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A Unique Lower Mantle Source for Southern Italy Volcanics

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Abstract

The Southern Italy volcanism is characterized by the unusual occurrence of volcanic rocks with ocean-island basalt (OIB)-like characteristics, in particular at Etna and Iblean Mts in Sicily. The geochemical properties of the source of the Italian magmatism are usually explained by a north-south binary mixing between a mantle- and a crustally-derived end-members. The nature of the mantle end-member is, however, not agreed upon. One type of interpretation invokes a mixture of depleted mantle (DMM) and high U/Pb (HIMU) end-members (Gasperini et al., 2002), whereas an alternative view holds that the mantle end-member is unique and homogeneous, and similar to the FOZO- or C-type end-member identified in oceanic basalts (Bell et al., 2004). Because mixing does not produce linear relationships between the isotopic compositions of different elements, we applied Principal Component Analysis (PCA) to the Pb isotope compositions of the Italian volcanics inclusive of Sicily volcanoes. We demonstrate that HIMU cannot be an end-member of the Italian volcanics, but rather that the common component C (~FOZO), which we interpret as reflecting the lower mantle, best represents the mantle source of the Italian magmatism. Our PCA calculation shows that the first principal component alone, which we take to be a mixture of two geochemical end-members, C and a crustally-derived component, explains 99.4% of the whole data variability. In contrast, the DMM end-member (the second principal component) is only present in the volcanics from the Tyrrhenian Sea floor. The C-like end-member, well represented by the Etna and Iblean Mts (Sicily), has relatively low $^{3}He/^{4}He$ ratios suggesting upwellings of lower mantle material from the 670 km transition zone. A slab detachment beneath the central- southern Italy and probably the Sicily could account for the particular character of Italian magmatism.

Keywords: Italian magmatism; OIB; Lead isotopes; Principal Component Analysis; Common component; Slab detachment.

1. Introduction

The presence in oceanic basalts of a common mantle component that is not the ubiquitous depleted upper mantle (asthenosphere) of mid-ocean ridge basalts (MORB) is probably one of the major findings of igneous isotope geochemistry (Farley and Craig, 1992; Hanan and Graham, 1996; Hart et al., 1992). Although all these authors concur that this common mantle component, dubbed FOZO (FOcus ZOne) by Hart et al. (1992), PHEM (Primitive HElium Mantle) by Farley and Craig (1992), and C (Common component) by Hanan and Graham (1996), may represent the lower mantle, it has been recognized, probably most vividly by Hanan and Graham, that it is not unequivocally associated with high $^{3}He/^{4}He$ ratios and therefore does not carry the signature of primordial material. How ubiquitous the common component (which we will hereafter refer to as C in recognition of the criteria used by Hanan and Graham that were probably the strongest) and therefore how widespread upwellings of lower mantle may be, is still unknown. One of the places where such an upwelling was suggested is Southern Italy. Since the work of Hamelin et al. (1979), several authors have emphasized the presence of a strong ocean island basalt (OIB) 'flavor' in the lavas erupted in the area centred around Mt Etna, Sicily. More specifically, D'Antonio et al. (1996) and Gasperini et al. (2002) suggested that this flavor was due to a mixture of two standard mantle end-members: DMM, for depleted MORB mantle, and HIMU, for a high U/Pb reservoir. Gasperini et al. (2002) observed very well-defined mixing hyperbolas between mantle-derived and crustally-derived (or EM II) components in a variety of isotopic systems, which they suggested reflect a thorough mixture between these two components in the lavas from Southern Italy. Gasperini et al. (2002) inferred that OIB-type mantle is injected through a slab window created under the Southern part of the peninsula by the rotation of the downgoing slab subsequent to the Apennine collision, but wondered how hot spot material may get trapped in such an upwelling. However, Bell et al. (2004) argued that such a thorough pre-mixture of HIMU and DMM reminiscent of plume material is not necessary if the mantle component in question is actually a FOZO-like end-member, e.g., what can be regarded as garden-variety lower mantle. This hanging question (i.e., one or two mantle end-members at the origin of Italian volcanics) justifies more isotopic work on Italian volcanics. With most mafic lavas having received a great deal of attention (Conticelli et al., 2002; D'Antonio et al., 1996; 1999; Gasperini et al., 2002; Hawkesworth and Vollmer, 1979; Vollmer, 1976), we instead focused on analyzing new samples of mostly silicic to intermediate composition. The Italian silicic magmatism is mainly limited to Tuscany and belongs to the so-called Tuscan Magmatic Province (TMP, Peccerillo, 2002). These volcanic and plutonic silicic rocks occur without, or with only minor associated mafic rocks. Other silicic outcrops, not associated with mafic rocks, are found in the Central Tyrrhenian Sea, on the islands of Ponza and Palmarola (Pontine Archipelago, Gaeta Gulf; Fig.1).

2. Selected Italian volcanics and analytical methods

Eighteen samples from the TMP (Elba Island, San Vincenzo, Roccastrada, Radicofani, and Mt. Amiata volcano) and eleven samples from the western Pontine Islands (Ponza and Palmarola Islands) were analyzed. Their compositions are trachytic to rhyolitic, except for the Radicofani sample (84BH), which is a basaltic andesite, and the summit unit (latitic flow) and magmatic enclaves of Mt. Amiata, which are of trachyandesitic basaltic to trachyandesitic composition (84AE & 84AF; 84AD, -AM and –AQ; Table 1). The major and trace element compositions of these samples are reported and discussed in Cadoux (2005) and Cadoux et al. (2005). Pb isotopic compositions are listed in Table 1 and plotted in Figure 2. The Pb isotope data reported here for the Mt. Amiata magmatic enclaves and the Ponza and Palmarola volcanic rocks are the first in the literature. Lead for isotope analysis was separated in the clean lab at the Ecole Normale Supérieure in Lyon (ENSL) and the Pb isotopic compositions were measured by MC-ICP-MS using the VG model Plasma 54 at ENSL using the Tl-doping procedure of White et al. (2000) with recent adjustments to the procedure documented by Albarède et al. (2004) and Blichert-Toft et al. (2005). Analysis between every two samples of the NBS-981 Pb standard and, twice during every analysis session, also of our in-house Pb standard mixture ENSL-98B showed external reproducibility of 300, 350 and 430 ppm for, respectively, $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$. We reanalyzed the sample solutions for nine samples and except for two duplicate measurements of 83AA and 84BH (which show 610 and 533 ppm differences, respectively, on the $^{208}Pb/^{204}Pb$ ratio between the two analyses), the analyzed replicates fall well within the external error bars (Blichert-Toft et al., 2005).

3. Results

Figure 2 shows that the Pb isotope compositions of analyzed silicic/intermediate rocks are consistent with literature values on lavas of mafic compositions. The differentiated rocks have thus preserved the Pb isotopic signature of their magmatic sources. The $^{206}Pb/^{204}Pb$ ratios are in general lower for the Tuscan samples than for the samples from the Pontine Islands. The mafic enclaves from the Monte Amiata volcano are slightly more radiogenic than their silicic host rocks. There is very little dispersion in $^{207}Pb/^{204}Pb$ (with the exception of the San Vincenzo aplites). Even if the range of Pb isotope compositions is relatively narrow, the precision of our analytical technique permits to distinguish regional correlations between $^{208}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$: positive for Tuscany and negative for the Pontine Islands. Our Pb isotope data for Tuscany fall within the field of TMP literature values (Peccerillo, 2005; Fig.2), with the exception of the San Vincenzo aplites, which are more radiogenic in Pb than the other Tuscan samples. On the scale of the entire Italian Peninsula, the igneous rocks forming the TMP and the Pontine Islands are characterized by low $^{206}Pb/^{204}Pb$ and, for a given $^{206}Pb/^{204}Pb$, by radiogenic $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$.

4. Discussion

The ambiguity between a single typical FOZO/C-like component (lower mantle) and an assemblage of two end-members, one of which involves the upper mantle (DMM), in the source of the Italian volcanics is of important dynamic significance. It is, however, difficult to resolve these two scenarios in plots involving curvilear mixing trends, typically those based on the isotopic compositions of different elements (e.g., Bell et al., 2004; Gasperini et al., 2002). Instead, here we chose a different approach. We ran a statistical treatment, by the principal component analysis (PCA) method, of the Pb isotopic compositions on magmatic rocks from Italy and Sicily (Fig. 1). For a complete description of the PCA method, readers can refer to Le Maître (1982) and Albarède (1995). Why has been the PCA exclusively based on Pb data?

(1) Partial melting fractionates elemental ratios and, as a result of different melt histories, a binary mixture in the source does not translate into a single hyperbola in the melts. The resulting deviations from linearity greatly increase dispersion in the multi-elemental space of isotopic compositions, often to the extent that spurious end-members will appear.

