               | 0.258        | 0.096        | 0.219        | <b>0.268</b> | 0.003 |
| TiO <sub>2</sub>               | <b>0.574</b> | 0.029        | 0.040        | 0.157        | 0.017 |
| MnO                            | 0.220        | 0.034        | <b>0.256</b> | 0.205        | 0.009 |
| V                              | <b>0.294</b> | 0.006        | 0.003        | 0.008        | 0.256 |
| Co                             | <b>0.246</b> | 0.083        | 0.013        | 0.054        | 0.008 |
| Ni                             | 0.022        | 0.037        | 0.018        | <b>0.544</b> | 0.043 |
| Zn                             | 0.024        | 0.028        | <b>0.102</b> | 0.027        | 0.082 |
| Rb                             | <b>0.199</b> | 0.132        | 0.075        | 0.180        | 0.155 |

|    |              |              |       |       |              |
|----|--------------|--------------|-------|-------|--------------|
| Sr | 0.259        | <b>0.510</b> | 0.007 | 0.004 | 0.035        |
| Y  | <b>0.400</b> | 0.025        | 0.021 | 0.243 | 0.025        |
| Zr | <b>0.422</b> | 0.319        | 0.021 | 0.002 | 0.046        |
| Ba | <b>0.414</b> | 0.151        | 0.134 | 0.025 | 0.033        |
| La | <b>0.686</b> | 0.126        | 0.037 | 0.014 | 0.006        |
| Ce | <b>0.670</b> | 0.066        | 0.089 | 0.013 | 0.009        |
| Pb | 0.204        | 0.013        | 0.025 | 0.001 | <b>0.378</b> |
| Th | <b>0.568</b> | 0.151        | 0.015 | 0.000 | 0.005        |
| U  | 0.040        | 0.031        | 0.048 | 0.069 | <b>0.353</b> |

*Values in bold correspond for each variable to the factor for which the squared cosine is the largest*

Factor scores:

|  | F1     | F2     | F3     | F4     | F5     |
|-----------------------------------------------------------------------------------|--------|--------|--------|--------|--------|
| ORD 16                                                                            | -0.988 | -1.604 | 1.475  | -0.072 | -0.766 |
| ORD 18                                                                            | -2.997 | -0.950 | 1.819  | -0.255 | 0.042  |
| ORD 19                                                                            | 1.799  | -0.942 | 0.676  | -0.655 | -0.012 |
| ORD 20                                                                            | -0.760 | 0.214  | 0.732  | -0.441 | 0.136  |
| ORD 21                                                                            | 1.573  | -0.935 | 1.729  | -0.714 | -0.177 |
| ORD 22                                                                            | -5.729 | -1.690 | 0.154  | -0.650 | 0.684  |
| ORD 23                                                                            | -0.569 | -1.535 | 0.261  | 0.071  | -0.656 |
| ORD 24                                                                            | 2.235  | -2.547 | -0.404 | -0.214 | -0.631 |
| ORD 25                                                                            | -0.151 | -2.209 | -0.028 | -0.420 | -0.561 |
| ORD 26                                                                            | 0.519  | -0.240 | 1.145  | -0.097 | -0.672 |
| ORD 27                                                                            | -0.242 | -2.076 | 2.700  | -0.318 | -0.563 |
| ORD 28                                                                            | 2.378  | -1.918 | 1.313  | -1.025 | 0.812  |
| ORD 29                                                                            | -4.174 | -2.207 | 1.287  | 0.996  | -2.097 |
| ORD 30                                                                            | -4.185 | -2.589 | 1.123  | 0.971  | -1.668 |
| ORD 31                                                                            | 1.494  | -1.737 | 1.523  | -0.765 | 1.370  |
| ORD 32                                                                            | -0.070 | -3.821 | -0.852 | 1.073  | 0.891  |
| ORD 33                                                                            | -1.251 | -0.361 | 1.299  | -0.113 | -0.128 |
| ORD 34                                                                            | 0.761  | -1.037 | 1.521  | -1.803 | 2.246  |
| ORD 35                                                                            | 0.203  | 0.781  | 2.043  | 3.729  | 1.085  |
| ORD 36                                                                            | 0.354  | 0.332  | 1.836  | 3.859  | 0.675  |
| GOLD 22                                                                           | -0.604 | -2.425 | -0.743 | 0.168  | -0.464 |
| GOLD 23                                                                           | 3.820  | -0.609 | 0.290  | 0.086  | -0.230 |
| GOLD 24                                                                           | 0.507  | 0.612  | 1.057  | -0.498 | 0.368  |
| GOLD 26                                                                           | -0.284 | -3.860 | -1.405 | 3.885  | 1.860  |
| GOLD 27                                                                           | -4.038 | 0.509  | 1.384  | -1.405 | 0.219  |
| GOLD 28                                                                           | -1.159 | -3.142 | -1.974 | 3.530  | 1.471  |
| GOLD 29                                                                           | 0.353  | -1.121 | 0.702  | -0.508 | 0.821  |
| GOLD 30                                                                           | 5.264  | -1.348 | 0.452  | -1.042 | 1.755  |
| GOLD 31                                                                           | 4.581  | -0.189 | 0.348  | -1.131 | 0.311  |
| GOLD 33                                                                           | 1.455  | -0.237 | 0.686  | -0.491 | 1.585  |
| GOLD 34                                                                           | 0.993  | -0.030 | 1.143  | -1.046 | 0.812  |
| GOLD 36                                                                           | 1.231  | -1.893 | 0.472  | 0.363  | -0.085 |
| GOLD 37                                                                           | 0.912  | -1.194 | 0.299  | -0.360 | 0.966  |
| GOLD 38                                                                           | 1.057  | -3.079 | 0.187  | 0.297  | 1.307  |
| FARA 1                                                                            | -6.210 | -0.733 | -4.206 | -2.765 | 0.504  |
| FARA 2                                                                            | -3.047 | -1.601 | -3.897 | -1.602 | 0.834  |
| FARA 3                                                                            | -1.318 | -0.324 | 0.509  | -0.027 | -0.895 |
| FARA 4                                                                            | -2.224 | -0.678 | -3.846 | -0.305 | -0.270 |
| FARA 5                                                                            | -2.270 | -1.158 | -2.096 | -1.081 | 0.830  |
| FARA 6                                                                            | -2.824 | -0.913 | -2.288 | -0.921 | 0.961  |
| FARA 7                                                                            | -1.884 | -2.411 | -2.952 | -0.445 | -0.527 |
| FARA 8                                                                            | -1.151 | -0.933 | -1.463 | -1.399 | 2.650  |
| FARA 9                                                                            | -2.752 | -1.197 | -1.858 | -0.705 | 0.601  |
| FARA 10                                                                           | -1.402 | -1.248 | -1.474 | -1.116 | 0.465  |
| FARA 11                                                                           | -1.373 | -0.858 | -2.476 | 0.102  | -1.035 |
| FARA 12                                                                           | -4.287 | -1.702 | -0.502 | -0.486 | 0.329  |

|         |        |        |        |        |        |
|---------|--------|--------|--------|--------|--------|
| FARA 13 | -1.820 | -3.363 | -2.088 | -1.028 | 0.143  |
| FARA 14 | -4.075 | -0.818 | 0.478  | -0.576 | -0.115 |
| FARA 15 | -3.018 | -2.584 | -2.911 | -1.672 | 2.890  |
| FARA 16 | -1.583 | -1.368 | -1.367 | -1.097 | -0.141 |
| POS 01  | -1.179 | -0.741 | 1.650  | -0.199 | 0.150  |
| POS 02  | -2.384 | 3.117  | 0.415  | -1.060 | 1.808  |
| POS 03  | -3.010 | -0.702 | 0.700  | 1.281  | 1.431  |
| POS 04  | -1.159 | 1.627  | -0.836 | 0.401  | 0.269  |
| POS 05  | -1.479 | 0.408  | -0.557 | -0.120 | 1.435  |
| POS 07  | -3.171 | 0.439  | 0.148  | 0.334  | 0.189  |
| POS 08  | -0.957 | 0.069  | 2.204  | -0.852 | 0.848  |
| POS 09  | 0.053  | -0.079 | -0.602 | 0.476  | -1.436 |
| POS 11  | 1.199  | 0.388  | -1.588 | -0.052 | 0.124  |
| POS 13  | 4.637  | -2.412 | -1.573 | -0.049 | 1.818  |
| POS 14  | 0.999  | 1.295  | 0.435  | -1.238 | 2.209  |
| POS 15  | 0.647  | 1.750  | 0.640  | 4.679  | 1.088  |
| POS 17  | 0.621  | 1.226  | 1.241  | 0.847  | 1.223  |
| POS 18  | 5.824  | -1.218 | -2.679 | 0.441  | 2.449  |
| POS 19  | -0.902 | 0.629  | 2.513  | -0.710 | 1.433  |
| POS 20  | -0.965 | 0.215  | 0.247  | -0.364 | 0.474  |
| POS 22  | -1.783 | 0.459  | -0.792 | 0.767  | -0.337 |
| POS 42  | -2.914 | -0.755 | 0.969  | 1.411  | -2.901 |
| POS 43  | -3.467 | -1.148 | 1.309  | 2.272  | -1.990 |
| POS 44  | -0.475 | -0.825 | 1.778  | 0.116  | -3.445 |
| POS 45  | 5.113  | -2.313 | -0.878 | 0.486  | -1.787 |
| POS 46  | 1.563  | 0.663  | 0.122  | 0.419  | -2.195 |
| POS 47  | 0.056  | -0.733 | 1.551  | -0.257 | -2.990 |
| POS 48  | -2.406 | -0.317 | 1.839  | -0.477 | -0.846 |
| SG 6    | 5.657  | -1.181 | -0.239 | -0.898 | -1.049 |
| SG 7    | 0.175  | 2.899  | -1.318 | -0.168 | -1.084 |
| SG 8    | 5.904  | -0.737 | 0.162  | -1.029 | -1.322 |
| SG 9    | 5.295  | -0.670 | 0.124  | -0.718 | -0.612 |
| SG 10   | 5.481  | -0.885 | -0.476 | -0.694 | -0.888 |
| SG 12   | 0.498  | 2.870  | -0.987 | -0.017 | -1.576 |
| SG 13   | 2.690  | -0.259 | 1.230  | 4.657  | -0.193 |
| SG 14   | -2.925 | -1.014 | 0.586  | -0.261 | -1.018 |
| SG 21   | 0.779  | 3.458  | -0.208 | -0.622 | 0.528  |
| SG 22   | -0.436 | 3.432  | 0.087  | -1.180 | -0.714 |
| SG 23   | 0.491  | 2.490  | -0.855 | 0.013  | -0.471 |
| SG 24   | -0.160 | 2.818  | -0.755 | -0.387 | -1.109 |
| SG 25   | 0.154  | 2.641  | -0.648 | -0.154 | -0.653 |
| SG 26   | -0.325 | 3.581  | -0.617 | -0.710 | -0.606 |
| SG 27   | 0.256  | 2.590  | -0.466 | -0.232 | -0.401 |
| SG 28   | -0.178 | 2.909  | -0.500 | -0.476 | -0.044 |
| SG 29   | -0.521 | 2.923  | -0.437 | -0.183 | -0.409 |
| SG 30   | -0.652 | 3.075  | -0.690 | 0.109  | 0.436  |
| SG 31   | -0.613 | 3.284  | -0.815 | -0.006 | -0.662 |
| SG 32   | -0.117 | 2.799  | -0.447 | -0.355 | -0.316 |
| SG 33   | 5.483  | -0.949 | -0.093 | -0.333 | -0.246 |
| SG 34   | 0.000  | 3.635  | -0.561 | -0.718 | -0.444 |
| SG 35   | 0.567  | 2.460  | -0.846 | 0.046  | -0.359 |
| SG 36   | 0.189  | 2.581  | -0.987 | -0.344 | 0.317  |
| SG 37   | 0.539  | 3.559  | 0.057  | -1.397 | -0.423 |
| SG 38   | 5.265  | -0.699 | -0.139 | -0.160 | 0.180  |
| SG 39   | 0.551  | 4.075  | -0.170 | -1.082 | 0.598  |
| SG 40   | 4.381  | -0.341 | -0.725 | -0.691 | 0.675  |
| SG 41   | -0.093 | 3.118  | -0.620 | -0.502 | -0.642 |
| SG 42   | 4.897  | -0.742 | -0.381 | -0.447 | -0.553 |
| SG 43   | 0.551  | 2.774  | -0.903 | -0.168 | -0.201 |
| SG 44   | 1.743  | 0.428  | 1.541  | 3.859  | 1.011  |
| SG 45   | -0.363 | 3.483  | -0.374 | -0.912 | -0.073 |

