Discussion of

Phantom plumes in Europe and the circum-Mediterranean region

by

Michele Lustrino and Eugenio Carminati

22nd January, 2007, Françoise Chalot-Prat

The paper by Lustrino and Carminati (this volume) presents an exhaustive review of the different hypothesis for the nature of mantle sources of Cenozoic to Quaternary Na-alkaline mafic volcanics from the Circum-Mediterranean and Europe regions, and the causes of mantle melting within the geodynamic setting of eruptions.

This magmatism is often proposed, based on geochemistry and tomography, to be related to mantle plumes coming from the core-mantle boundary. Nevertheless the authors show that, considering not only major-element and isotope geochemistry and tomographic models, but also the geodynamic evolution of both regions, the mantle sources are likely to be much shallower and mostly in a heterogeneous metasomatized lithospheric mantle. Mantle melting is checked by plate tectonic processes. In these regions where lithospheric extension was and is always the prevailing mechanism during eruptions, mantle melting occurs by decompression during rifting-related uplift and is enhanced by the low melting points of crust-contaminated lithologies.

Furthermore, I think that the main problem concerning the "plume or no-plume" debate comes from petrologists themselves. They often include plate tectonic concepts in their models without taking into account the tectonic constraints they imply. Besides, a number of petrologists exclude *a priori* the mantle lithosphere as a possible source of some basalts, whereas experimental work (dating from the 1970's, and largely confirmed nowadays) and numerous studies on mantle xenoliths support it. I will try to clarify my comments below.

A magma should never be defined from a geodynamic point of view, such as orogenic (subduction-related) or anorogenic (not subduction-related). This last term is not only too vague, but is meaningless in terms of plate tectonics.

A magma is defined in terms of major- and trace-element composition. On the whole its composition is a function of the composition of its solid source (if it is a partial melt) or liquid source (if it derives from a parent magma), and also the P-T-f parameters that prevailed during both its formation and ascent up to its emplacement at the surface or at depth.

Magmatism, extrusive or/and intrusive, is associated with all the stages of the Wilson orogenic cycle. The absence of volcanics does not mean the absence of magmatism as suggested by some petrologists. Crustal under- and intra-plating are common processes at every stage of the cycle. Also, and it is a major point, volcanism always implies that melt genesis is synchronous with opening of fractures up to the surface of the continental or oceanic lithosphere. Whatever the geodynamic setting, the feeder dike network of any eruptive area is dependent on regional tectonic constraints, and thus on the plate-tectonic context. The same applies to plutonism, except that this results from the closure of the fractures upwards at depth. In any case, there is always a link between magmatism and tectonics, which cannot be clarified by geochemistry and tomography and is ignored in the plume hypothesis.

The fact that a type of mantle magma (the subject of Lustrino and Carminati, this volume) occurs, either always, frequently or even never at some stages, only depends on the composition of the mantle involved.

If more than one type occurs during the same stage, sometimes at the same site, and even synchronously (geologically speaking), this means that more than one mantle source is involved. So either the tapped mantle source is heterogeneous, or distinct mantle sources at different depths are tapped simultaneously.

Then the fact that one (or several) type(s) of mantle source(s) is(are), either always, frequently or even never involved in some stages, depends on the plate-tectonic setting (including lithosphere type and thickness) at the time of the eruptions. The plate tectonic processes involved generate tectonic constraints (decoupling or/and shearing between rheologically different zones) within the lithospheric or/and asthenospheric mantles, or even the lower/upper mantle transition zone, which trigger melting. These processes must work with brittle behaviour of overlying crustal or lithospheric layers, leading to the formation of feeder dikes.