(2) The Pb isotopes space preserves linearity during mixing so that the nature of the source components may be ascertained with a much higher degree of confidence. As discussed in Debaille et al. (2006), we chose the space of ^{206}Pb- instead of the conventional ^{204}Pb-normalized ratios so that correlations between analytical errors are minimized.

Our data set includes our new Pb isotopic data on silicic rocks from the Tuscany and the Pontine Islands (Table 1) combined with published data on mafic rocks from the Tuscan, Roman and Campanian Provinces, as well as data on the Tyrrhenian Sea floor (ODP sites 651 & 655), the Aeolian Islands and Sicily (Gasperini et al., 2002). The Pb isotope data set of

Gasperini et al. (2002) was selected here because it was obtained by the same analytical procedures in the same lab as the data of the present work.

In order to minimize ambiguities we will restrict the use of "component" to principal components, and contrary to general usage, refer to "end-members" for the geochemical components. Our PCA calculation indicates that the first two axis projections cover almost the totality of the initial information: axes 1+2 = 99.8 % of the total variability (Appendix 1). The first axis (or component) alone accounts for 99.4 % of the total variability. The third axis is thus considered as pure noise. It is noteworthy that there is a factor of about ten difference between component 1 (-3.3 to +0.7) and component 2 (-0.1 to +0.3).

In Figure 3, we plotted our own and the literature data in $^{208}Pb/^{206}Pb$ vs. $^{204}Pb/^{206}Pb$ and $^{208}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ diagrams together with compositions of Mid Atlantic Ridge (MAR) basalts (DMM end-member), ocean island basalts representative of the HIMU end-member, the common component C, and compositions of subducted sediments of world's trenches and the Italian crust. In order to determine the nature of the principal components 1 and 2, we projected the corresponding eigenvectors of the PCA in these two isotope spaces (Fig. 3). It reveals that the first component, accounting for nearly all the variability (99.4 %), does not point toward the HIMU composition defined by the type-locality samples but rather passes through the C end-member of Hanan and Graham (1996). This shows that the end-member giving rise to the OIB-like signatures of southern Italy volcanoes is consistent with C and not, as widely accepted so far (e.g., D'Antonio et al., 1996; Esperanza and Crisci, 1995; Gasperini et al., 2002; Hamelin et al., 1976; Schiano et al., 2001; Trua et al., 1998) with the HIMU end-member. The involvement of C component (or FOZO-like) rather than HIMU was already invoked by Bell et al. (2004) but here it is for the first time indisputably demonstrated with a different method.

The first principal component therefore corresponds to a mixture of two geochemical end-members: the C end-member and a crustally-derived end-member (Fig. 3). Our data do not allow discriminating between continental crust or subducted sediments. Even combined with other isotopic systems, it is very difficult to determine the exact nature of the crustal-like end-member, as attested by the multiple different names attributed to this end-member (e.g.: crustally-derived end-member, Gasperini et al., 2002; ITEM, Bell et al., 2004; or EM2*e*, Peccerillo and Lustrino, 2005). Based on a number of geochemical criteria, Gasperini et al. (2002) considered that the crustally-derived end-member is dominated by pelagic rather than terrigenous sediments. ITEM (for ITalian Enriched Mantle) is isotopically similar to the upper continental crust and Atlantic pelagic sediments and could represent metasomatized mantle (Bell et al., 2004). Finally, the EM2*e* (*e* for *enriched*) is an end-member defined by Peccerillo and Lustrino (2005) with Pb isotopic ratio close to EM2 (Enriched Mantle 2), but with much higher $^{87}Sr/^{86}Sr$. These authors favor the hypothesis of a mantle contamination by upper crust material brought into the upper mantle by subduction processes.

Taking into account the geology and tectonic setting of the region, both subducted sediments and upper continental crust are probably involved. Our interest here being the MANTLE source end-member of the Italian volcanics, we will not investigate further on the "*crustal*" one. Whatever its nature, it is better represented by the peninsular Italy volcanic rocks while the C end-member is better expressed in Sicily (Fig. 3). The Aeolian Islands seem to be a (nearly homogeneous) mixture of these two geochemical end-members.

The second eigenvector trends toward the MAR basalt field and the Tyrrhenian Sea floor basalts fall along this vector. We will thus accordingly assume that the second principal component is controlled by a DMM-type geochemical end-member. As emphasized by Bell et al. (2004) and shown by the present analysis, however, the contribution of the DMM end-member in the source of the Italian volcanism is extremely small since it represents no more than 0.4 % of the total variability present in our data, whereas the bulk of the variance of our data set is accounted for by the C and crustally-derived end-members mixture.

It is remarkable that a nearly pure composition of C is reached in Sicily (Etna and Ibleans; Fig. 3). In the following discussion we will focus on the isotope characteristics, the possible origin and the reasons for why the C component is sampled in this particular area.

Using the published isotopic data on Etna and Iblean Mts, the composition of the C end-member found in Sicily can be constrained as follows: low $^{87}Sr/^{86}Sr$ (~ 0.703), intermediate $^{143}Nd/^{144}Nd$ (0.51288-0.51306) and Pb isotope ratios ($^{206}Pb/^{204}Pb$ = 19.8-19.9, $^{207}Pb/^{204}Pb$ = 15.62-15.68, $^{208}Pb/^{204}Pb$ = 39.2-39.6; Gasperini et al., 2002), and relatively low $^{3}He/^{4}He$ (6.7-7.5 Ra; Sapienza et al., 2005 and references therein). This suggests a source with low Rb/Sr, moderate Sm/Nd, U/Pb, and Th/Pb, and low time-integrated $^{3}He/(U+Th)$. This latter feature could be explained by a source enriched in U+Th relative to primordial ^{3}He or a source relatively depleted in ^{3}He, such as the convecting upper-mantle MORB source ($^{3}He/^{4}He = 8 \pm 1$ Ra; Farley and Neroda, 1998; Hilton and Porcelli, 2003). It is noteworthy that the C end-member (Etna & Iblean Mts) displays the highest He isotope ratios (6.7-7.5 Ra) of all of the Italian volcanics (0.5 Ra < $^{3}He/^{4}He$ < 7.5 Ra; Sapienza et al., 2005).

The isotopic characteristics described above are roughly similar to those given by Hanan and Graham (1996), who defined the common component C on the basis of the convergence of MORB Pb isotope arrays (Atlantic, Pacific, and Indian MORB): $^{87}Sr/^{86}Sr$ = 0.703-0.704, $^{143}Nd/^{144}Nd$ = 0.51285-0.51295, $^{206}Pb/^{204}Pb$ = 19.2-19.8, $^{207}Pb/^{204}Pb$ = 15.55-15.65, and $^{208}Pb/^{204}Pb$ = 38.8-39.6, while He isotopic ratios are variable (both higher and lower than normal MORB). Regardless of the $^{3}He/^{4}He$ ratio of C, an increase in $^{3}He/^{4}He$ with the proportion of the C component is observed in both oceanic basalts (MORB and OIB) and Italian volcanics. Thus, the Italian volcanoes are part of the fan-shaped pattern of oceanic basalts converging on C in the Pb isotope space (Fig.1 in Hanan and Graham, 1996). Unlike

MORB and OIB, where the dominant binary mixing is C + DMM and C + EM1 respectively, the Italian volcanism is dominated by a C + crustally-derived end-members binary mixing.

Figure 4 shows that in the Italian volcanics, $^{3}He/^{4}He$ increases linearly with increasing $^{206}Pb/^{204}Pb$, i.e. in rocks plotting toward C (toward Southern Italy). The C-rich lavas from Southern Italy have $^{3}He/^{4}He$ transitional between the ratios commonly reported for MORB [24] and the SubContinental Lithospheric Mantle (SCLM, Gautheron and Moreira, 2002). In contrast, in Northern Italy, volcanic rocks have He and Pb isotopic compositions similar to those of the continental crust. This trend in He-Pb isotope space confirms that the Italian volcanism as a whole is a binary mixture between C and a crustally-derived source. The C end-member therefore may be representative of the mantle source of Italian volcanics. The stronger crustal isotopic signature in the northern Italy might be due to:

1) Shallow processes such as crustal anatexis, important interactions of the mantle liquids with continental crust, and

2) Compositionally different slabs: the presence of continental lithosphere (Adriatic slab) underneath the northern Apennines since about 25 Ma, while below the Calabrian Arc and the southern Tyrrhenian region a Mesozoic oceanic lithosphere (the Ionian slab) is subducting (e.g., Gueguen et al., 1998; Serri, 1990, Serri et al., 1993).