|        |        |        |        |        |        |
|--------|--------|--------|--------|--------|--------|
| SG 46  | 0.039  | 3.147  | -0.568 | -0.280 | -0.494 |
| SG 47  | -0.086 | 2.868  | -0.405 | -0.572 | -0.696 |
| SG 48  | 4.231  | 0.084  | -0.452 | -0.275 | -0.109 |
| SG 49  | 4.669  | -0.103 | 0.284  | -0.648 | 0.412  |
| SG 50  | 4.201  | 0.166  | 0.148  | -0.422 | 0.302  |
| SG 64  | -2.839 | 0.155  | 0.889  | 0.725  | 0.314  |
| SG 65  | -1.875 | 2.804  | -0.333 | -0.117 | 0.270  |
| SG 66  | -2.002 | 0.251  | 1.239  | 0.182  | -0.342 |
| SG 67  | -0.391 | -0.451 | 2.023  | -0.424 | 0.873  |
| SG 68  | -5.079 | 1.478  | 0.241  | -0.463 | 0.910  |
| SG 69  | 0.202  | 0.319  | 2.064  | 0.141  | 0.584  |
| SG 70  | -1.364 | -0.636 | 1.730  | -0.283 | -1.459 |
| SG 71  | 0.196  | -0.380 | 0.273  | -0.178 | 0.667  |
| SG 72  | -0.152 | 4.897  | -0.033 | 2.870  | 0.628  |
| SG 73  | 4.668  | -1.806 | 0.110  | -0.880 | 1.746  |
| SG 74  | -1.825 | 1.456  | 3.765  | 1.849  | 3.591  |
| SG 75  | 0.694  | 2.357  | 2.047  | 3.807  | 0.493  |
| SG 76  | -0.830 | -0.595 | 1.739  | -0.613 | 0.499  |
| SG 77  | 2.641  | 1.359  | 0.323  | -0.224 | -0.583 |
| SG 78  | -3.239 | -1.544 | -0.170 | 0.147  | -0.134 |
| SG 79  | -1.139 | -0.396 | 1.875  | -0.867 | 1.770  |
| SG 80  | -1.241 | -1.917 | 2.960  | 0.095  | -1.694 |
| SPV 6  | 3.860  | -1.599 | -0.529 | -1.215 | -1.433 |
| SPV 7  | 2.057  | 1.719  | -7.805 | 4.403  | -1.664 |
| SPV 8  | -2.097 | -0.814 | 1.403  | -0.809 | -1.474 |
| SPV 9  | -2.301 | -1.672 | -3.758 | 4.944  | 0.605  |
| SPV 10 | -2.018 | -0.402 | 1.279  | -0.840 | 0.200  |
| SPV 11 | -0.793 | -0.245 | 1.166  | -0.750 | 0.284  |
| SPV 12 | 0.832  | -0.494 | 0.339  | -1.526 | -1.982 |
| SPV 14 | -2.325 | -1.106 | -0.088 | -0.287 | -1.411 |
| SPV 22 | 0.629  | -3.385 | -0.352 | 0.235  | -5.305 |

## Supplementary Material no. 3

### Principal Component Analysis

Eigenvalues:

|             | F1    | F2    | F3    | F4    | F5    | F6    | F7    | F8    | F9    | F10   | F11   | F12   |
|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Eigenvalue  | 7.75  | 3.37  | 3.03  | 1.87  | 1.17  | 0.90  | 0.86  | 0.66  | 0.57  | 0.52  | 0.42  | 0.39  |
| Variability | 33.70 | 14.66 | 13.16 | 8.13  | 5.10  | 3.92  | 3.73  | 2.86  | 2.49  | 2.26  | 1.83  | 1.69  |
| Cumulative  | 33.70 | 48.36 | 61.51 | 69.64 | 74.74 | 78.66 | 82.39 | 85.25 | 87.74 | 90.00 | 91.84 | 93.53 |

|             | F13   | F14   | F15   | F16   | F17   | F18   | F19   | F20   | F21   | F22    | F23    |
|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|
| Eigenvalue  | 0.32  | 0.25  | 0.21  | 0.19  | 0.15  | 0.13  | 0.10  | 0.06  | 0.04  | 0.04   | 0.00   |
| Variability | 1.41  | 1.08  | 0.93  | 0.83  | 0.65  | 0.55  | 0.43  | 0.26  | 0.18  | 0.16   | 0.00   |
| Cumulative  | 94.94 | 96.01 | 96.94 | 97.77 | 98.42 | 98.97 | 99.40 | 99.66 | 99.84 | 100.00 | 100.00 |

Factor loadings:

|                                | F1     | F2     | F3     | F4     | F5     |
|--------------------------------|--------|--------|--------|--------|--------|
| SiO <sub>2</sub>               | -0.650 | -0.198 | -0.507 | 0.312  | 0.081  |
| Al <sub>2</sub> O <sub>3</sub> | -0.776 | 0.435  | 0.230  | 0.052  | 0.196  |
| Fe <sub>2</sub> O <sub>3</sub> | -0.624 | -0.058 | 0.506  | 0.346  | -0.208 |
| MgO                            | 0.079  | 0.510  | 0.542  | -0.341 | 0.167  |
| CaO                            | 0.897  | -0.032 | 0.085  | -0.311 | -0.127 |
| Na <sub>2</sub> O              | 0.034  | -0.526 | 0.258  | 0.562  | 0.097  |
| K <sub>2</sub> O               | -0.591 | 0.177  | 0.118  | -0.006 | 0.509  |
| TiO <sub>2</sub>               | -0.645 | 0.679  | 0.059  | 0.035  | 0.104  |
| MnO                            | 0.426  | -0.331 | 0.600  | 0.221  | -0.012 |
| V                              | -0.680 | 0.366  | 0.255  | -0.042 | 0.105  |
| Co                             | -0.724 | -0.407 | 0.220  | -0.273 | -0.160 |
| Ni                             | -0.407 | 0.211  | 0.679  | 0.153  | -0.138 |
| Zn                             | -0.543 | 0.196  | 0.360  | 0.249  | -0.391 |
| Rb                             | -0.512 | -0.563 | 0.245  | -0.266 | 0.269  |
| Sr                             | 0.507  | -0.031 | 0.613  | -0.321 | 0.160  |
| Y                              | -0.426 | 0.666  | -0.172 | -0.006 | 0.042  |
| Zr                             | -0.636 | -0.144 | -0.424 | 0.354  | 0.028  |
| Ba                             | 0.519  | -0.114 | 0.312  | 0.057  | 0.301  |
| La                             | -0.792 | -0.460 | 0.082  | -0.301 | -0.035 |
| Ce                             | -0.673 | -0.595 | 0.193  | -0.103 | -0.040 |
| Pb                             | 0.225  | -0.101 | -0.213 | 0.210  | 0.544  |
| Th                             | -0.680 | -0.465 | -0.124 | -0.438 | 0.138  |
| U                              | -0.404 | 0.171  | -0.403 | -0.518 | -0.210 |

Correlations between variables and factors:

|                                | F1     | F2     | F3     | F4     | F5     |
|--------------------------------|--------|--------|--------|--------|--------|
| SiO <sub>2</sub>               | -0.650 | -0.198 | -0.507 | 0.312  | 0.081  |
| Al <sub>2</sub> O <sub>3</sub> | -0.776 | 0.435  | 0.230  | 0.052  | 0.196  |
| Fe <sub>2</sub> O <sub>3</sub> | -0.624 | -0.058 | 0.506  | 0.346  | -0.208 |
| MgO                            | 0.079  | 0.510  | 0.542  | -0.341 | 0.167  |
| CaO                            | 0.897  | -0.032 | 0.085  | -0.311 | -0.127 |
| Na <sub>2</sub> O              | 0.034  | -0.526 | 0.258  | 0.562  | 0.097  |
| K <sub>2</sub> O               | -0.591 | 0.177  | 0.118  | -0.006 | 0.509  |
| TiO <sub>2</sub>               | -0.645 | 0.679  | 0.059  | 0.035  | 0.104  |
| MnO                            | 0.426  | -0.331 | 0.600  | 0.221  | -0.012 |
| V                              | -0.680 | 0.366  | 0.255  | -0.042 | 0.105  |
| Co                             | -0.724 | -0.407 | 0.220  | -0.273 | -0.160 |
| Ni                             | -0.407 | 0.211  | 0.679  | 0.153  | -0.138 |

|    |        |        |        |        |        |
|----|--------|--------|--------|--------|--------|
| Zn | -0.543 | 0.196  | 0.360  | 0.249  | -0.391 |
| Rb | -0.512 | -0.563 | 0.245  | -0.266 | 0.269  |
| Sr | 0.507  | -0.031 | 0.613  | -0.321 | 0.160  |
| Y  | -0.426 | 0.666  | -0.172 | -0.006 | 0.042  |
| Zr | -0.636 | -0.144 | -0.424 | 0.354  | 0.028  |
| Ba | 0.519  | -0.114 | 0.312  | 0.057  | 0.301  |
| La | -0.792 | -0.460 | 0.082  | -0.301 | -0.035 |
| Ce | -0.673 | -0.595 | 0.193  | -0.103 | -0.040 |
| Pb | 0.225  | -0.101 | -0.213 | 0.210  | 0.544  |
| Th | -0.680 | -0.465 | -0.124 | -0.438 | 0.138  |
| U  | -0.404 | 0.171  | -0.403 | -0.518 | -0.210 |

Contribution of the variables (%):

|                                | F1     | F2     | F3     | F4     | F5     |
|--------------------------------|--------|--------|--------|--------|--------|
| SiO <sub>2</sub>               | 5.445  | 1.157  | 8.499  | 5.207  | 0.556  |
| Al <sub>2</sub> O <sub>3</sub> | 7.768  | 5.618  | 1.747  | 0.147  | 3.262  |
| Fe <sub>2</sub> O <sub>3</sub> | 5.024  | 0.100  | 8.476  | 6.421  | 3.683  |
| MgO                            | 0.080  | 7.701  | 9.716  | 6.219  | 2.389  |
| CaO                            | 10.379 | 0.030  | 0.236  | 5.177  | 1.370  |
| Na <sub>2</sub> O              | 0.015  | 8.221  | 2.197  | 16.891 | 0.809  |
| K <sub>2</sub> O               | 4.511  | 0.931  | 0.462  | 0.002  | 22.081 |
| TiO <sub>2</sub>               | 5.372  | 13.687 | 0.115  | 0.066  | 0.918  |
| MnO                            | 2.338  | 3.254  | 11.914 | 2.611  | 0.012  |
| V                              | 5.960  | 3.974  | 2.157  | 0.094  | 0.938  |
| Co                             | 6.759  | 4.916  | 1.604  | 3.990  | 2.186  |
| Ni                             | 2.137  | 1.324  | 15.223 | 1.249  | 1.624  |
| Zn                             | 3.805  | 1.134  | 4.287  | 3.310  | 13.017 |
| Rb                             | 3.378  | 9.416  | 1.984  | 3.793  | 6.186  |
| Sr                             | 3.322  | 0.029  | 12.416 | 5.525  | 2.174  |
| Y                              | 2.344  | 13.151 | 0.975  | 0.002  | 0.154  |
| Zr                             | 5.222  | 0.613  | 5.930  | 6.720  | 0.067  |
| Ba                             | 3.476  | 0.386  | 3.226  | 0.174  | 7.738  |
| La                             | 8.087  | 6.265  | 0.224  | 4.845  | 0.104  |
| Ce                             | 5.852  | 10.510 | 1.229  | 0.570  | 0.139  |
| Pb                             | 0.655  | 0.302  | 1.498  | 2.356  | 25.198 |
| Th                             | 5.963  | 6.414  | 0.511  | 10.269 | 1.633  |
| U                              | 2.105  | 0.866  | 5.371  | 14.362 | 3.759  |

Squared cosines of the variables:

|                                | F1           | F2           | F3           | F4           | F5    |
|--------------------------------|--------------|--------------|--------------|--------------|-------|
| SiO <sub>2</sub>               | <b>0.422</b> | 0.039        | 0.257        | 0.097        | 0.007 |
| Al <sub>2</sub> O <sub>3</sub> | <b>0.602</b> | 0.189        | 0.053        | 0.003        | 0.038 |
| Fe <sub>2</sub> O <sub>3</sub> | <b>0.389</b> | 0.003        | 0.256        | 0.120        | 0.043 |
| MgO                            | 0.006        | 0.260        | <b>0.294</b> | 0.116        | 0.028 |
| CaO                            | <b>0.804</b> | 0.001        | 0.007        | 0.097        | 0.016 |
| Na <sub>2</sub> O              | 0.001        | 0.277        | 0.066        | <b>0.316</b> | 0.009 |
| K <sub>2</sub> O               | <b>0.350</b> | 0.031        | 0.014        | 0.000        | 0.259 |
| TiO <sub>2</sub>               | 0.416        | <b>0.461</b> | 0.003        | 0.001        | 0.011 |
| MnO                            | 0.181        | 0.110        | <b>0.361</b> | 0.049        | 0.000 |
| V                              | <b>0.462</b> | 0.134        | 0.065        | 0.002        | 0.011 |
| Co                             | <b>0.524</b> | 0.166        | 0.049        | 0.075        | 0.026 |
| Ni                             | 0.166        | 0.045        | <b>0.461</b> | 0.023        | 0.019 |
| Zn                             | <b>0.295</b> | 0.038        | 0.130        | 0.062        | 0.153 |
| Rb                             | 0.262        | <b>0.317</b> | 0.060        | 0.071        | 0.073 |
| Sr                             | 0.257        | 0.001        | <b>0.376</b> | 0.103        | 0.026 |
| Y                              | 0.182        | <b>0.443</b> | 0.030        | 0.000        | 0.002 |
| Zr                             | <b>0.405</b> | 0.021        | 0.179        | 0.126        | 0.001 |
| Ba                             | <b>0.269</b> | 0.013        | 0.098        | 0.003        | 0.091 |

|    |              |       |       |              |              |
|----|--------------|-------|-------|--------------|--------------|
| La | <b>0.627</b> | 0.211 | 0.007 | 0.091        | 0.001        |
| Ce | <b>0.454</b> | 0.354 | 0.037 | 0.011        | 0.002        |
| Pb | 0.051        | 0.010 | 0.045 | 0.044        | <b>0.296</b> |
| Th | <b>0.462</b> | 0.216 | 0.015 | 0.192        | 0.019        |
| U  | 0.163        | 0.029 | 0.163 | <b>0.268</b> | 0.044        |

*Values in bold correspond for each variable to the factor for which the squared cosine is the largest*

Factor scores:

|  | F1     | F2     | F3     | F4     | F5     |
|-----------------------------------------------------------------------------------|--------|--------|--------|--------|--------|
| ORD 01                                                                            | -0.803 | -0.323 | -0.328 | -2.279 | -0.751 |
| ORD 02                                                                            | -1.678 | 0.990  | -1.039 | -0.223 | 0.402  |
| ORD 03                                                                            | -1.852 | 0.392  | -0.906 | -0.345 | -0.213 |
| ORD 04                                                                            | 1.880  | 0.066  | -1.350 | -0.029 | -1.323 |
| ORD 05                                                                            | -1.421 | 3.078  | 2.954  | -1.504 | 1.284  |
| ORD 06                                                                            | -1.952 | 0.745  | 1.982  | -1.693 | -0.524 |
| ORD 07                                                                            | -1.754 | -0.373 | -4.671 | 2.642  | 1.716  |
| ORD 08                                                                            | -1.271 | 1.553  | -1.052 | 0.867  | -0.015 |
| ORD 09                                                                            | 0.286  | -2.915 | -2.648 | -0.937 | -0.249 |
| ORD 10                                                                            | -0.707 | -1.067 | -0.893 | 0.585  | 2.605  |
| ORD 11                                                                            | -1.791 | 1.548  | 0.051  | -1.693 | 0.510  |
| ORD 12                                                                            | -1.302 | 0.784  | -0.103 | -0.259 | -0.729 |
| ORD 13                                                                            | 0.245  | -0.649 | -2.213 | -0.752 | -1.332 |
| ORD 14                                                                            | -5.044 | 0.779  | 0.921  | -1.466 | 0.434  |
| ORD 15                                                                            | -0.019 | -3.106 | -4.041 | -0.408 | 1.175  |
| GOLD 01                                                                           | -0.587 | 2.855  | 0.696  | 0.260  | 1.291  |
| GOLD 02                                                                           | 0.003  | 2.581  | -1.831 | -1.898 | -1.129 |
| GOLD 03                                                                           | -0.658 | 3.657  | -3.308 | 0.131  | -1.079 |
| GOLD 04                                                                           | -1.654 | 2.449  | -3.205 | 0.118  | -1.378 |
| GOLD 05                                                                           | -5.285 | 2.466  | -1.931 | 0.277  | -0.589 |
| GOLD 06                                                                           | -0.100 | 3.090  | -0.603 | 0.987  | 0.473  |
| GOLD 07                                                                           | 0.699  | 2.620  | -1.119 | -0.195 | -0.696 |
| GOLD 08                                                                           | -1.795 | 1.777  | 0.365  | -0.248 | -0.811 |
| GOLD 09                                                                           | -2.823 | 2.083  | -3.011 | -0.670 | -1.369 |
| GOLD 10                                                                           | -0.655 | 3.058  | 0.062  | -0.065 | 0.640  |
| GOLD 11                                                                           | -2.105 | 2.177  | -1.857 | -0.444 | -0.486 |
| GOLD 12                                                                           | -4.287 | -1.372 | 1.484  | -3.768 | 0.251  |
| GOLD 13                                                                           | -1.447 | -2.485 | -1.500 | -1.178 | -0.101 |
| GOLD 14                                                                           | -4.537 | -1.968 | 0.487  | -0.662 | 1.484  |
| GOLD 15                                                                           | -2.748 | -2.749 | -0.908 | -1.229 | 1.060  |
| GOLD 16                                                                           | -3.309 | -0.382 | 0.819  | -2.270 | 1.284  |
| GOLD 17                                                                           | -4.491 | 1.078  | -2.842 | -2.193 | -0.740 |
| GOLD 18                                                                           | -3.883 | 0.059  | -1.186 | 0.333  | 0.865  |
| GOLD 20                                                                           | -1.783 | 1.211  | -1.742 | -3.337 | -1.087 |
| FARA 17                                                                           | -1.902 | -0.829 | 0.882  | 0.899  | -1.336 |
| FARA 18                                                                           | -2.657 | -1.617 | 2.227  | -0.055 | -1.466 |
| FARA 19                                                                           | -0.725 | -0.340 | 0.842  | -0.613 | -1.005 |
| FARA 20                                                                           | -1.816 | -1.897 | 1.189  | 0.395  | -1.655 |
| FARA 21                                                                           | -1.344 | -2.986 | 1.846  | 3.042  | -2.906 |
| FARA 22                                                                           | -2.759 | -2.218 | 0.152  | 1.695  | 0.879  |
| FARA 23                                                                           | -4.146 | -1.277 | 2.464  | 2.881  | -1.815 |
| FARA 24                                                                           | -3.255 | -1.476 | 1.737  | 0.211  | 0.034  |
| FARA 25                                                                           | 0.889  | -1.301 | 0.801  | -0.221 | -1.421 |
| FARA 26                                                                           | -1.202 | -1.665 | 1.525  | 0.059  | -0.977 |
| FARA 27                                                                           | -5.738 | -6.088 | -0.024 | 2.733  | 2.018  |
| FARA 28                                                                           | -2.552 | -2.053 | 1.368  | 1.763  | -0.169 |
| FARA 29                                                                           | -2.164 | -1.087 | 2.190  | 0.438  | -0.994 |
| FARA 30                                                                           | -2.962 | -1.181 | 3.862  | 1.352  | -1.778 |
| POS 21                                                                            | 1.756  | -0.380 | -3.242 | 2.832  | 1.163  |
| POS 23                                                                            | 2.158  | 1.786  | 1.288  | 1.152  | 0.397  |
| POS 24                                                                            | 0.579  | 2.601  | 2.773  | -0.286 | 0.274  |
| POS 25                                                                            | 3.344  | 0.996  | -0.674 | 1.323  | -0.599 |

|        |        |        |        |        |        |
|--------|--------|--------|--------|--------|--------|
| POS 26 | 4.397  | 1.531  | 0.036  | -0.199 | -0.622 |
| POS 27 | 2.930  | 1.457  | 0.720  | 0.418  | 0.786  |
| POS 28 | 4.076  | 0.828  | 0.224  | 0.574  | 0.480  |
| POS 29 | 0.293  | 1.811  | -0.091 | 2.182  | 0.433  |
| POS 30 | 3.753  | 0.424  | -0.003 | 1.506  | -0.024 |
| POS 31 | 2.850  | 2.243  | -0.807 | 0.367  | -0.118 |
| POS 32 | 2.489  | 0.740  | 0.695  | 2.326  | 1.451  |
| POS 33 | 0.382  | 1.490  | 0.919  | 1.254  | -0.616 |
| POS 34 | -0.861 | 1.922  | 2.936  | 1.401  | 0.837  |
| POS 35 | 2.798  | 1.599  | 3.186  | 0.315  | 0.358  |
| POS 36 | 3.287  | 0.148  | -1.979 | 2.079  | 0.174  |
| POS 37 | 3.689  | 0.954  | 0.128  | 1.729  | -1.215 |
| POS 38 | 1.818  | 1.778  | 4.149  | 0.509  | 0.703  |
| POS 39 | 1.404  | 1.460  | 0.519  | 0.923  | -0.198 |
| POS 40 | -1.218 | 2.101  | 0.960  | 1.402  | 0.843  |
| POS 41 | 3.069  | 1.989  | 3.266  | -0.135 | 1.311  |
| SG 62  | 2.040  | -0.741 | 0.755  | 0.021  | -0.173 |
| SG 63  | 0.155  | -0.334 | 0.717  | 0.116  | 0.006  |
| SG 15  | 3.075  | -2.332 | 2.066  | -3.238 | 1.822  |
| SG 16  | 5.199  | -3.822 | 0.023  | -1.497 | -1.262 |
| SG 51  | 7.752  | -1.444 | -0.761 | -1.355 | 0.397  |
| SG 52  | 6.054  | -3.319 | -0.702 | -0.706 | -0.510 |
| SG 53  | 4.561  | -1.336 | -0.434 | -1.075 | -0.995 |
| SG 54  | 7.640  | -1.349 | 0.881  | -1.809 | -0.105 |
| SG 55  | 0.786  | -0.506 | 0.920  | -1.257 | -0.911 |
| SG 56  | 3.221  | -1.720 | 0.150  | -0.206 | -0.039 |
| SG 57  | -1.086 | -0.984 | 0.168  | 0.112  | 1.541  |
| SG 58  | 2.540  | -0.733 | 1.576  | -1.042 | -0.243 |
| SG 59  | -1.549 | -0.074 | 0.211  | 0.284  | -0.273 |
| SG 60  | -0.640 | -0.034 | 2.089  | -1.846 | 2.141  |
| SG 61  | -0.051 | -1.707 | -1.013 | 0.177  | -1.456 |
| SPV 15 | 3.229  | -0.667 | -0.442 | 0.162  | 0.395  |
| SPV 16 | 1.931  | -0.924 | -1.349 | 0.259  | -0.700 |
| SPV 17 | -0.644 | 0.586  | -0.227 | -0.533 | 1.763  |
| SPV 18 | 1.552  | -0.773 | -1.023 | -0.263 | 0.115  |
| SPV 19 | 2.115  | -0.549 | -1.219 | -0.670 | 0.837  |
| SPV 20 | -1.223 | 0.120  | -0.105 | -0.838 | 1.632  |
| SPV 23 | 0.441  | -0.513 | -1.050 | 0.702  | -0.858 |
| SPV 21 | 2.046  | -1.806 | -2.378 | 1.211  | 2.127  |
| SPV 24 | -1.172 | -0.207 | -0.450 | 0.584  | 0.647  |