Hanan and Graham (1996) pointed out that in oceanic (MORB, OIB) basalts the C end-member is well characterized by its range in Sr, Nd, and Pb isotopic compositions but displays variable He isotopic ratios. The present interpretation also suggests that the C end-member beneath Southern Italy has $^{3}He/^{4}He$ ratios slightly lower than MORB values. Hart et al. (1992) first suggested that FOZO (or C) represents the lower mantle, which leads to the conclusion that the lower mantle has variable $^{3}He/^{4}He$. This is different from the canonical view (e.g., Allègre et al., 1983; Kellogg and Wasserburg, 1990; O'Nions and Oxburgh, 1983) that the lower mantle is a consistently high-$^{3}He/^{4}He$ reservoir. Such variability, however, does not necessarily create a problem if the lower mantle contains juxtaposed streaks of recycled oceanic lithosphere and primitive mantle (Boyet et al., 2005). Alternatively, one may choose to emphasize the similarity between $^{3}He/^{4}He$ ratios in the Southern Italian volcanics and in inclusions from the subcontinental lithosphere (Gautheron and Moreira, 2002) and consider that the C end-member represents delaminated SCLM. We do not favor this interpretation for two reasons:

(1) The ubiquitous association of DMM and C in mixing trends in Atlantic MORB (Agranier et al., 2005; Blichert-Toft et al., 2005, Graham, 2002) strongly suggests that the C end-member does not originate by melting of the modern SCLM. If it did, it would require that surprisingly large fractions of the convective mantle formed by foundered remnants of subcontinental lithosphere.

(2) SCLM formed at different times and does not mix laterally: a broad range of isotopic properties would therefore be expected corresponding to the various formation ages, which does not fit the rather well-defined Sr, Nd, and Pb isotopic compositions of the C end-member.

We therefore favor the interpretation of the C end-member as representing lower mantle. The lower mantle being usually considered to be a high $^{3}He/^{4}He$ mantle reservoir (Allègre et al., 1983; Kellogg and Wasserburg, 1990; O'Nions and Oxburgh, 1983), we suggest that C is located at the 670 km seismic discontinuity (the boundary between upper and lower mantle) rather than inside the lower mantle or at the core-mantle boundary because of its relatively low (MORB-like) helium isotopic ratios in Sicily. As discussed in Hanan and Graham (1996), C material can have both high and low He isotopic ratios; C with low $^{3}He/^{4}He$ might originate from regions of the 670 km transition zone where recycled or altered oceanic crust has been stored (e.g., Ringwood, 1994). Taking into account that the geodynamic history of the Mediterranean area is marked by several subductions since the last

Cretaceous time (e.g., Stampfli and Borel, 2004), this hypothesis is credible. In our mind, the most probable mechanism allowing the sampling of C material from the 670 km boundary layer is a slab detachment or slab window beneath the central-southern Italy. This hypothesis is supported by different arguments:

1) Many independent tomographic studies corroborate the existence of a zone of negative wave-speed anomalies in the top 200-250 km under the central-southern Apennines (e.g., Bijwaard and Spakman, 2000; Cimini and Gori, 2001; Piromallo and. Morelli, 1997, 2003; Spakman, 1991; Spakman et al., 1993, Spakman and. Wortel, 2004).

2) This is consistent with the modelling results of Van der Zeddle and Wortel (2001) who showed that slab detachment can occur at shallow level (until Moho depth) and allow inflow of hot asthenosphere and subduction wedge mantle.

3) Numerical modelling (Wong and Wortel, 1997; Yoshioka and. Wortel, 1995) further demonstrates that slab detachment and its lateral migration is a feasible process, particularly in the late subduction stage, when continental lithosphere enters the trench (i.e., the collision stage).

4) According to Carminati et al. (2002), the strong rheologic contrast between a continental (Adriatic) and an oceanic (Ionian) slab is likely amplified by the higher strain rates and cooler slab temperatures in the southern Italy due to the faster subduction rollback and the oceanic composition of the downgoing lithosphere.

5) Paleogeographic and tectonic reconstructions demonstrate that the central-southern Apennines detachment could have occurred in the Pliocene because of differential plate velocities between the Northern Apennines (where continental lithosphere was subducting) and the Central-Southern Apennines beneath which the slab were rolling back quickly toward southeast (e.g., Carminati, et al., 1998; Rosenbaum et al., 2002; Rosenbaum and Lister, 2004).

6) Finally, Davies and Von Blanckenburg (1995) noted that a slab detachment may cause specific change in the volcanics geochemistry from more subduction-related calc-alkaline to more intraplate-like alkaline as it is observed from Northern to Southern Italy, respectively (e.g., Peccerillo, 2005 and references therein).

One problem encountered with this model is that the negative wave-speed anomaly (interpreted as a slab detachment) becomes smaller toward the Calabria arc and is not visible beneath Sicily in most of the tomographic mantle models. However, as mentioned by Spakman and Wortel (2004), none of these models has the spatial resolution to exclude a small slab detachment in this area. An alternative (or complementary) process could be invoked for this particular Sicilian area: the development of a tear at the western edge of the Ionian plate combined with its roll-back and steepening motion, could favor the "suction" of asthenospheric material from under the neighboring African plate (Dvorkin et al., 1993; Gvirtzman and Nur, 1999; Trua et al., 2003). According to Dvorkin et al. (1993), the narrow slabs rolling back relatively quickly, such as the Ionian plate, are excellent candidates for lateral asthenospheric fluxes above the slab. It is important to consider the particular location of Mt Etna. It is situated on the suture between the converging European and African plates (Fig.1), a little to the side of the Ionian slab rather than directly above it, and it lies where the top of the slab is as at ~70 km depth (Gvirtzman and Nur, 1999); this depth is too shallow to permit melting of the Tyrrhenian mantle wedge (however beneath the Aeolian islands, the top of the slab is deep enough to produce such a melting). Moreover, it is noteworthy that the Etna and Iblean Mts have the same nearly pure C composition (suggesting a similar source) while they are located on either side of the subduction front (Fig.1). Finally, as emphasized by Trua et al. [55], Etna is an OIB-*like* rather than an OIB-*type* as it the case for Iblean Mts. All these observations further support the idea that Mt Etna is not fed by material coming from the Tyrrhenian mantle wedge between the subducting and overriding plates (Gvirtzman and Nur, 1999).

Figure 5 illustrates our view of the mantle structure beneath Italy. Here, we emphasized the involvement of AFRICAN mantle in the source of Italian volcanics as it has been already suggested for the most southern Italy volcanoes (e.g., Etna and Ibleans; Gvirtzman and Nur, 1999; Trua et al., 2003) and recently for the Campanian volcanoes (e.g., Vesuvius; De Astis et al., 2006). How the African mantle passes through the slab detachment is difficult to determine. In our model, we arbitrary assume fingers-like upwellings.

How such a process could have taken place without triggering the entrainment of depleted upper mantle probably reflects that the upper mantle beneath Italy is particularly cold, likely as a result of the multiple Mediterranean subduction systems (Apennines, Maghrebides, Betic-Alboran, Dinarides, Aegean) that have been present for the last ~30 My over a rather small distance (e.g., Gueguen et al., 1998).

4. Conclusions

A single end-member, the common component C, representative of lower mantle, can account for the OIB flavor of the southern Italy volcanoes, particularly Etna and Iblean Mts. The whole of Italian magmatism can be considered as a dominant mixture of C and a crustally-derived end-member, with a more important proportion of this latter in Northern Italy. The presence of C in Italy further supports the idea that the common end-member of oceanic basalts is also present in continental domains (e.g., Bell and Tilton, 2001; Dunworth and Bell, 2001) and is thus as ubiquitous as the DMM end-member. The reasons for why the DMM is so poorly expressed in the source of the Italian volcanism and the mechanisms responsible for the upwelling of the lower mantle have yet to be explored.

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REFERENCES

Agranier, A., Blichert-Toft, J., Graham, D., Debaille, V., Schiano, P., Albarède, F., 2005.The spectra of isotopic heterogeneities along the mid-Atlantic Ridge, Earth Planet. Sci. Lett. 238, 96-109.

Albarède, F., Introduction to Geochemical Modeling, 1995 Cambridge Univ. Press, New York.

Albarède, F., Télouk, P., Blichert-Toft, J., Boyet, M., Agranier, A., Nelson, B., 2004. Precise and accurate isotopic measurements using multiple-collector ICPMS, Geochim. Cosmochim. Acta 68, 2725-2744.

Allègre, C.J., Staudacher, T., Sarda, P., Kurz, M., 1983. Constraints on evolution of Earth's mantle from rare gas systematics, Nature 303, 762-766.

Bell, K., Tilton, G.R., 2001. Nd, Pb and Sr isotopic compositions of East African carbonatites: Evidence for mantle mixing and plume inhomogeneity, J. Petrol. 42, 1927–1945.

Bell, K., Castorina, F., Lavecchia, G., Rosatelli, G., Stoppa, F., 2004. Is there a mantle plume below Italy? EOS 85, 541-547.

Bijwaard, H., Spakman, W., 2000. Non-linear global P-wave tomography by iterated linearized inversion, Geophys. J. Int. 141, 71–82.

Blichert-Toft, J., Agranier, A., Andres, M., Kingsley, R., Schilling, J.-G, Albarède, F., 2005. Geochemical segmentation of the Mid-Atlantic Ridge north of Iceland and ridge–hot spot interaction in the North Atlantic, G-cubed 6, 1-27.

Boriani, A., Origoni, E.G., Pinarelli, L., 1995. Paleozoic evolution of southern Alpine crust (northern Italy) as indicated by contrasting granitoid suites, Lithos 35, 47-63.

Boyet, M., Garcia, M.O., Pik, R., Albarède, F., 2005. A search for ^{142}Nd evidence of primordial mantle heterogeneities in plume basalts, Geophys. Res. Lett. 32, (L04306, doi:04310.01029/02004GL021873.).

Cadoux, A., 2005. Le magmatisme acide Plio-Pleistocène de la Marge Tyrrhénienne (Italie Centrale) : Géochronologie, Pétrogénèse et Implications Géodynamiques, Earth Sciences PhD Thesis, Université Paris Sud XI.

Cadoux, A., Pinti, D.L., Aznar, C., Chiesa, S., Gillot, P.-Y., 2005. New Chronological and Geochemical Constraints on the Genesis and Geological Evolution of Ponza and Palmarola Volcanic Islands (Tyrrhenian Sea, Italy), Lithos 81, 121-151.

Caggianelli, A., Del Moro, A., Paglionico, A., Piccarreta, G., Pinarelli, L., Rottura, A., 1991. Lower crustal granite genesis connected with chemical fractionation in the continental crust of Calabria (Southern Italy), Eur. J. Mineral. 3, 159-180.

Carminati, E., Wortel, M.J.R., Spakman, W., Sabadini, R., 1998. The role of slab detachment processes in the opening of the western-central Mediterranean basins: some geological and geophysical evidence, Earth Planet. Sci. Lett. 160, 651-665.

Carminati, E., Giardina, F., Doglioni, C., 2002. Rheological control of subcrustal seismicity in the Apennines subduction (Italy), Geophys. Res. Lett. 291882, doi:1810.1029/2001GL014084.

Cimini, G.B., De Gori, P., 2001. Nonlinear P-wave tomography of subducted lithosphere beneath central-southern Apennines (Italy), Geophysical Research Letters 28, 4387-4390.

Conticelli, S., 1998. The effect of crustal contamination on ultrapotassic magmas with lamproitic affinity: mineralogical, geochemical and isotope data from the Torre Alfina lavas and xenoliths, Central Italy, Chem. Geol. 149, 51-81.

Conticelli, S., D'Antonio, M., Pinarelli, L., Civetta, L., 2002. Source contamination and mantle heterogeneity in the genesis of Italian potassic and ultrapotassic volcanic rocks: Sr-Nd-Pb isotope data from Roman province and southern Tuscany, Mineralogy and Petrology 74, 189-222.

D'Antonio, M., Di Girolamo, P., 1995. Petrological and geochemical study of mafic shoshonitic volcanics from Procida-Vivara and Ventotene Islands (Campanian Region, South Italy), Acta Vulcanol. 5, 69-80.

D'Antonio, M., Tilton, G.R., Civetta, L., 1996. Petrogenesis of Italian alkaline lavas deduced from Pb-Sr-Nd isotope relationships, in: Basu, A., and Hart, S.R., (Eds), Earth processes: reading the isotopic code 95, AGU (Monograph Series), Washington, DC, pp. 253–267.

D'Antonio, M., Civetta, L., Di Girolamo, P., 1999. Mantle source heterogeneity in the Campanian Region (South Italy) as inferred from geochemical and isotopic fetaures of mafic volcanic rocks with shoshonitic affinity, Mineralogy and Petrology 67, 163-192.

Davies, J.H., Von Blanckenburg, F., 1995. Slab breakoff: A model of lithosphere detachment and its test in the magmatism and deformation of collisional orogens, Earth Planet. Sci. Lett. 129, 85-102.

De Astis, G., Kempton, P.D., Peccerillo, A., Wu, T.W., 2006. Trace element and isotopic variations from Mt. Vulture to Campanian volcanoes: constraints for slab detachment and mantle inflow beneath southern Italy, Contrib Mineral. Petrol. 151, 331–351.

Debaille, V., Blichert-Toft, J., Agranier, A., Doucelance, R., Schiano, P., Albarède, F., 2006. Geochemical component relationships in MORB from the Mid-Atlantic Ridge, 22-35°N, Earth Planet. Sci. Lett. 241, 844-862.

Dunworth, E.A., Bell, K., 2001. The Turiy Massif, Kola Peninsula, Russia: isotopic and geochemical evidence for multi-source evolution, J. Petrol. 42, 377–405.

Dvorkin, J., Nur, A., Mavko, G., Ben-Avraham, Z., 1993. Narrow subducting slabs and the origin of backarc basins, Tectonophysics 227, 63-79.

Esperanza, S., Crisci, G.M. 1995. The island of Pantelleria: a case for the development of DMM-HIMU isotopic compositions in a long-lived extensional setting, Earth Planet. Sci. Lett. 136, 167-182.

Farley, K.A., Craig, H., 1998. Mantle plumes and mantle sources, Science 258(1992) 821-822.

Farley, K.A., Neroda, E., 1998. Noble Gases in the Earth's mantle, Annual Review of Earth and Planetary Sciences 26, 189-218.

Gasperini, D., Blichert – Toft, J., Bosch, D., Del Moro, A., Macera, P., Albarède, F., 2002. Upwelling of deep mantle material through a plate window: Evidence from the geochemistry of Italian basaltic volcanics, J. Geophys. Res. 107, 2367-2386.

Gautheron, C.E., Moreira, M., 2002. Helium signature of the subcontinental lithospheric mantle, Earth Planet. Sci. Lett. 199, 39-47.

Gianelli, G., Puxeddu, M., 1979. An attempt of classifying the Tuscan Paleozoic: geochemical data, Mem. Soc. Geol. It. 20, 435-446.

Graham, D.W., 2002. Noble Gas Isotope Geochemistry of Mid-Ocean Ridge and Ocean Island Basalts: Characterization of Mantle Source Reservoirs, in: Porcelli, D., Ballentine, C.J., Wieler, R., (Eds), Noble Gases in Geochemistry and Cosmochemistry, Reviews in Mineralogy and Geochemistry 47, Mineralogiocal Society of America, Washington DC, pp. 247-319.

Gueguen, E., Doglioni, C., Fernandez, M., 1998. On the past-25 Ma geodynamic evolution of the western Mediterranean, Tectonophysics 298, 259-269.

Gvirtzman, Z., Nur, A., 1999. The formation of Mount Etna as the consequence of slab rollback, Nature 401, 782-785.

Hamelin, B., Lambret, B., Moron, J.L., Treuil, M., Allègre, C.J., 1979. Geochemistry of basalts from the Tyrrhenian Sea, Nature 278, 832-834.

Hanan, B.B., Graham, D.W., 1996. Lead and Helium Isotope Evidence from Oceanic Basalts for a Common Deep Source of Mantle Plumes, Science 272, 991-995.

Hart, S.R., Hauri, E.H., Oschmann, L.A., Whitehead, J.A., 1992. Mantle plumes and entrainment: Isotopic evidence, Science 256, 517-520.

Hawkesworth, C.J., Vollmer, R., 1979. Crustal contamination versus enriched mantle: $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ evidence from the Italian volcanics, Contrib. Mineral. Petrol. 69, 151-165.

Hilton, D.R., Porcelli, D., 2003. Noble gases as mantle tracers, in: Carlson, R.W., (Ed), Treatise on Geochemistry 2, Elsevier, pp. 277-318.

Kellogg, L.H., Wasserburg, G.J., 1990. The role of plumes in mantle helium fluxes, Earth Planet. Sci. Lett. 99, 276-289.

Le Maitre, R.W., 1982, Numerical Petrology; statistical interpretation of geochemical data, Elsevier, Amsterdam.

O'Nions, R.K., Oxburgh, E.R., Heat and helium in the Earth, Nature 306(1983) 429-431.