## Supplementary Material no. 4

### Principal Component Analysis

Eigenvalues:

|                 | F1    | F2    | F3    | F4    | F5    | F6    | F7    | F8    | F9    | F10   | F11   | F12   |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Eigenvalue      | 8.79  | 3.33  | 2.18  | 1.94  | 1.69  | 1.05  | 0.88  | 0.61  | 0.52  | 0.39  | 0.35  | 0.27  |
| Variability (%) | 38.21 | 14.47 | 9.46  | 8.41  | 7.33  | 4.58  | 3.81  | 2.63  | 2.25  | 1.68  | 1.52  | 1.18  |
| Cumulative %    | 38.21 | 52.68 | 62.14 | 70.55 | 77.88 | 82.46 | 86.27 | 88.90 | 91.15 | 92.83 | 94.35 | 95.52 |

|                 | F13   | F14   | F15   | F16   | F17   | F18   | F19   | F20   | F21   | F22    | F23    |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|
| Eigenvalue      | 0.25  | 0.17  | 0.13  | 0.12  | 0.10  | 0.10  | 0.06  | 0.04  | 0.03  | 0.03   | 0.00   |
| Variability (%) | 1.08  | 0.75  | 0.57  | 0.53  | 0.45  | 0.43  | 0.27  | 0.16  | 0.13  | 0.12   | 0.00   |
| Cumulative %    | 96.60 | 97.35 | 97.92 | 98.45 | 98.89 | 99.32 | 99.59 | 99.76 | 99.88 | 100.00 | 100.00 |

Factor loadings:

|                                | F1    | F2    | F3    | F4    | F5    |
|--------------------------------|-------|-------|-------|-------|-------|
| SiO <sub>2</sub>               | -0.71 | -0.33 | 0.19  | -0.02 | -0.38 |
| TiO <sub>2</sub>               | -0.82 | 0.40  | -0.21 | -0.21 | 0.07  |
| Al <sub>2</sub> O <sub>3</sub> | -0.82 | 0.15  | 0.14  | -0.31 | 0.10  |
| FeO                            | -0.93 | 0.08  | -0.16 | -0.16 | 0.10  |
| MnO                            | 0.00  | -0.34 | 0.12  | -0.53 | 0.59  |
| CaO                            | 0.95  | 0.01  | -0.06 | 0.17  | 0.07  |
| MgO                            | 0.14  | 0.66  | 0.23  | -0.20 | 0.43  |
| Na <sub>2</sub> O              | -0.20 | -0.21 | -0.20 | 0.64  | 0.17  |
| K <sub>2</sub> O               | -0.81 | 0.08  | -0.24 | -0.35 | 0.07  |
| V                              | -0.75 | 0.15  | -0.21 | -0.06 | 0.18  |
| Co                             | 0.02  | 0.38  | 0.76  | 0.09  | 0.12  |
| Ni                             | -0.16 | 0.79  | 0.41  | 0.12  | 0.11  |
| Zn                             | -0.17 | 0.80  | -0.21 | 0.09  | -0.06 |
| Rb                             | -0.59 | -0.44 | 0.57  | -0.03 | 0.15  |
| Sr                             | 0.20  | 0.14  | -0.22 | 0.61  | 0.55  |
| Y                              | -0.46 | 0.63  | 0.13  | 0.35  | -0.19 |
| Zr                             | -0.77 | -0.22 | 0.14  | 0.19  | -0.29 |
| Ba                             | -0.58 | -0.17 | -0.45 | 0.07  | 0.44  |
| La                             | -0.89 | -0.09 | 0.05  | 0.07  | 0.04  |
| Pb                             | 0.61  | 0.10  | 0.30  | -0.34 | -0.12 |
| Ce                             | -0.65 | -0.29 | 0.24  | 0.23  | 0.09  |
| Th                             | -0.63 | -0.29 | 0.47  | 0.40  | 0.13  |
| U                              | -0.57 | 0.32  | -0.25 | 0.02  | -0.44 |

Correlations between variables and factors:

|                                | F1    | F2    | F3    | F4    | F5    |
|--------------------------------|-------|-------|-------|-------|-------|
| SiO <sub>2</sub>               | -0.71 | -0.33 | 0.19  | -0.02 | -0.38 |
| TiO <sub>2</sub>               | -0.82 | 0.40  | -0.21 | -0.21 | 0.07  |
| Al <sub>2</sub> O <sub>3</sub> | -0.82 | 0.15  | 0.14  | -0.31 | 0.10  |
| FeO                            | -0.93 | 0.08  | -0.16 | -0.16 | 0.10  |
| MnO                            | 0.00  | -0.34 | 0.12  | -0.53 | 0.59  |
| CaO                            | 0.95  | 0.01  | -0.06 | 0.17  | 0.07  |
| MgO                            | 0.14  | 0.66  | 0.23  | -0.20 | 0.43  |
| Na <sub>2</sub> O              | -0.20 | -0.21 | -0.20 | 0.64  | 0.17  |
| K <sub>2</sub> O               | -0.81 | 0.08  | -0.24 | -0.35 | 0.07  |
| V                              | -0.75 | 0.15  | -0.21 | -0.06 | 0.18  |
| Co                             | 0.02  | 0.38  | 0.76  | 0.09  | 0.12  |

|    |       |       |       |       |       |
|----|-------|-------|-------|-------|-------|
| Ni | -0.16 | 0.79  | 0.41  | 0.12  | 0.11  |
| Zn | -0.17 | 0.80  | -0.21 | 0.09  | -0.06 |
| Rb | -0.59 | -0.44 | 0.57  | -0.03 | 0.15  |
| Sr | 0.20  | 0.14  | -0.22 | 0.61  | 0.55  |
| Y  | -0.46 | 0.63  | 0.13  | 0.35  | -0.19 |
| Zr | -0.77 | -0.22 | 0.14  | 0.19  | -0.29 |
| Ba | -0.58 | -0.17 | -0.45 | 0.07  | 0.44  |
| La | -0.89 | -0.09 | 0.05  | 0.07  | 0.04  |
| Pb | 0.61  | 0.10  | 0.30  | -0.34 | -0.12 |
| Ce | -0.65 | -0.29 | 0.24  | 0.23  | 0.09  |
| Th | -0.63 | -0.29 | 0.47  | 0.40  | 0.13  |
| U  | -0.57 | 0.32  | -0.25 | 0.02  | -0.44 |

Contribution of the variables (%):

|                                | F1    | F2    | F3    | F4    | F5    |
|--------------------------------|-------|-------|-------|-------|-------|
| SiO <sub>2</sub>               | 5.67  | 3.19  | 1.61  | 0.03  | 8.44  |
| TiO <sub>2</sub>               | 7.67  | 4.89  | 2.09  | 2.22  | 0.33  |
| Al <sub>2</sub> O <sub>3</sub> | 7.58  | 0.69  | 0.87  | 4.84  | 0.63  |
| FeO                            | 9.91  | 0.22  | 1.12  | 1.28  | 0.57  |
| MnO                            | 0.00  | 3.54  | 0.65  | 14.55 | 20.54 |
| CaO                            | 10.26 | 0.00  | 0.15  | 1.53  | 0.27  |
| MgO                            | 0.22  | 12.96 | 2.50  | 1.98  | 11.09 |
| Na <sub>2</sub> O              | 0.46  | 1.34  | 1.83  | 20.92 | 1.76  |
| K <sub>2</sub> O               | 7.47  | 0.17  | 2.72  | 6.24  | 0.30  |
| V                              | 6.41  | 0.70  | 2.08  | 0.20  | 1.97  |
| Co                             | 0.01  | 4.35  | 26.68 | 0.46  | 0.84  |
| Ni                             | 0.31  | 18.95 | 7.79  | 0.73  | 0.74  |
| Zn                             | 0.34  | 19.37 | 2.01  | 0.39  | 0.23  |
| Rb                             | 3.98  | 5.84  | 14.81 | 0.06  | 1.37  |
| Sr                             | 0.44  | 0.60  | 2.27  | 19.00 | 17.85 |
| Y                              | 2.45  | 12.07 | 0.78  | 6.25  | 2.04  |
| Zr                             | 6.82  | 1.52  | 0.84  | 1.83  | 5.14  |
| Ba                             | 3.87  | 0.88  | 9.40  | 0.23  | 11.73 |
| La                             | 8.99  | 0.27  | 0.10  | 0.25  | 0.08  |
| Pb                             | 4.22  | 0.28  | 4.21  | 5.96  | 0.84  |
| Ce                             | 4.76  | 2.50  | 2.59  | 2.84  | 0.51  |
| Th                             | 4.46  | 2.55  | 9.94  | 8.18  | 1.05  |
| U                              | 3.71  | 3.11  | 2.96  | 0.02  | 11.67 |

Squared cosines of the variables:

|                                | F1          | F2          | F3          | F4          | F5          |
|--------------------------------|-------------|-------------|-------------|-------------|-------------|
| SiO <sub>2</sub>               | <b>0.50</b> | 0.11        | 0.04        | 0.00        | 0.14        |
| TiO <sub>2</sub>               | <b>0.67</b> | 0.16        | 0.05        | 0.04        | 0.01        |
| Al <sub>2</sub> O <sub>3</sub> | <b>0.67</b> | 0.02        | 0.02        | 0.09        | 0.01        |
| FeO                            | <b>0.87</b> | 0.01        | 0.02        | 0.02        | 0.01        |
| MnO                            | 0.00        | 0.12        | 0.01        | 0.28        | <b>0.35</b> |
| CaO                            | <b>0.90</b> | 0.00        | 0.00        | 0.03        | 0.00        |
| MgO                            | 0.02        | <b>0.43</b> | 0.05        | 0.04        | 0.19        |
| Na <sub>2</sub> O              | 0.04        | 0.04        | 0.04        | <b>0.40</b> | 0.03        |
| K <sub>2</sub> O               | <b>0.66</b> | 0.01        | 0.06        | 0.12        | 0.01        |
| V                              | <b>0.56</b> | 0.02        | 0.05        | 0.00        | 0.03        |
| Co                             | 0.00        | 0.14        | <b>0.58</b> | 0.01        | 0.01        |
| Ni                             | 0.03        | <b>0.63</b> | 0.17        | 0.01        | 0.01        |
| Zn                             | 0.03        | <b>0.64</b> | 0.04        | 0.01        | 0.00        |
| Rb                             | <b>0.35</b> | 0.19        | 0.32        | 0.00        | 0.02        |
| Sr                             | 0.04        | 0.02        | 0.05        | <b>0.37</b> | 0.30        |
| Y                              | 0.21        | <b>0.40</b> | 0.02        | 0.12        | 0.03        |

|    |             |      |      |      |      |
|----|-------------|------|------|------|------|
| Zr | <b>0.60</b> | 0.05 | 0.02 | 0.04 | 0.09 |
| Ba | <b>0.34</b> | 0.03 | 0.20 | 0.00 | 0.20 |
| La | <b>0.79</b> | 0.01 | 0.00 | 0.00 | 0.00 |
| Pb | <b>0.37</b> | 0.01 | 0.09 | 0.12 | 0.01 |
| Ce | <b>0.42</b> | 0.08 | 0.06 | 0.05 | 0.01 |
| Th | <b>0.39</b> | 0.08 | 0.22 | 0.16 | 0.02 |
| U  | <b>0.33</b> | 0.10 | 0.06 | 0.00 | 0.20 |

*Values in bold correspond for each variable to the factor for which the squared cosine is the largest*