Peccerillo, A., 2002. Plio-Quaternary magmatism in Central-Southern Italy: a new classification scheme for volcanic provinces and its geodynamic implications, Boll. Soc. Geol. It. Volume speciale n.1, 113-127, 112 ff.

Peccerillo, A., 2005. Plio-Quaternary volcanism in Italy. Petrology, Geochemistry, Geodynamics, Springer, Heidelberg.

Peccerillo, A., Lustrino, M., 2005, Compositional variations of Plio-Quaternary magmatism in the circum-Tyrrhenian area: Deep- vs. shallow-mantle processes, in: Foulger, G.R., Natland, J.H., Presnall, D.C., Anderson, D.L., (Eds), Plates, Plumes & Paradigms Special Paper 388, Geological Society of America, pp. 422-434.

Pinarelli, L., 1991. Geochemical and isotopic (Sr, Pb) evidence of crust-mantle interaction in acidic melts - The Tolfa-Cerveteri-Manziana volcanic complex (central Italy): a case history, Chem. Geol. 92, 177-195.

Piromallo, C., Morelli, A., 1997. Imaging the Mediterranean upper mantle by P-wave travel time tomography, Ann. Geofis. XL, 963-979.

Piromallo, C., Morelli, A., P wave 2003. tomography of the mantle under the Alpine-Mediterranean area, J. Geophys. Res. 108, 110, 123.

Plank, T., Langmuir, C.H., 1998. The geochemical composition of subducting sediment and its consequences for the crust and mantle, Chem. Geol. 145, 325-394.

Ringwood, A.E., 1994. Role of the transition zone and 660 km discontinuity in mantle dynamics, Physics of The Earth and Planetary Interiors 86, 5-24.

Rosenbaum, G., Lister, G.S., Duboz, C., 2002. Reconstruction of the tectonic evolution of the western Mediterranean since the Oligocene, J. Virtual Explorer 8, 107 – 130.

Rosenbaum, G., Lister, G.S., 2004. Neogene and Quaternary rollback evolution of the Tyrrhenian Sea, the Apennines, and the Sicilian Maghrebides, Tectonics 23, 1-17.

Sapienza, G., Hilton, D.R., Scribano, V., 2005. Helium isotopes in peridotite mineral phases from Hyblean Plateau xenoliths (south-eastern Sicily, Italy), Chem. geol. 219, 115-129.

Schiano, P., Clocchiatti, R., Ottolini, L., Busà, T., 2001. Transition of Mount Etna lavas from a mantle-plume to an island-arc magmatic source, Nature 412, 900-904.

Serri, G., 1990. Neogene-Quaternary magmatism of the Tyrrhenian region: characterization of the magma sources and geodynamic implications, Mem. Soc. Geol. It. 41, 219-242.

Serri, G., Innocenti, F., Manetti, P., 1993. Geochemical and petrological evidence of the subduction of delaminated Adriatic continental lithosphere in the genesis of the Neogene-Quaternary magmatism of central Italy, Tectonophysics 223, 117-147.

Spakman, W., 1991. Delay time tomography of the upper mantle below Europe, the Mediterranean, and Asia Minor, Geophys. J. Int. 107, 309-332.

Spakman, W., Van der Lee, S., Van der Hilst, R., 1993. Travel-time tomography of the European-Mediterranean mantle down to 1400 km, Physics of The Earth and Planetary Interiors 79, 3-74.

Spakman, W., Wortel, R., 2004. A Tomographic View on Western Mediterranean Geodynamics, in: Cavazza, W., Roure, F., Spakman, W., Stampfli, G.M., Ziegler, P.A., (Eds), The TRANSMED Atlas, The Mediterranean Region from Crust to Mantle, Springer-Verlag, Berlin Heidelberg, pp. 31-52.

Stampfli, G.M., Borel, G.D., 2004. The TRANSMED Transects in space and time: Constraints on the Paleotectonic Evolution of the Mediterranean Domain, in: W. Cavazza, F. Roure, W. Spakman, G.M. Stampfli, P.A. Ziegler, (Eds), The TRANSMED Atlas - The Mediterranean Region from Crust to Mantle, Springer, Berlin, Heidelberg, pp. 53-80.

Trua, T., Esperanza, S., and Mazzuoli, R., 1998. The evolution of the lithospheric mantle along the N. African plate: geochemical and isotopic evidence from the tholeiitic and alkaline volcanic rocks of the Hyblean plateau, Italy, Cont. Min. Pet. 131, 307-332.

Trua, T., Serri, G., M. Marani, P., 2003. Lateral flow of African mantle below the nearby Tyrrhenian plate: geochemical evidence, Terra Nova 15, 433-440.

Van de Zedde, D.M.A., Wortel, M.J.R., 2001. Shallow slab detachment as a transient source of heat at midlithospheric depths, Tectonics 20, 868–882.

Vollmer, R., 1976. Rb-Sr and U-Th-Pb systematics of alkaline rocks: the alkaline rocks from Italy, Geochim. Cosmochim. Acta 40, 283-295.

White, W.M., Albarède, F., Telouk, P., 2000, High-precision analysis of Pb isotope ratios by multi-collector ICP-MS, Chem. Geol. 167, 257-270.

Wong, S.Y.M., Ton, A., Wortel, M.J.R, 1997. Slab detachment in continental collision zones: An analysis of controlling parameters, Geophys. Res. Lett. 24, 2095-2098 (GeoRL Homepage).

Yoshioka, S., Wortel, M.J.R., 1995. Three-dimensional numerical modeling of detachment of subducted lithosphere, Journal of Geophysical Research 100, 20223-20244 (JGR Homepage).

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FIGURE CAPTIONS

Fig. 1. Digital Elevation Model of Italy (built from 1 minute gridded GEBCO data) with data location. White squares: this study (data reported in Table 1); black squares: Gasperini et al. (2002). TMP, Tuscan Magmatic Province; RMP, Roman Magmatic Province. The present location of the subduction front (D. Frizon de Lamotte, personal communication) and the European and African plates are indicated.

Fig. 2. a) $^{208}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ and **b)** $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ with their respective error bars for the studied rocks of Tuscany and the Pontine archipelago. Pontine symbols: black triangles = Palmarola, squares = Ponza (white = rhyolites, grey = trachytic unit). Tuscan (TMP) sample symbols: black bold right cross = Radicofani; circles = Amiata (white = rhyodacites, grey = latites, black = enclaves), white tilted crosses = Roccastrada, black tilted cross = Elba, white diamonds = San Vincenzo samples.

TMP and RMP mafic rocks fields are drawn from the database of Peccerillo (2005); Ventotene island data from D'Antonio and Girolamo (1995).

Fig. 3. $^{208}Pb/^{206}Pb$ vs. $^{204}Pb/^{206}Pb$ and $^{208}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ diagrams showing the rocks studied relative to the DM and HIMU end-members, the C common component, and crustal reservoirs. Data sources: HIMU data from the GEOROC database (http://georoc.mpch-mainz.gwdg.de/georoc/), MAR data from the PETDB database (http://www.petdb.org/index.jsp), C composition from Hanan & Graham (1996), subducted sediments of world's trenches from Plank and Langmuir (1998), and Italian Crust from Gianelli & Puxeddu (1979), Caggianelli et al. (1991), Pinarelli (1991), Boriani et al. (1995), Conticelli (1998), and Conticelli et al. (2002) The first two principal component eigenvectors

are drawn from the mean value of Pb isotope compositions of Italian magmatic rocks (this study and Gasperini et al., 2002).

Fig. 4. $^{3}He/^{4}He$ (R/Ra) vs. $^{206}Pb/^{204}Pb$ covariation of Italian volcanic rocks. Helium data for Italian rocks are extracted from the compilation of Sapienza et al. (2005). Typical MORB and SCLM He isotopic ranges are reported (Farley and Neroda, 1998; Gautheron and Moreira, 2002; Hilton and Porcelli, 2003) for reference. Italian crust range is from Conticelli et al. (2002) Italian rocks: same symbols as in Fig. 3.

Fig. 5. Cartoon depicting a possible geodynamic model for Italian magmatism (modified after the interpretative model of Spakman and Wortel (2004). For sake of clarity, only the subducting lithospheres have been represented. This model focuses on the slab detachment process and its probable lateral migration toward Calabria and Sicily, the slab tearing would induce decompression triggering vertical fluxes of African mantle from the 670km boundary layer. In the particular case of Sicily, two possibilities have been illustrated based on two hypotheses: 1) the Ionian slab is slightly detached at shallow level (so that the tomography does not detect it) and C material passes through the tear, and/or 2) as suggested by Gvirtzman and Nur (1999), there is a tear at the western edge of Ionian slab (between the Ionian and African plates) which, combined with the slab roll-back and steepening motions trigger suction of the neighbor African asthenosphere.