Factor scores:

|  | F1     | F2    | F3    | F4    | F5    |
|-----------------------------------------------------------------------------------|--------|-------|-------|-------|-------|
| SPV 24                                                                            | -2.15  | -0.13 | 0.23  | -0.93 | 0.70  |
| GOLD 01                                                                           | -2.16  | 1.63  | -1.52 | -1.79 | 1.77  |
| GOLD 02                                                                           | -1.44  | 1.21  | -2.80 | -0.54 | -0.76 |
| GOLD 03                                                                           | -1.92  | 2.08  | -2.54 | 0.39  | -2.77 |
| GOLD 04                                                                           | -2.36  | 1.82  | -2.38 | 0.62  | -2.80 |
| GOLD 05                                                                           | -5.35  | 2.92  | 0.24  | 0.50  | -1.80 |
| GOLD 06                                                                           | -1.70  | 1.32  | -2.85 | -1.19 | 0.13  |
| GOLD 07                                                                           | -0.91  | 1.19  | -2.42 | -1.14 | 0.28  |
| GOLD 08                                                                           | -2.64  | 2.15  | -0.36 | -0.01 | 1.02  |
| GOLD 09                                                                           | -2.94  | 2.67  | -0.99 | 1.67  | -2.90 |
| GOLD 10                                                                           | -1.91  | 1.66  | -1.45 | -1.44 | 1.11  |
| GOLD 11                                                                           | -3.04  | 1.58  | -1.23 | 0.03  | -1.03 |
| GOLD 20                                                                           | -2.69  | 1.20  | -1.43 | 0.36  | -0.70 |
| SPV 16                                                                            | 0.28   | -2.34 | -1.83 | -0.60 | 0.92  |
| SPV 17                                                                            | -1.96  | -1.08 | -1.49 | -1.84 | 1.79  |
| SPV 18                                                                            | -0.10  | -1.92 | -0.82 | -0.70 | 1.12  |
| SPV 15                                                                            | 0.19   | -2.45 | -3.32 | -0.73 | 2.46  |
| SPV 19                                                                            | -0.13  | -2.62 | -2.87 | -0.58 | 1.36  |
| GOLD 12                                                                           | -4.17  | 1.72  | 2.49  | 0.86  | 1.76  |
| GOLD 13                                                                           | -2.41  | -1.53 | 0.09  | 0.43  | 0.06  |
| GOLD 14                                                                           | -5.63  | 0.00  | -0.03 | 1.88  | 0.85  |
| GOLD 15                                                                           | -3.81  | -1.56 | 0.34  | 1.42  | 0.35  |
| GOLD 16                                                                           | -3.87  | 0.35  | 0.68  | -0.40 | 1.85  |
| GOLD 17                                                                           | -4.29  | 1.81  | 0.16  | 0.69  | -2.34 |
| GOLD 18                                                                           | -4.89  | 0.34  | -0.33 | 0.43  | -0.19 |
| SPV 22                                                                            | -10.86 | -8.66 | 3.50  | 0.88  | -1.40 |
| SPV 23                                                                            | -0.70  | -1.17 | -0.72 | -0.17 | 0.58  |
| SPV 20                                                                            | -2.50  | -1.45 | -0.01 | -1.68 | 2.01  |
| SPV 21                                                                            | 0.28   | -3.38 | -1.43 | -1.12 | 0.29  |
| SP 1                                                                              | 0.92   | 0.83  | 1.41  | -0.41 | -0.04 |
| SP 2                                                                              | 1.36   | 0.94  | 1.16  | -0.80 | -0.04 |
| SP 3                                                                              | 2.38   | 0.88  | 0.73  | 0.16  | 0.98  |
| SP 4                                                                              | 0.28   | 0.01  | 1.78  | 0.72  | -0.12 |
| SP 5                                                                              | 2.34   | 0.30  | 0.59  | -1.17 | 0.08  |
| SP 6                                                                              | 1.56   | 0.93  | 0.79  | -0.17 | -0.66 |
| SP 8                                                                              | 2.37   | 0.61  | -0.27 | 1.65  | -0.16 |
| SP 11                                                                             | 2.13   | 0.64  | 0.36  | -2.11 | -0.11 |
| SP 12                                                                             | 3.03   | 0.55  | 1.44  | -0.60 | -0.21 |
| SP 13                                                                             | 1.14   | 0.37  | 0.99  | -0.83 | -0.15 |
| SP 24                                                                             | 3.08   | 1.20  | 1.24  | -0.71 | 0.34  |
| SP 25                                                                             | 1.60   | 0.36  | 1.67  | 0.05  | -0.39 |
| SP 26                                                                             | 1.91   | 0.09  | 1.19  | -0.19 | -0.34 |
| SP 27                                                                             | 1.21   | 0.25  | 1.50  | -0.73 | 0.46  |
| SP 28                                                                             | -0.25  | 1.94  | 2.12  | -0.74 | 1.55  |
| SP 29                                                                             | 1.77   | 0.05  | 0.99  | 0.03  | 0.33  |
| SP 30                                                                             | 1.66   | -0.11 | 0.77  | 0.22  | 0.19  |
| SP 31                                                                             | 1.32   | 0.74  | 1.69  | -1.10 | -0.05 |
| SP 32                                                                             | 1.73   | 0.23  | 0.90  | -1.12 | -0.51 |
| SP 33                                                                             | 1.87   | 0.45  | 1.46  | -0.17 | -0.27 |

|       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|
| SP 9  | 4.41  | 0.80  | -0.40 | 0.42  | 0.06  |
| SP 10 | 2.34  | -0.07 | 1.22  | 0.30  | -0.30 |
| SP 14 | -0.63 | 1.94  | 1.47  | 0.55  | 1.66  |
| SP 15 | 5.05  | -2.69 | -1.25 | 0.79  | -0.74 |
| SP 18 | 4.05  | -2.86 | -0.89 | 3.06  | -1.28 |
| SAB 1 | -1.58 | 2.03  | 1.95  | 1.35  | 1.56  |
| SAB 2 | 1.74  | 0.17  | 0.87  | 0.45  | -0.30 |
| SP 20 | 2.52  | -1.38 | 0.33  | -1.03 | -0.97 |
| SP 21 | 3.36  | -1.93 | -1.42 | 2.69  | -1.54 |
| SP 22 | 4.08  | -1.06 | -0.45 | 1.06  | -0.87 |
| SP 34 | 2.89  | -1.88 | 0.44  | 0.04  | -1.49 |
| SP 35 | 3.57  | -1.06 | -0.57 | -1.94 | -0.99 |
| SP 36 | 3.55  | -1.65 | -0.26 | -2.43 | -0.75 |
| SP 7  | 0.70  | -0.48 | 0.45  | 0.99  | -1.55 |
| SP 23 | 1.56  | 0.40  | 0.87  | -0.72 | -0.77 |
| SP 16 | 3.77  | 0.89  | -1.55 | 6.87  | 4.24  |
| SP 19 | 1.02  | 0.22  | 1.74  | 0.28  | -0.58 |

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## Supplementary Material no. 5

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### Principal Component Analysis

Eigenvalues:

|             | F1    | F2    | F3    | F4    | F5    | F6    | F7    |
|-------------|-------|-------|-------|-------|-------|-------|-------|
| Eigenvalue  | 5.93  | 2.49  | 1.29  | 1.07  | 0.87  | 0.55  | 0.48  |
| Variability | 42.36 | 17.76 | 9.21  | 7.65  | 6.22  | 3.93  | 3.43  |
| Cumulative  | 42.36 | 60.12 | 69.33 | 76.98 | 83.20 | 87.13 | 90.56 |

|             | F8    | F9    | F10   | F11   | F12   | F13   | F14    |
|-------------|-------|-------|-------|-------|-------|-------|--------|
| Eigenvalue  | 0.36  | 0.23  | 0.22  | 0.17  | 0.16  | 0.10  | 0.07   |
| Variability | 2.58  | 1.66  | 1.56  | 1.24  | 1.17  | 0.74  | 0.48   |
| Cumulative  | 93.15 | 94.81 | 96.37 | 97.61 | 98.78 | 99.52 | 100.00 |

Factor loadings:

|                                | F1    | F2    | F3    | F4    | F5    |
|--------------------------------|-------|-------|-------|-------|-------|
| SiO <sub>2</sub>               | -0.77 | -0.26 | -0.20 | 0.11  | -0.17 |
| TiO <sub>2</sub>               | -0.53 | 0.73  | -0.05 | -0.09 | 0.10  |
| Al <sub>2</sub> O <sub>3</sub> | -0.85 | 0.34  | -0.05 | -0.16 | -0.05 |
| FeO                            | -0.63 | 0.39  | -0.12 | -0.20 | -0.45 |
| MnO                            | -0.25 | 0.07  | 0.81  | -0.31 | -0.31 |
| CaO                            | 0.87  | 0.28  | 0.18  | -0.03 | 0.02  |
| MgO                            | 0.37  | 0.78  | 0.09  | 0.20  | -0.06 |
| Na <sub>2</sub> O              | -0.51 | 0.00  | -0.03 | 0.76  | -0.04 |
| K <sub>2</sub> O               | -0.82 | 0.10  | 0.18  | 0.27  | -0.11 |
| V                              | -0.52 | 0.64  | -0.27 | -0.03 | 0.06  |
| Sr                             | 0.50  | 0.55  | 0.34  | 0.24  | 0.25  |
| Y                              | -0.64 | 0.13  | -0.05 | -0.28 | 0.61  |
| Zr                             | -0.82 | -0.38 | 0.16  | -0.12 | 0.18  |
| Ba                             | -0.67 | -0.19 | 0.53  | 0.22  | 0.21  |

Correlations between variables and factors:

|                                | F1    | F2    | F3    | F4    | F5    |
|--------------------------------|-------|-------|-------|-------|-------|
| SiO <sub>2</sub>               | -0.77 | -0.26 | -0.20 | 0.11  | -0.17 |
| TiO <sub>2</sub>               | -0.53 | 0.73  | -0.05 | -0.09 | 0.10  |
| Al <sub>2</sub> O <sub>3</sub> | -0.85 | 0.34  | -0.05 | -0.16 | -0.05 |
| FeO                            | -0.63 | 0.39  | -0.12 | -0.20 | -0.45 |
| MnO                            | -0.25 | 0.07  | 0.81  | -0.31 | -0.31 |
| CaO                            | 0.87  | 0.28  | 0.18  | -0.03 | 0.02  |
| MgO                            | 0.37  | 0.78  | 0.09  | 0.20  | -0.06 |
| Na <sub>2</sub> O              | -0.51 | 0.00  | -0.03 | 0.76  | -0.04 |
| K <sub>2</sub> O               | -0.82 | 0.10  | 0.18  | 0.27  | -0.11 |
| V                              | -0.52 | 0.64  | -0.27 | -0.03 | 0.06  |
| Sr                             | 0.50  | 0.55  | 0.34  | 0.24  | 0.25  |
| Y                              | -0.64 | 0.13  | -0.05 | -0.28 | 0.61  |
| Zr                             | -0.82 | -0.38 | 0.16  | -0.12 | 0.18  |
| Ba                             | -0.67 | -0.19 | 0.53  | 0.22  | 0.21  |

Contribution of the variables (%):

|                  | F1    | F2    | F3   | F4   | F5   |
|------------------|-------|-------|------|------|------|
| SiO <sub>2</sub> | 10.00 | 2.71  | 3.04 | 1.11 | 3.52 |
| TiO <sub>2</sub> | 4.80  | 21.71 | 0.16 | 0.82 | 1.20 |

|                                |       |       |       |       |       |
|--------------------------------|-------|-------|-------|-------|-------|
| Al <sub>2</sub> O <sub>3</sub> | 12.17 | 4.66  | 0.23  | 2.28  | 0.26  |
| FeO                            | 6.63  | 6.22  | 1.09  | 3.74  | 22.75 |
| MnO                            | 1.09  | 0.22  | 51.40 | 8.92  | 10.73 |
| CaO                            | 12.86 | 3.08  | 2.50  | 0.10  | 0.05  |
| MgO                            | 2.28  | 24.73 | 0.63  | 3.55  | 0.41  |
| Na <sub>2</sub> O              | 4.47  | 0.00  | 0.06  | 54.33 | 0.21  |
| K <sub>2</sub> O               | 11.25 | 0.38  | 2.62  | 6.79  | 1.36  |
| V                              | 4.50  | 16.37 | 5.64  | 0.09  | 0.39  |
| Sr                             | 4.21  | 12.00 | 8.90  | 5.29  | 7.33  |
| Y                              | 6.86  | 0.68  | 0.16  | 7.32  | 42.73 |
| Zr                             | 11.31 | 5.86  | 1.90  | 1.32  | 3.80  |
| Ba                             | 7.58  | 1.38  | 21.67 | 4.35  | 5.26  |

Squared cosines of the variables:

|                                | F1          | F2          | F3          | F4          | F5   |
|--------------------------------|-------------|-------------|-------------|-------------|------|
| SiO <sub>2</sub>               | <b>0.59</b> | 0.07        | 0.04        | 0.01        | 0.03 |
| TiO <sub>2</sub>               | 0.28        | <b>0.54</b> | 0.00        | 0.01        | 0.01 |
| Al <sub>2</sub> O <sub>3</sub> | <b>0.72</b> | 0.12        | 0.00        | 0.02        | 0.00 |
| FeO                            | <b>0.39</b> | 0.15        | 0.01        | 0.04        | 0.20 |
| MnO                            | 0.06        | 0.01        | <b>0.66</b> | 0.10        | 0.09 |
| CaO                            | <b>0.76</b> | 0.08        | 0.03        | 0.00        | 0.00 |
| MgO                            | 0.13        | <b>0.61</b> | 0.01        | 0.04        | 0.00 |
| Na <sub>2</sub> O              | 0.26        | 0.00        | 0.00        | <b>0.58</b> | 0.00 |
| K <sub>2</sub> O               | <b>0.67</b> | 0.01        | 0.03        | 0.07        | 0.01 |
| V                              | 0.27        | <b>0.41</b> | 0.07        | 0.00        | 0.00 |
| Sr                             | 0.25        | <b>0.30</b> | 0.11        | 0.06        | 0.06 |
| Y                              | <b>0.41</b> | 0.02        | 0.00        | 0.08        | 0.37 |
| Zr                             | <b>0.67</b> | 0.15        | 0.02        | 0.01        | 0.03 |
| Ba                             | <b>0.45</b> | 0.03        | 0.28        | 0.05        | 0.05 |