TABLE CAPTION

Table 1. Lead isotopic compositions for intermediate-silicic rocks from the Tuscan Magmatic Province and the Pontine Islands (this study). The location and rock type of the samples are indicated. The variable values for component 1 (C1) and component 2 (C2) of the Principal Component Analysis are also reported.

Table 1. Pb isotope compositions for intermediate-silicic rocks from the islands of Ponza and Palmarola (Pontine Archipelago) and Tuscany

Sample	Locality	Unit	Rock type	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	C1 (99.4%)	C2 (0.4%)
Pontine Archipelago								
83A	Ponza Island	dyke	rhyolite	18.789	15.674	38.979	0.264	0.018
83E	Ponza Island	hyaloclastite	rhyolite	18.807	15.678	38.996	0.214	0.010
83F2	Ponza Island	hyaloclastite	rhyolite	18.803	15.676	38.993	0.224	0.011
83L	Ponza Island	hyaloclastite	rhyolite	18.807	15.678	38.997	0.214	0.009
83M3	Ponza Island	hyaloclastite	rhyolite	18.802	15.676	38.994	0.228	0.010
				18.797	15.669	38.973	0.223	0.026
83N	Ponza Island	dyke	rhyolite	18.783	15.676	38.972	0.284	0.022
				18.778	15.671	38.957	0.285	0.033
83T	Ponza Island	hyaloclastite	rhyolite	18.793	15.667	38.968	0.231	0.028
83R	Ponza Island	Punta della Guardia neck	trachyte	18.766	15.671	38.967	0.337	0.020
83T2	Ponza Island	Mt. Guardia dome	trachyte	18.760	15.665	38.942	0.334	0.039
				18.757	15.663	38.940	0.341	0.040
83AA	Palmarola Island	hyaloclastite	rhyolite	18.825	15.677	39.038	0.174	-0.020
				18.812	15.663	38.991		
83Z	Palmarola Island	dome	rhyolite	18.810	15.671	39.008	0.201	0.000
Tuscany (TMP)								
84AE	Monte Amiata	OLL	trachydacite	18.721	15.678	38.992	0.534	-0.018
84AF	Monte Amiata	OLL	trachydacite	18.723	15.680	38.999	0.534	-0.023
84AH	Monte Amiata	DLC	trachydacite	18.721	15.681	39.003	0.545	-0.027
84AN	Monte Amiata	DLC	trachydacite	18.718	15.681	39.003	0.557	-0.029
84AO	Monte Amiata	DLC	trachydacite	18.716	15.677	38.994	0.552	-0.022
84AV	Monte Amiata	BTC	trachydacite	18.716	15.676	38.987	0.546	-0.016
84AW	Monte Amiata	BTC	trachydacite	18.712	15.674	38.980	0.554	-0.011
84BD	Monte Amiata	BTC	trachydacite	18.716	15.677	38.991	0.550	-0.019
84BE	Monte Amiata	BTC	trachydacite	18.714	15.674	38.977	0.544	-0.008
84AD	Monte Amiata	magmatic enclave	trachyandesite	18.730	15.679	39.003	0.509	-0.024
84AM	Monte Amiata	magmatic enclave	basaltic trachyandesite	18.731	15.678	39.002	0.503	-0.023
				18.724	15.671	38.978	0.503	-0.005
84AQ	Monte Amiata	magmatic enclave	trachyandesite	18.733	15.678	39.000	0.494	-0.021
84BH	Radicofani		basaltic andesite	18.694	15.680	39.017	0.656	-0.049
				18.687	15.669	38.975		
84V	Roccastrada		rhyolite	18.725	15.679	38.978	0.510	-0.004
84X	Roccastrada		rhyolite	18.732	15.685	38.992	0.502	-0.014
TOS10	San Vincenzo		rhyolite	18.739	15.685	38.948	0.444	0.027
				18.742	15.688	38.954	0.441	0.023
TOS11	San Vincenzo	Botro ai Marmi	aplite	18.764	15.704	38.954	0.381	0.032
				18.768	15.708	38.969	0.382	0.020
ELB7	Elba Island	Monte Capanne	rhyolite	18.751	15.688	38.963	0.414	0.018
				18.746	15.682	38.944	0.411	0.033
mean value				18.753	15.677	38.982		
std deviation				0.038	0.009	0.022		

C1, C2 : 1st and 2nd Principal Components obtained after PCA of Pb isotopic data of this study and those of Gasperini et al. [6].
BTC = Basal Trachydacitic Complex; DLC = Domes and Lava flows Complex; OLL = final Olivine Latitic Lava Flows

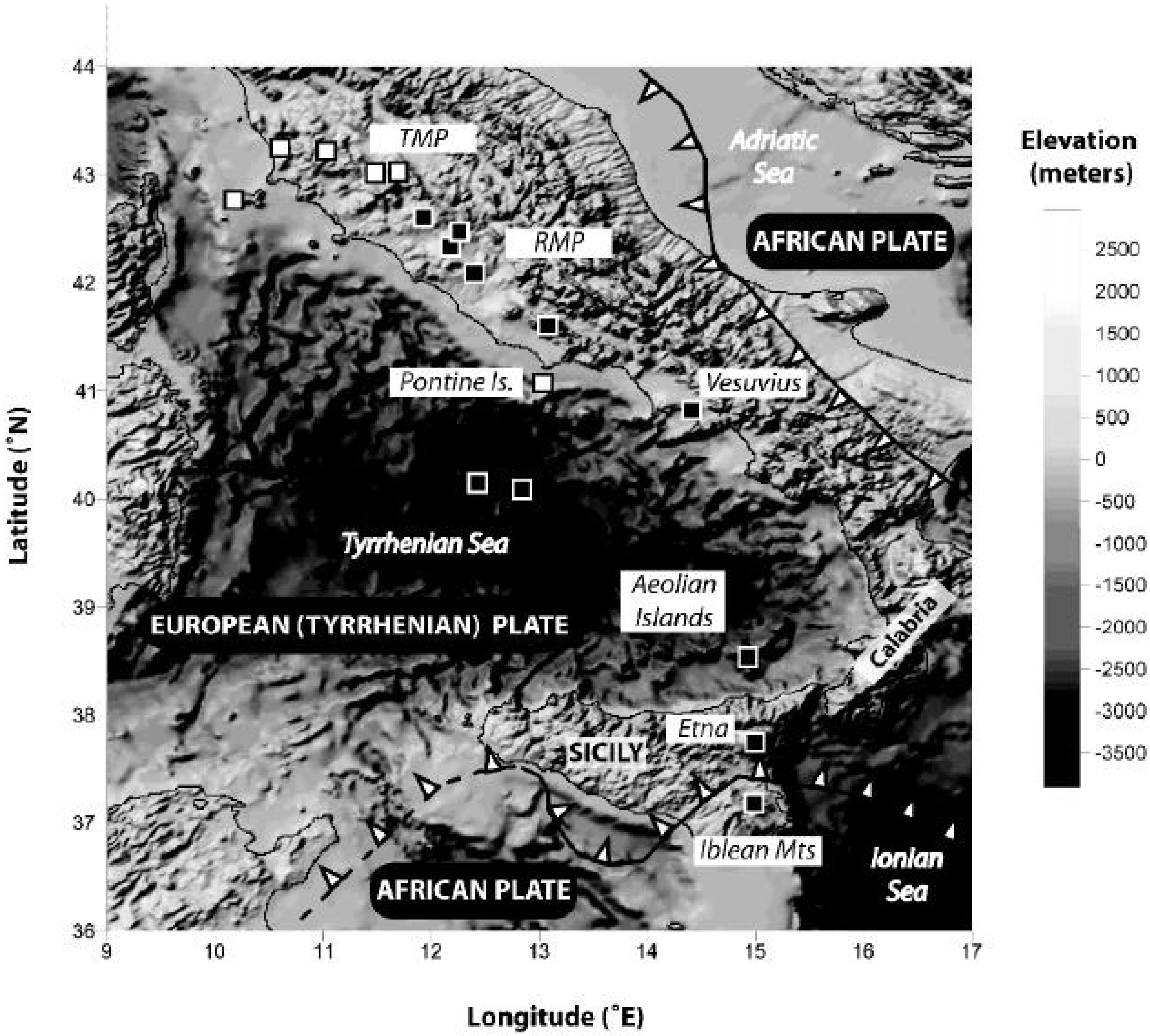
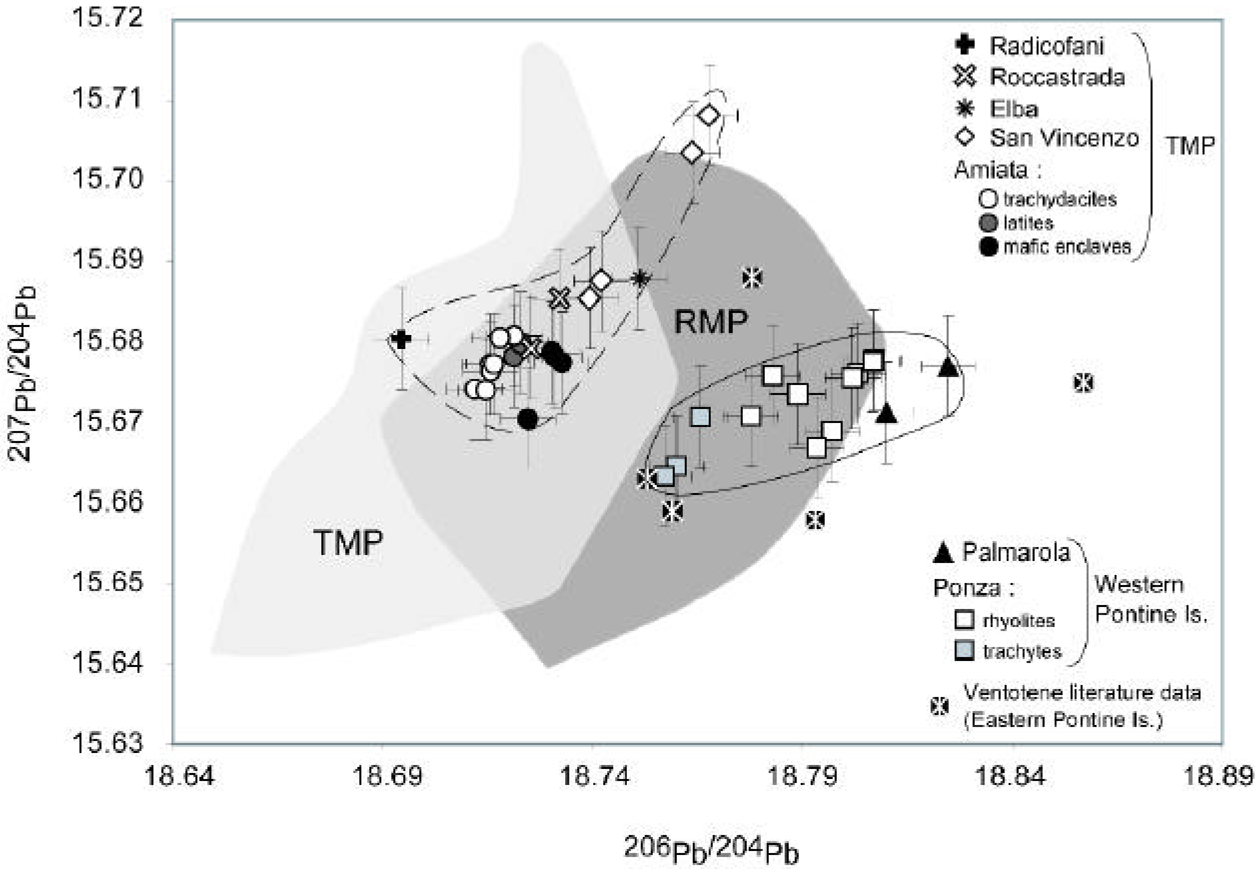