Values in bold correspond for each variable to the factor for which the squared cosine is the largest

Factor scores:

|       | F1   | F2    | F3    | F4    | F5    |
|-------|------|-------|-------|-------|-------|
| FAR 7 | 1.72 | 0.07  | 1.04  | -0.20 | 0.59  |
| SP 1  | 2.03 | 1.05  | -0.98 | -0.59 | 0.43  |
| SP 11 | 2.56 | 0.96  | -1.05 | -1.48 | -0.01 |
| SP 12 | 3.08 | 0.36  | -0.72 | -0.96 | 0.60  |
| SP 13 | 1.97 | 0.59  | -0.76 | -0.53 | 0.36  |
| SP 2  | 2.05 | 0.95  | -1.11 | -0.96 | 0.33  |
| SP 24 | 3.22 | 0.54  | -0.27 | -0.78 | 0.56  |
| SP 25 | 2.70 | 0.32  | -0.90 | -1.07 | 0.43  |
| SP 26 | 2.71 | 0.22  | -0.89 | -0.85 | 0.44  |
| SP 27 | 2.25 | 0.24  | -0.28 | -0.93 | 0.28  |
| SP 28 | 1.53 | 1.56  | -0.43 | -0.91 | 0.36  |
| SP 29 | 2.38 | 0.37  | -0.53 | -0.52 | 0.60  |
| SP 3  | 2.73 | 1.12  | -0.51 | 0.34  | 0.59  |
| SP 30 | 2.71 | 0.40  | -0.71 | -0.64 | 0.50  |
| SP 31 | 2.08 | 0.47  | -0.46 | -0.73 | 0.43  |
| SP 32 | 2.37 | 0.63  | -0.99 | -1.08 | 0.31  |
| SP 33 | 2.66 | 0.08  | -0.53 | -0.80 | 0.48  |
| SP 4  | 1.99 | 0.59  | -1.05 | -0.84 | 0.55  |
| SP 5  | 2.84 | 0.56  | -0.53 | -1.35 | 0.51  |
| SP 6  | 2.17 | 0.43  | -1.12 | -0.64 | 0.41  |
| SP 8  | 2.73 | 0.32  | -0.58 | 1.02  | 0.60  |
| FAR 6 | 2.00 | -0.38 | 0.64  | 0.29  | 0.48  |
| SP 10 | 3.03 | -0.19 | -0.61 | -0.84 | 0.50  |
| SP 14 | 1.27 | 1.55  | -0.46 | 0.23  | 0.60  |
| SP 15 | 4.54 | -1.60 | -0.04 | 0.00  | 0.68  |
| SP 18 | 3.60 | -1.70 | -0.76 | 0.93  | 0.76  |

|         |       |       |       |       |       |
|---------|-------|-------|-------|-------|-------|
| SP 9    | 4.09  | 0.13  | -0.05 | -0.06 | 0.80  |
| SAB 1   | 1.03  | 2.01  | -0.73 | 0.11  | 0.87  |
| SAB 2   | 2.41  | 0.39  | -0.83 | 0.29  | 0.44  |
| FAR 1   | 1.74  | 0.00  | -0.15 | -0.41 | 0.52  |
| FAR 10  | 2.41  | 0.99  | -0.20 | 0.40  | 0.33  |
| FAR 11  | 2.33  | -1.44 | 0.10  | 0.22  | 0.74  |
| FAR 2   | 2.08  | -0.06 | -0.44 | -0.24 | 0.47  |
| FAR 3   | 1.31  | -0.16 | -0.70 | 0.54  | 0.53  |
| FAR 4   | 2.27  | -0.58 | -0.31 | -0.92 | 0.48  |
| FAR 5   | 2.07  | -0.09 | -0.41 | -0.57 | 0.49  |
| FAR 8   | 3.79  | 1.94  | 0.55  | 2.02  | 0.35  |
| FAR 9   | 2.72  | 0.10  | 0.12  | -0.86 | 0.56  |
| SP 23   | 2.09  | 0.08  | -0.62 | -0.76 | 0.50  |
| SP 7    | 1.94  | -0.43 | -0.92 | -0.24 | 0.69  |
| SP 16   | 5.69  | 4.39  | 2.37  | 2.70  | 5.03  |
| SP 19   | 2.12  | -0.64 | -0.25 | -0.44 | 0.38  |
| 1       | 1.43  | 1.36  | 0.09  | 0.55  | -0.50 |
| 65      | 1.82  | 1.45  | 0.19  | 0.65  | -0.56 |
| 66      | 0.51  | 1.45  | 2.18  | 1.13  | 0.24  |
| SG 62   | 1.54  | 0.60  | 0.82  | 0.25  | 0.03  |
| 69      | 0.97  | 0.58  | -0.97 | 0.57  | -0.70 |
| 104     | -1.12 | 1.52  | -0.99 | -1.15 | -0.17 |
| SG 63   | 0.86  | 1.11  | 0.20  | 0.07  | 0.23  |
| 18      | 0.15  | 2.58  | -0.96 | 0.19  | -0.49 |
| 34      | 0.12  | 1.81  | -0.01 | 0.69  | -0.25 |
| 35      | 0.44  | 1.36  | 0.29  | 1.08  | -0.18 |
| 106     | 0.61  | -1.08 | 0.28  | 0.35  | -0.66 |
| GOLD 01 | -0.21 | 2.68  | -0.37 | -0.25 | 0.13  |
| GOLD 02 | 0.81  | 1.83  | -0.77 | -0.81 | 0.55  |
| GOLD 03 | 0.28  | 1.29  | -1.52 | -0.82 | 0.90  |
| GOLD 04 | 0.23  | 1.14  | -1.57 | -0.28 | 0.36  |
| GOLD 05 | -1.28 | 2.14  | -2.05 | -1.17 | 0.58  |
| GOLD 06 | -0.05 | 1.90  | -0.65 | -0.49 | 0.40  |
| GOLD 07 | 0.60  | 1.89  | -0.52 | -0.81 | 0.42  |
| GOLD 08 | 0.02  | 2.45  | -0.86 | -0.60 | 0.37  |
| GOLD 09 | 0.13  | 1.21  | -1.79 | -0.49 | 0.94  |
| GOLD 10 | 0.07  | 2.66  | -0.60 | -0.73 | 0.26  |
| GOLD 11 | -0.09 | 1.58  | -0.87 | -0.82 | 0.69  |
| GOLD 20 | 0.61  | 2.21  | -0.99 | -0.87 | 0.83  |
| ORD 02  | 0.04  | 2.08  | -1.41 | -0.03 | -0.04 |
| POS 21  | 0.81  | -0.38 | -0.31 | 0.50  | 0.46  |
| POS 23  | 0.40  | 1.95  | 0.36  | 0.52  | 0.29  |
| POS 24  | 0.51  | 3.24  | -0.12 | -0.03 | 0.46  |
| POS 25  | 1.26  | 0.46  | 0.09  | 0.15  | 0.26  |
| SG 15   | 2.35  | 1.71  | 1.30  | 0.67  | 0.05  |
| SG 16   | 3.18  | -0.89 | 1.24  | 0.94  | -0.44 |
| SG 51   | 4.42  | 0.05  | 1.11  | 1.24  | -0.10 |
| SG 52   | 3.21  | -1.03 | 1.37  | 0.81  | 0.02  |
| SG 53   | 3.07  | -0.05 | 0.39  | 0.68  | 0.05  |
| SG 54   | 3.78  | 0.05  | 2.24  | 1.34  | 0.65  |
| SG 55   | 1.62  | 1.57  | -0.32 | 0.56  | 0.13  |
| SG 56   | 1.69  | -0.03 | 1.09  | 0.50  | 0.29  |
| SPV 16  | 1.39  | 0.70  | -0.48 | 0.10  | -0.31 |
| SPV 17  | 0.13  | 1.96  | -0.24 | -0.32 | -0.17 |
| SPV 18  | 1.51  | 0.80  | -0.25 | 0.33  | -0.44 |
| FARA 23 | -0.82 | 1.73  | -1.30 | 0.59  | -1.47 |
| FARA 24 | -0.56 | 2.22  | -1.01 | -0.08 | -1.09 |
| ORD 07  | -0.22 | -0.50 | -1.81 | 0.42  | -0.63 |
| ORD 08  | 0.01  | 1.57  | -1.29 | 0.00  | -0.41 |
| ORD 09  | 1.51  | -0.76 | -0.36 | 0.65  | 0.28  |
| ORD 13  | 1.49  | 0.36  | -1.04 | -0.07 | -0.17 |
| ORD 14  | -0.43 | 2.29  | -1.76 | -0.67 | -0.58 |
| POS 40  | -0.70 | 2.49  | -0.60 | -0.11 | 0.45  |
| SG 57   | 0.14  | 1.52  | -0.43 | 0.59  | 0.45  |

|         |       |       |       |       |       |
|---------|-------|-------|-------|-------|-------|
| 8       | 0.89  | 0.25  | -0.64 | 1.26  | -0.21 |
| 115     | 0.79  | 0.27  | -0.22 | 0.72  | -0.78 |
| 126     | 0.12  | 0.94  | -0.66 | 0.94  | -0.46 |
| POS 28  | 1.31  | 0.95  | 0.65  | 0.75  | 0.22  |
| POS 29  | 0.16  | 1.68  | -0.79 | -0.05 | 0.13  |
| POS 30  | 1.13  | 0.48  | 0.51  | 1.16  | 0.55  |
| SPV 15  | 1.30  | 0.39  | 0.88  | 0.46  | 0.08  |
| ORD 01  | 1.53  | 1.12  | -0.65 | -0.39 | -0.13 |
| POS 26  | 2.19  | 1.27  | 0.09  | 0.27  | 0.43  |
| POS 27  | 1.25  | 1.61  | 0.36  | 0.64  | 0.48  |
| 3       | 0.10  | 1.73  | -1.31 | 0.29  | -0.39 |
| FARA 30 | -0.20 | 2.21  | -0.24 | 0.04  | -1.82 |
| SPV 24  | 0.23  | 1.46  | -0.80 | -0.67 | -0.08 |
| FARA 17 | 0.32  | 1.37  | -0.75 | 0.04  | -0.69 |
| FARA 18 | 0.21  | 2.11  | -0.66 | -0.12 | -1.14 |
| FARA 19 | 1.11  | 1.91  | -0.79 | 0.38  | -0.10 |
| 9       | -0.48 | -0.90 | -0.03 | -0.01 | 0.02  |
| 24      | 0.33  | 0.97  | -0.78 | 0.30  | -0.24 |
| 53      | 0.58  | 2.41  | -1.16 | 0.97  | -0.63 |
| 68      | -0.24 | 1.52  | -0.96 | 0.17  | -0.36 |
| 86      | -0.45 | 1.69  | -0.97 | 1.06  | -0.48 |
| 99      | 0.10  | 1.68  | -1.09 | 0.70  | -0.28 |
| 120     | -2.02 | 4.27  | 0.37  | 0.40  | 0.02  |
| POS 31  | 1.24  | 1.34  | -0.48 | 0.03  | 0.31  |
| POS 32  | 0.65  | 1.48  | 0.51  | 1.29  | 0.41  |
| 44      | -1.40 | 0.48  | -1.15 | 2.28  | 0.63  |
| 47      | 0.22  | 0.66  | -0.35 | 0.96  | -0.31 |
| 112     | 0.20  | 1.43  | -0.98 | 0.00  | -0.46 |
| 116     | 1.13  | -0.43 | -0.55 | 1.05  | -0.39 |
| POS 36  | 1.70  | -0.23 | 0.10  | 0.10  | 0.34  |
| POS 37  | 1.40  | 0.84  | 0.19  | 0.87  | 0.16  |
| POS 38  | 0.74  | 2.54  | 0.99  | 0.20  | -0.40 |
| POS 39  | 1.03  | 1.53  | -0.43 | 0.07  | 0.07  |
| POS 41  | 1.42  | 2.55  | 0.80  | 1.35  | -0.11 |
| FARA 28 | -0.56 | 1.34  | -0.56 | 0.47  | -1.23 |
| FARA 29 | 0.15  | 2.21  | -0.67 | 0.25  | -1.02 |
| ORD 03  | 0.28  | 1.58  | -1.13 | 0.10  | 0.18  |
| SPV 19  | 1.21  | 1.20  | 0.02  | 0.54  | 0.12  |
| FARA 20 | 0.49  | 1.69  | -1.09 | 0.28  | -0.71 |
| FARA 21 | -0.17 | 0.53  | 0.27  | -0.08 | -2.02 |
| FARA 22 | -0.67 | 1.15  | -0.85 | 0.70  | -0.87 |
| GOLD 12 | 0.54  | 2.34  | -0.51 | -0.28 | 0.30  |
| GOLD 13 | 0.84  | 0.26  | -0.43 | 0.47  | -0.06 |
| GOLD 14 | -1.05 | 1.74  | -0.56 | 1.40  | 0.07  |
| GOLD 15 | 0.10  | 0.95  | -0.38 | 1.00  | 0.44  |
| GOLD 16 | -0.16 | 2.56  | -0.71 | -0.25 | 0.12  |
| GOLD 17 | -0.36 | 1.54  | -1.76 | -0.81 | 0.52  |
| GOLD 18 | -1.13 | 1.78  | -1.18 | 0.09  | 0.46  |
| ORD 04  | 1.69  | 0.52  | -0.44 | -0.08 | -0.43 |
| ORD 05  | 0.40  | 3.37  | -0.06 | 0.39  | 0.17  |
| ORD 06  | 0.39  | 3.05  | -0.71 | 0.43  | -0.02 |
| ORD 10  | 0.31  | 1.15  | -0.51 | 0.91  | 0.15  |
| ORD 11  | 0.43  | 2.17  | -1.08 | -0.07 | -0.12 |
| ORD 12  | 0.60  | 1.11  | -0.93 | -0.54 | -0.39 |
| FARA 25 | 1.27  | 1.35  | -0.29 | 0.19  | -0.70 |
| FARA 26 | 0.48  | 1.67  | -0.37 | 0.34  | -0.76 |
| FARA 27 | -2.13 | 0.37  | -0.61 | 0.83  | -1.94 |
| 11      | 0.16  | 0.99  | -1.26 | 0.77  | -0.44 |
| 26      | 0.50  | 0.59  | -0.72 | 0.27  | -0.53 |
| POS 33  | 0.38  | 2.05  | -0.59 | 0.12  | 0.20  |
| POS 34  | -0.53 | 2.85  | 0.17  | 0.08  | 0.29  |
| POS 35  | 0.87  | 2.71  | 0.72  | 0.86  | 0.20  |
| SG 58   | 2.14  | 0.69  | 0.90  | 0.37  | -0.17 |
| SG 59   | 0.10  | 1.46  | -0.55 | 0.16  | -0.02 |

|         |       |       |       |       |       |
|---------|-------|-------|-------|-------|-------|
| SG 60   | 0.41  | 2.43  | -0.08 | 0.86  | 0.80  |
| SG 61   | 1.11  | -0.12 | -0.11 | 0.22  | 0.36  |
| SPV 22  | -3.23 | -0.11 | -1.92 | -1.66 | -0.80 |
| SPV 23  | 1.03  | 1.03  | -0.75 | -0.05 | -0.19 |
| SPV 20  | 0.08  | 1.79  | -0.52 | -0.09 | -0.68 |
| SPV 21  | 1.10  | -0.04 | -0.02 | 0.62  | -0.38 |
| ORD 15  | 1.19  | -1.01 | -0.59 | 0.76  | 0.04  |
| SG 64   | -1.83 | -2.19 | -1.48 | 1.06  | 0.81  |
| SG 65   | -0.54 | -1.26 | 0.42  | 1.21  | 0.35  |
| SG 66   | -2.10 | -1.41 | -1.07 | 1.00  | 0.06  |
| SG 67   | -2.65 | -2.01 | 0.19  | 0.79  | 0.46  |
| POS 18  | -4.72 | 0.70  | 2.20  | -2.72 | 2.15  |
| POS 19  | -3.87 | -1.24 | -0.26 | 2.99  | 0.16  |
| SG 79   | -2.55 | -2.76 | 0.02  | 1.46  | 0.80  |
| FARA 10 | -1.47 | -1.65 | -0.41 | -0.72 | -1.49 |
| FARA 11 | -0.89 | -0.92 | -1.04 | -1.32 | -0.64 |
| FARA 12 | -1.16 | -2.37 | -1.86 | 0.29  | -2.27 |
| FARA 13 | -1.54 | -2.10 | -1.15 | -1.69 | -2.17 |
| FARA 4  | -0.90 | -1.49 | -0.14 | -1.53 | -2.43 |
| FARA 5  | -1.09 | -2.13 | -0.08 | -0.77 | -2.23 |
| FARA 6  | -0.65 | -2.36 | -0.17 | -0.84 | -2.02 |
| FARA 7  | -1.54 | -1.67 | -0.78 | -1.77 | -2.33 |
| FARA 8  | -2.36 | -2.25 | 1.20  | -0.32 | -1.94 |
| FARA 9  | -0.86 | -1.91 | -0.76 | -0.90 | -1.35 |
| GOLD 22 | -2.16 | -1.69 | -0.74 | -1.67 | -0.10 |
| GOLD 23 | -4.08 | 0.04  | 0.90  | -0.51 | 1.28  |
| GOLD 24 | -3.49 | -0.83 | 0.22  | 0.74  | 0.44  |
| GOLD 26 | -3.16 | -1.59 | -2.83 | -3.23 | 3.75  |
| GOLD 27 | -1.00 | -2.75 | -0.93 | 0.97  | -0.59 |
| GOLD 28 | -2.76 | -1.56 | -2.71 | -3.07 | 2.28  |
| GOLD 29 | -3.62 | -1.33 | 0.00  | -0.28 | 0.43  |
| GOLD 30 | -4.73 | -0.23 | 2.03  | -0.64 | 1.17  |
| GOLD 31 | -4.49 | 0.64  | 1.14  | -0.13 | 1.30  |
| GOLD 33 | -2.93 | -0.80 | 0.57  | 0.12  | 0.47  |
| GOLD 34 | -3.11 | -0.97 | 0.76  | 0.45  | 0.55  |
| GOLD 36 | -3.72 | -1.02 | -0.22 | -0.87 | 0.72  |
| GOLD 37 | -3.32 | -1.25 | 0.29  | -0.52 | 0.53  |
| GOLD 38 | -3.23 | -2.10 | -0.59 | -0.83 | 1.10  |
| ORD 26  | -2.97 | -0.62 | -0.13 | 0.49  | -0.16 |
| ORD 27  | -2.68 | -2.10 | -1.29 | 0.88  | 0.58  |
| ORD 28  | -3.72 | -1.46 | 0.70  | -0.05 | 0.52  |
| ORD 29  | -1.57 | -1.78 | -3.27 | -0.49 | 0.05  |
| ORD 30  | -1.86 | -1.75 | -3.39 | -0.70 | 0.08  |
| ORD 31  | -3.40 | -1.75 | 0.52  | 0.10  | 0.63  |
| ORD 32  | -3.36 | -1.86 | -0.79 | -2.37 | 0.36  |
| ORD 33  | -2.42 | -1.75 | -0.24 | 0.53  | 0.01  |
| ORD 34  | -3.41 | -1.97 | 0.69  | 0.48  | 0.06  |
| ORD 35  | -3.02 | -0.67 | -1.24 | 1.36  | 1.34  |
| ORD 36  | -3.27 | -0.18 | -1.47 | 1.27  | 0.17  |
| POS 08  | -2.75 | -1.55 | -0.37 | 1.13  | 0.47  |
| POS 09  | -3.09 | 0.73  | -0.90 | -1.03 | -0.06 |
| POS 11  | -2.64 | 0.42  | 0.57  | -1.26 | -0.11 |
| POS 13  | -5.48 | 0.20  | 1.44  | -2.51 | 1.35  |
| POS 14  | -3.26 | -0.73 | 1.46  | 0.53  | 0.43  |
| POS 15  | -3.29 | 0.24  | -0.71 | 0.41  | 0.82  |
| POS 20  | -3.09 | -0.75 | 0.32  | -0.42 | -0.02 |
| POS 44  | -1.87 | -1.37 | -0.99 | 0.79  | -0.21 |
| POS 45  | -4.37 | 0.44  | 0.46  | -1.72 | 0.96  |
| SG 10   | -3.75 | 0.54  | 1.40  | -0.66 | 0.59  |
| SG 12   | -1.18 | 0.33  | 0.84  | 0.68  | -0.13 |
| SG 13   | -3.54 | -0.04 | -1.12 | 0.57  | 1.35  |
| SG 14   | -1.41 | -2.71 | -0.45 | -0.23 | -1.02 |
| SG 21   | -2.20 | 0.23  | 1.53  | 1.27  | 0.34  |
| SG 22   | -1.78 | 0.15  | 1.29  | 1.17  | -0.34 |

|         |       |       |       |       |       |
|---------|-------|-------|-------|-------|-------|
| SG 23   | -1.65 | 0.44  | 0.60  | 0.42  | 0.12  |
| SG 24   | -1.77 | 0.23  | 1.25  | 0.27  | -0.16 |
| SG 25   | -1.32 | 0.00  | 0.72  | 0.64  | 0.14  |
| SG 26   | -1.59 | 0.28  | 0.97  | 1.08  | -0.09 |
| SG 27   | -1.63 | 0.05  | 0.94  | 0.62  | 0.07  |
| SG 28   | -1.53 | 0.11  | 0.78  | 0.84  | -0.12 |
| SG 29   | -1.29 | 0.22  | 0.39  | 0.75  | -0.08 |
| SG 30   | -1.49 | 0.01  | 0.85  | 0.76  | -0.11 |
| SG 31   | -1.34 | 0.09  | 0.56  | 0.82  | -0.08 |
| SG 32   | -1.52 | 0.16  | 0.75  | 0.81  | -0.03 |
| SG 33   | -4.24 | 0.48  | 1.26  | -0.65 | 0.99  |
| SG 34   | -1.47 | 0.20  | 1.31  | 1.06  | 0.05  |
| SG 35   | -1.90 | 0.39  | 0.58  | 0.36  | 0.35  |
| SG 36   | -1.55 | 0.12  | 0.65  | 0.57  | 0.22  |
| SG 37   | -2.15 | 0.35  | 1.11  | 1.43  | -0.12 |
| SG 38   | -4.38 | 0.59  | 1.16  | -0.62 | 1.16  |
| SG 39   | -1.98 | 0.30  | 1.50  | 1.79  | 0.24  |
| SG 40   | -4.00 | 0.47  | 1.39  | -0.91 | 0.81  |
| SG 41   | -1.61 | 0.09  | 1.18  | 0.83  | -0.32 |
| SG 42   | -4.25 | 0.49  | 1.37  | -0.97 | 0.99  |
| SG 43   | -1.78 | 0.43  | 0.69  | 0.48  | 0.44  |
| SG 44   | -3.45 | -0.48 | -0.67 | 1.17  | 1.39  |
| SG 45   | -1.60 | 0.03  | 1.44  | 0.99  | -0.32 |
| SG 46   | -1.70 | 0.33  | 0.69  | 0.88  | -0.03 |
| SG 47   | -1.69 | 0.30  | 0.76  | 0.81  | -0.19 |
| SG 6    | -3.93 | 0.59  | 1.14  | -0.55 | 0.53  |
| SG 7    | -0.87 | 0.02  | 0.84  | 0.58  | -0.39 |
| SG 71   | -1.89 | -1.78 | 0.09  | 0.22  | 0.89  |
| SG 72   | -0.56 | -0.60 | 0.57  | 2.35  | 1.12  |
| SG 73   | -4.45 | -0.56 | 1.72  | -0.84 | 0.90  |
| SG 74   | -1.49 | -2.65 | -0.80 | 3.71  | 0.67  |
| SG 75   | -2.31 | -0.46 | -0.47 | 2.26  | 1.18  |
| SG 8    | -4.32 | 0.70  | 1.25  | -0.22 | 0.72  |
| SG 9    | -3.74 | 0.37  | 1.19  | -0.35 | 0.68  |
| SPV 10  | -2.44 | -2.01 | -0.51 | 0.66  | -0.33 |
| SPV 6   | -4.09 | -0.44 | 1.70  | -1.17 | 0.36  |
| SPV 7   | 0.35  | 0.86  | 0.01  | -4.59 | 3.28  |
| SPV 8   | -2.51 | -2.25 | -0.74 | 0.49  | -0.18 |
| SPV 9   | -2.12 | -0.96 | -2.22 | -4.59 | 2.61  |
| FARA 16 | -2.09 | -1.06 | -1.22 | 0.20  | -1.89 |
| POS 17  | -3.52 | -0.23 | 0.03  | 1.14  | 0.32  |
| POS 43  | -1.18 | -2.91 | -1.67 | -0.05 | 0.39  |
| SPV 12  | -3.16 | -0.68 | 1.45  | -0.52 | -0.82 |
| FARA 1  | -1.24 | -1.80 | 1.64  | -1.70 | -6.22 |
| FARA 2  | -0.90 | -1.86 | 0.57  | -1.98 | -3.78 |
| FARA 3  | -2.12 | -1.49 | -0.67 | 0.55  | -0.66 |
| POS 07  | -1.44 | -1.28 | -1.73 | 0.52  | -0.15 |
| POS 46  | -2.72 | 0.08  | -0.17 | 0.08  | 1.29  |
| SG 68   | 0.13  | -3.32 | -0.36 | 1.10  | -0.70 |
| SPV 11  | -2.43 | -1.79 | -0.04 | 0.70  | 0.19  |
| POS 22  | -1.85 | -0.47 | -1.13 | -0.55 | 0.30  |
| FARA 14 | -1.48 | -2.23 | -1.83 | 1.42  | -2.40 |
| FARA 15 | -0.92 | -2.46 | -0.81 | -0.98 | -1.64 |
| SG 48   | -3.68 | 0.57  | 1.08  | -0.52 | 0.84  |
| SG 49   | -4.07 | 0.36  | 1.37  | -0.10 | 0.83  |
| SG 50   | -3.94 | 0.37  | 1.32  | -0.09 | 0.33  |
| SG 77   | -3.16 | 0.21  | 1.18  | 0.37  | 0.92  |
| SG 78   | -0.54 | -2.70 | -1.20 | -0.67 | -0.34 |
| SPV 14  | -1.91 | -1.27 | -1.24 | -0.85 | -0.93 |
| ORD 16  | -2.43 | -1.40 | -1.74 | 0.44  | -0.19 |
| ORD 18  | -1.67 | -2.39 | -2.08 | 1.48  | -0.36 |
| ORD 19  | -3.01 | -0.67 | 0.05  | 0.07  | 0.53  |
| ORD 20  | -2.40 | -1.09 | -0.53 | 0.52  | -0.03 |
| ORD 21  | -3.53 | -0.79 | -0.30 | 0.74  | 0.25  |