Figure 1
Cadoux et al., 2007



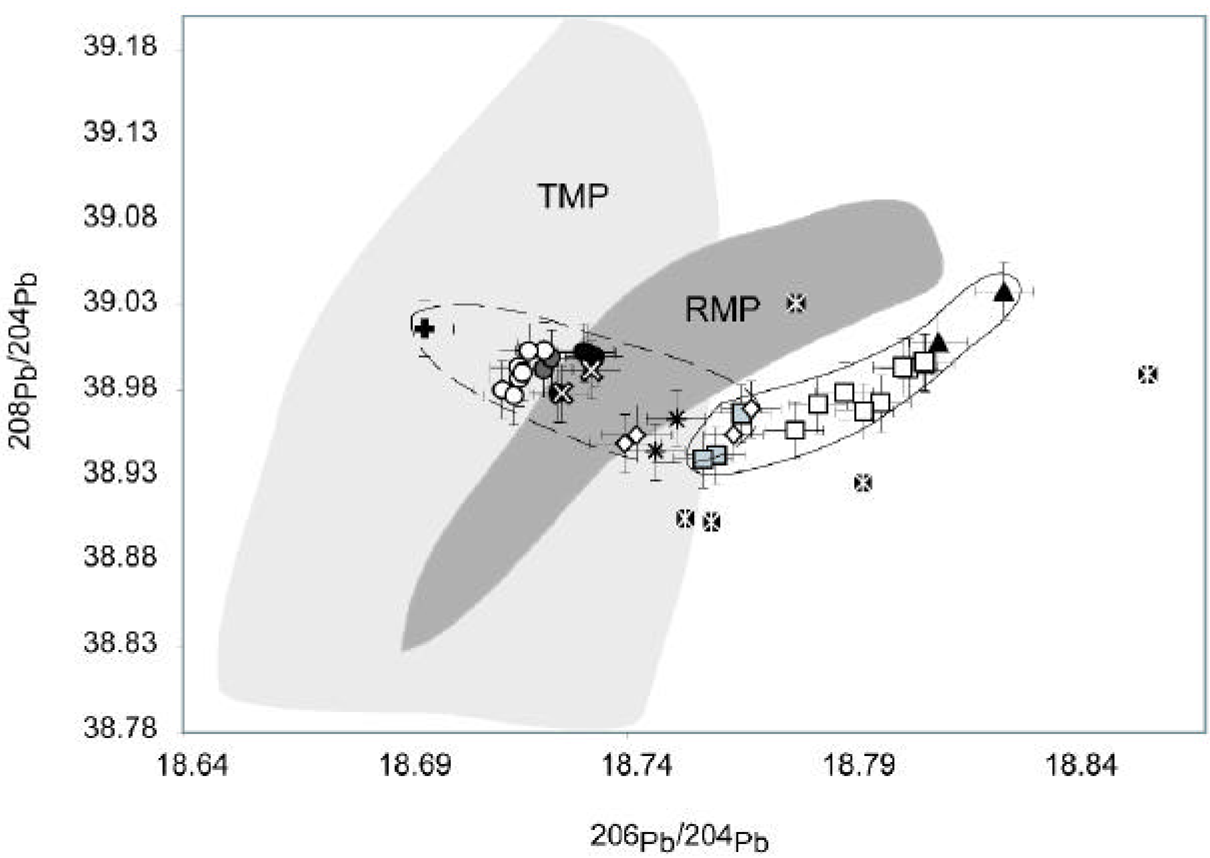


Figure 2
Cadoux et al., 2007

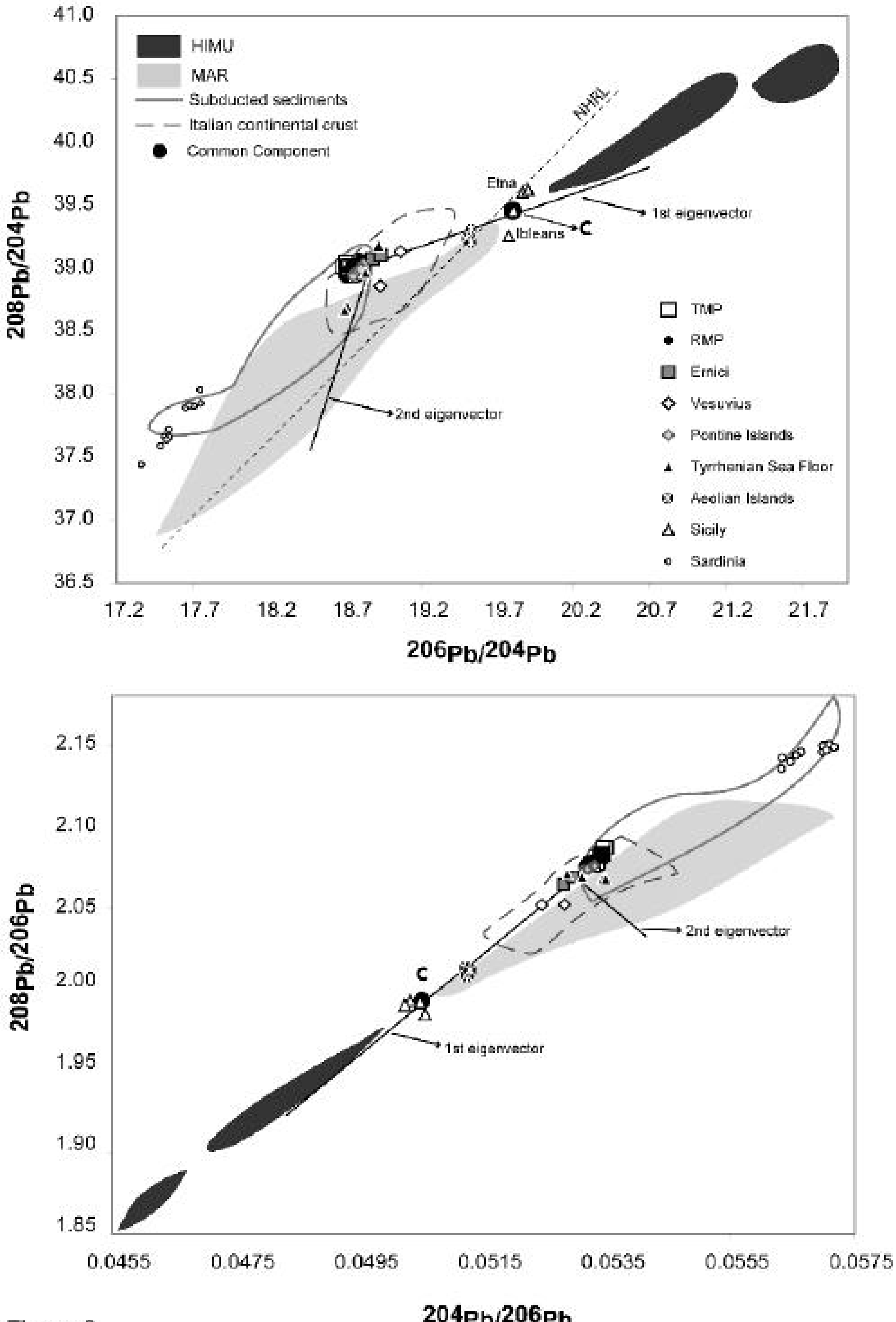


Figure 3
Cadoux et al., 2007