|        |       |       |       |       |       |
|--------|-------|-------|-------|-------|-------|
| ORD 22 | -0.33 | -3.70 | -1.43 | -0.41 | -1.31 |
| ORD 23 | -3.03 | -1.45 | -0.25 | -0.71 | -0.24 |
| ORD 24 | -3.55 | -0.63 | 0.11  | -1.62 | 0.14  |
| ORD 25 | -2.99 | -1.70 | 0.17  | -1.47 | -0.40 |
| POS 01 | -2.85 | -1.01 | -1.49 | 0.69  | 0.27  |
| POS 02 | -0.95 | -1.51 | 1.21  | 1.18  | -0.17 |
| POS 03 | -2.17 | -2.40 | -1.24 | -0.07 | 1.11  |
| POS 04 | -1.80 | -0.66 | 0.34  | -0.14 | 0.54  |
| POS 05 | -2.30 | -1.44 | 0.86  | -0.72 | -0.24 |
| POS 42 | -1.58 | -1.01 | -2.74 | 0.28  | -0.53 |
| POS 47 | -2.77 | -0.62 | -0.76 | 0.13  | -0.13 |
| POS 48 | -1.99 | -2.02 | -1.20 | 0.95  | -0.17 |
| SG 69  | -2.91 | -1.25 | -0.46 | 1.61  | 0.69  |
| SG 70  | -1.85 | -1.49 | -1.58 | 1.00  | 0.29  |
| SG 80  | -2.76 | -1.51 | -1.92 | 0.97  | -0.15 |
| SG 76  | -2.47 | -1.83 | -0.86 | 1.14  | 0.37  |
| FAR 12 | 2.34  | -1.43 | 0.58  | -1.57 | 0.22  |
| FAR 13 | 3.13  | -1.65 | 0.63  | -1.54 | 0.13  |
| SP 20  | 2.61  | -0.63 | -0.79 | -1.05 | 0.22  |
| SP 21  | 3.33  | -1.24 | -0.99 | 0.90  | 0.61  |
| SP 22  | 3.15  | -1.09 | -0.26 | 0.80  | 0.68  |
| SP 34  | 3.16  | -1.16 | -0.96 | -0.99 | 0.44  |
| SP 35  | 3.12  | -0.24 | -0.69 | -1.20 | 0.22  |
| SP 36  | 3.22  | 0.08  | -1.27 | -1.68 | -0.16 |
| SGA 1  | 3.55  | 0.21  | 1.50  | -1.22 | 0.17  |
| SGA 2  | 3.47  | -0.44 | 3.00  | -0.52 | 0.47  |
| SGA 3  | 0.35  | 0.76  | 1.11  | 0.63  | 0.41  |
| 24     | 1.43  | -0.74 | 2.67  | 0.43  | -0.68 |
| 25     | 0.25  | -0.07 | 1.38  | -1.32 | -1.42 |
| 28     | -0.83 | 0.74  | 2.34  | -0.31 | -0.55 |
| 29     | 0.04  | 1.07  | 2.13  | -0.78 | -1.06 |
| 36     | 1.16  | -0.87 | 3.35  | -1.99 | -1.77 |
| 39     | 0.37  | -0.34 | 1.88  | -1.06 | -0.54 |
| 43     | -0.11 | 1.88  | 1.09  | -1.67 | -1.64 |
| 46     | -0.70 | 1.52  | 0.85  | -2.20 | -1.05 |
| 40     | 2.81  | -0.30 | 2.20  | -0.97 | -1.24 |
| 10     | 1.29  | 0.98  | 2.91  | -0.25 | -0.03 |
| 12     | -1.29 | 0.23  | 2.80  | 0.60  | -0.07 |
| 18     | 0.59  | 1.26  | 1.90  | -1.17 | -0.57 |
| 09     | 1.48  | 0.98  | 0.16  | 0.67  | -0.09 |
| 38     | 1.77  | 1.05  | 2.16  | -1.29 | -0.55 |
| 44     | 1.75  | 1.26  | 1.73  | -1.73 | -0.86 |
| 45     | 0.93  | 2.34  | -0.80 | -1.72 | -0.56 |
| 50     | 0.07  | -0.27 | 1.28  | -1.19 | -0.40 |
| 51     | 1.11  | 1.49  | -0.29 | -0.18 | -0.39 |
| 04     | 2.38  | -0.01 | 2.23  | -0.78 | -0.93 |
| 07     | -0.94 | 0.41  | 1.06  | -2.00 | -0.96 |
| 03     | -0.44 | -0.48 | 1.82  | -0.82 | -0.84 |
| 05     | 1.76  | -0.59 | -0.08 | 1.18  | -0.65 |
| 19     | 2.70  | 0.63  | 2.16  | -0.96 | -0.86 |
| 20     | -0.93 | 0.34  | 1.94  | -0.70 | -0.85 |
| 21     | 0.53  | 0.57  | 1.91  | -0.73 | -1.04 |
| FARS 2 | 7.59  | -6.13 | -0.01 | -1.06 | 2.73  |
| FARS 3 | 6.69  | -6.10 | 0.42  | -0.54 | 3.26  |
| SGA 10 | -3.15 | 1.57  | 2.57  | -0.77 | 0.93  |
| SGA 11 | 2.58  | -0.59 | 1.83  | -0.93 | 0.39  |
| SGA 7a | 6.50  | -2.46 | 2.22  | -0.61 | 0.69  |
| SGA 7c | 3.77  | -0.77 | 1.69  | -0.99 | 0.54  |
| SGA 8a | 4.72  | -2.35 | 1.52  | -1.10 | -0.24 |
| SGA 8b | 5.99  | -3.31 | 1.34  | -0.97 | -0.20 |
| SGA 8c | 7.30  | -4.12 | 1.01  | -0.82 | -0.24 |
| SGA 9a | 5.38  | -2.03 | 0.87  | -1.04 | -0.13 |
| SGA 9b | 6.12  | -2.39 | 0.62  | -1.11 | 0.07  |
| SGA 9c | 4.23  | -1.23 | -0.69 | -1.24 | -0.22 |

|         |       |       |       |       |       |
|---------|-------|-------|-------|-------|-------|
| 32      | -2.99 | -0.10 | 2.14  | 0.09  | -0.43 |
| 41      | 1.49  | -2.25 | 0.96  | 1.75  | -0.23 |
| 42      | 0.20  | -1.35 | 0.62  | 0.29  | 0.02  |
| 31      | -0.64 | -1.66 | -0.18 | 0.53  | -0.45 |
| 35      | -2.97 | -0.59 | 2.33  | 0.28  | -0.05 |
| 17      | -5.13 | 1.40  | 3.15  | 0.64  | 0.90  |
| 48      | -2.40 | -0.37 | 1.90  | -0.15 | -0.75 |
| 49      | -0.74 | -1.78 | 2.10  | 0.42  | -0.91 |
| 53      | -0.43 | -3.53 | 0.55  | 1.46  | 0.47  |
| 52      | -2.67 | -1.76 | 2.55  | 0.11  | 0.73  |
| 56      | 5.45  | -2.43 | 1.97  | 1.54  | 0.20  |
| 55      | 4.58  | -1.52 | 1.78  | 0.97  | 0.79  |
| SGA 4a  | 2.45  | 0.40  | -0.73 | 1.10  | -0.75 |
| SGA 4b  | 2.55  | 0.80  | -0.63 | -0.21 | -0.53 |
| TFA     | 7.66  | -6.39 | -0.11 | -1.16 | 2.71  |
| 23      | 2.80  | -0.95 | -0.36 | 0.36  | -0.84 |
| 26      | 3.25  | -2.85 | -0.24 | 0.49  | -0.93 |
| 47      | -0.45 | -0.87 | -0.01 | 0.81  | -0.22 |
| 27      | 1.92  | -0.94 | -0.65 | -0.17 | -0.33 |
| 22      | -1.81 | 3.42  | 0.17  | -3.95 | -1.57 |
| 34      | 1.30  | -2.03 | -0.03 | 0.02  | -0.11 |
| 33      | 2.31  | -3.81 | -0.03 | 1.11  | -0.61 |
| 30      | 0.66  | -0.18 | 2.33  | -0.75 | -0.83 |
| 08      | 3.84  | 0.68  | -0.12 | -0.19 | -0.37 |
| 15      | 2.74  | 2.16  | -0.39 | 0.21  | -0.86 |
| SGA 5   | 2.43  | 0.74  | -0.79 | 0.99  | -1.20 |
| 14      | 2.71  | 0.08  | -0.07 | -0.15 | -0.30 |
| 37      | -0.23 | 1.29  | 0.26  | 0.85  | -0.18 |
| 57      | 3.65  | -3.68 | -0.02 | 2.22  | -0.33 |
| 54      | 1.90  | -1.30 | -0.59 | 0.46  | -0.26 |
| 06      | 3.28  | -0.06 | -0.52 | 0.09  | -0.93 |
| 01      | 2.21  | 1.93  | -0.73 | 1.11  | -0.90 |
| 02A     | 2.33  | 0.75  | -0.94 | 0.10  | -1.24 |
| 02B     | 2.44  | 0.16  | -0.71 | 0.46  | -1.25 |
| 11      | 1.92  | 2.59  | -0.59 | -0.02 | -0.58 |
| 13      | 1.70  | 1.24  | -0.63 | 0.19  | -0.47 |
| 16      | 2.95  | -1.27 | -0.21 | 2.34  | -0.54 |
| SGA 6   | 2.28  | 0.96  | -0.68 | 0.86  | -1.19 |
| FARA 31 | 1.80  | -0.50 | -0.17 | 0.80  | -0.13 |