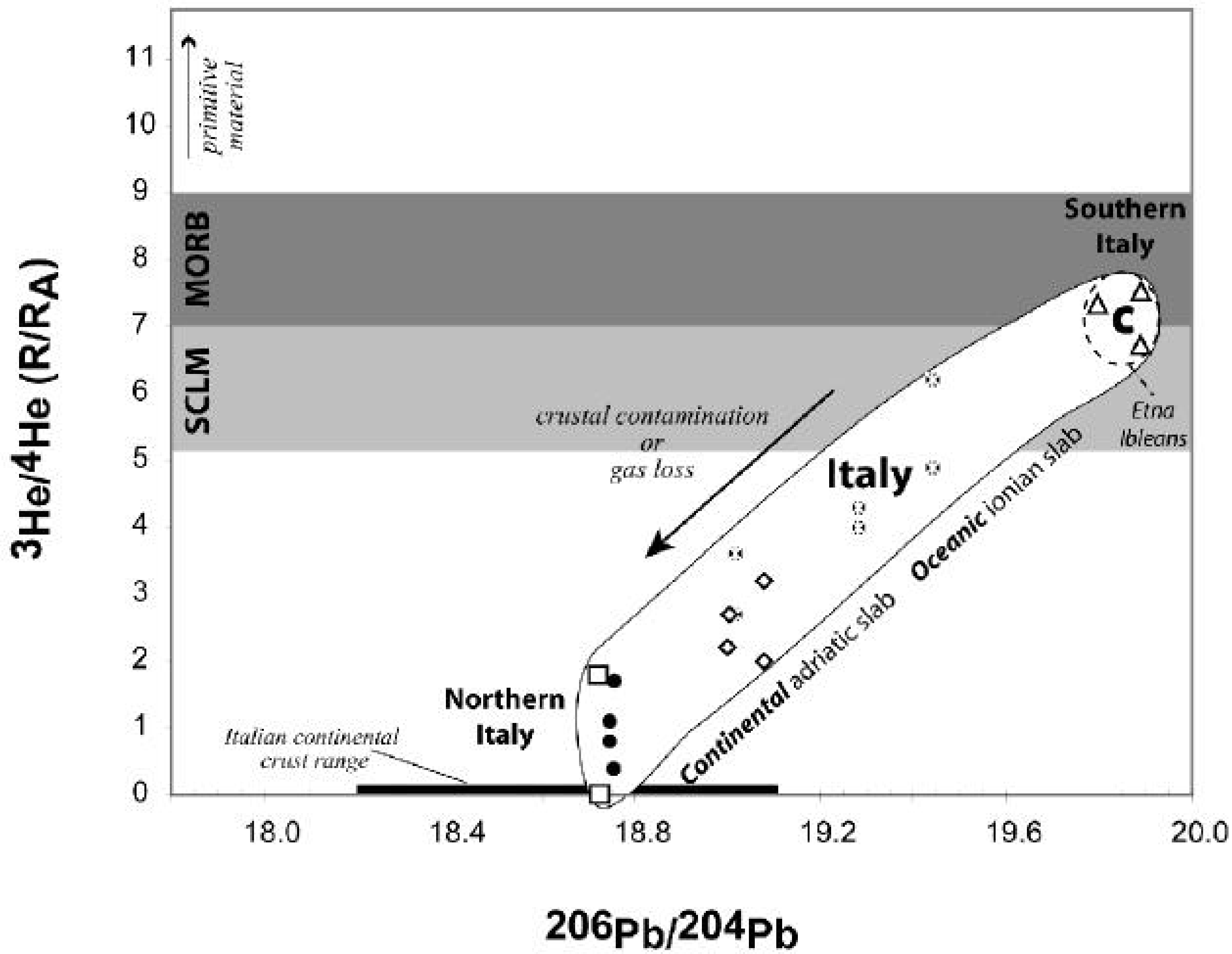


Figure 4
Cadoux et al., 2007

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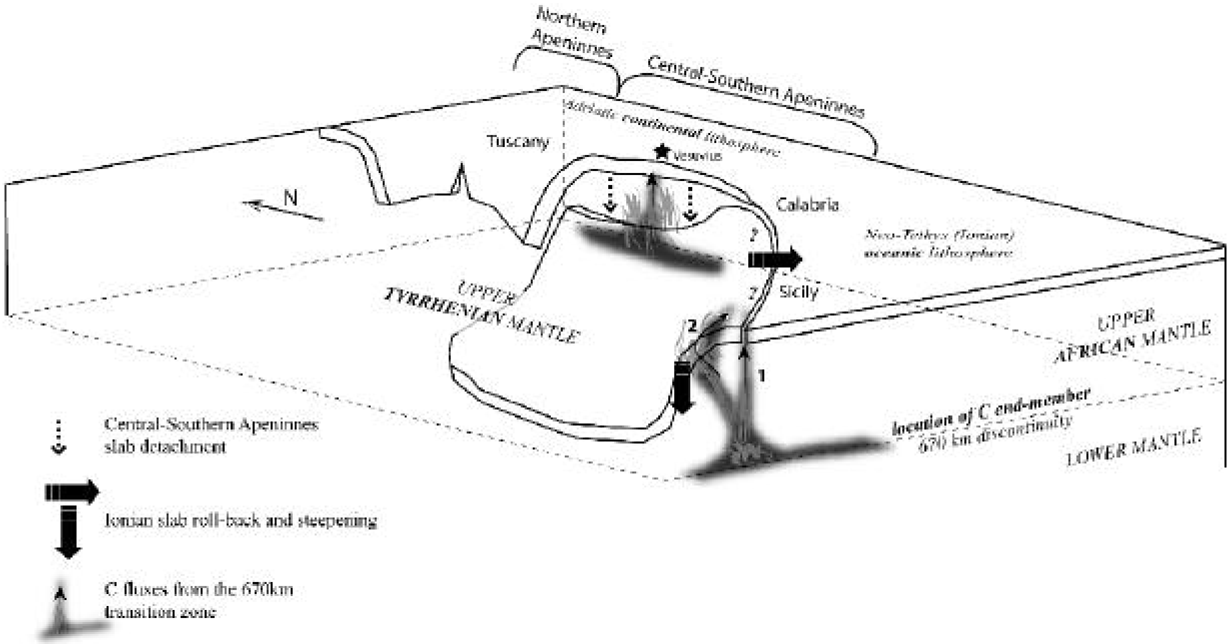

Figure 5
Cadoux et al., 2007