The ultimate question concerns the location of the mantle sources accounting for their composition deduced from the mafic eruptives. The necessary involvement of plate tectonic processes leads to consideration of three possible locations: the asthenospheric mantle, the lithospheric mantle and the upper-lower mantle transition zone. As a well-accepted hypothesis, the asthenosphere would correspond to a “depleted” mantle (Primitive Mantle residue) source of N-MOR basalts, the only type of basalt occurring in only one type of plate tectonic context (oceanic spreading). This fact is at odds with the hypothesis that the asthenosphere includes blobs of enriched mantle. The lithospheric mantle and the upper-lower mantle transition zone would correspond to an “enriched” mantle source of both other types of basalts–alkaline and calc-alkaline. From continental mantle xenoliths or ridge oceanic mantle sample studies, this enriched mantle, always heterogeneous at a regional scale, was initially a depleted mantle which later underwent melt percolation and metasomatism. It reflects the mixing between an “asthenospheric” component and melts coming either from the underlying mantle (asthenosphere), or from eclogitic oceanic and/or continental subducted lithospheres. It is even probable that portions of eclogitic slabs, tracers of previous sutures, are stored in the lithospheric mantle for a long time after subduction. Besides, any enriched mantle may have been involved in several successive orogenic cycles with several episodes of melting and metasomatism, which means that the effects of continental crust recycling (including old oceanic crust) likely dominate over those of recent oceanic crust.

29th January, 2007, Romain Meyer

Françoise Chalot-Prat makes an important point about the geochemical and petrological location of the mantle source for Central European primary magmas. Petrological and geochemical investigation of igneous rocks from the Rhoen Mountains and the Grabfeld (Heldburg Dike Swarm) - integral areas of the Central European Volcanic Province (CEVP) - have revealed the metasomatically overprinted, heterogeneous, sub-continental lithosphere to be a potential mantle source (Meyer et al. 2002).

The age spectrum of these rocks, according to new $^{40}Ar/^{39}Ar$ data, is clearly divided into two distinct subsets, with volcanic rocks of the Rhoen dated at 20-18 Ma and those of the Grabfeld area in the SE dated at 16 – 14 Ma (Abratis et al., in press). This clearly indicates regionally and temporally distinct evolution for the Miocene volcanism. The composition of the volcanic rocks in the two volcanic fields is remarkably diverse, and includes alkali basalts, tholeiites and minor basanites, and nephelinites. Comparable Cenozoic igneous suites are reported from the nearby Vogelsberg and the northern Hessian Depression.

The geochemical and isotopic characteristics of the different magma types correlate strongly for every rock type in both areas e.g. $^{87}Sr/^{86}Sr_i$ = 0.7034 to 0.7040; εNd = 3.9 to 4.7; and $^{206}Pb/^{207}Pb_i$ = 19.0 to 19.3). REE patterns can be interpreted as reflecting melts derived by variable degrees of partial melting within the transitional zone between a garnet-peridotite and spinel-peridotite mantle facies, close to the base of the lithosphere (Meyer et al., 2002). Similar radiogenic isotope signatures (Sr, Nd, Pb) for the same magma types in both sub-areas of the CEVP point to a chemically uniform source which is identical to the source of most of the other, western-to-Mid-European magma fields. Minor differences in the magma composition are either due to decreasing degrees of melting of the subcontinental mantle, or to increasing depths of melting. A major question for the understanding of rift-related magmatism is why the volcanic activity ceased (18 Ma) in the Rhoen area whereas it continued in the Vogelsberg and the northern Hessian Depression in the W-NW, and started in the Grabfeld (16 Ma) farther to the SE.

Partial melting of the mantle source was induced by adiabatic decompression in both areas. A lack of magmatic activity between 18 and 16 Ma in combination with the transition and onset of magmatism from the Rhoen Mts. into the Grabfeld during this volcanic period indicates a geochemically similar, fertile mantle package at subcontinental levels below both areas. In the Rhoen, this fertile mantle domain acted as a magma source over ca. 2 Ma (20-18 Ma), prior to tapping a virtually identical reservoir in the Grabfeld area with a comparable lifetime between 16 and 14 Ma.

References

Abratis, M., Mädler, J., Hautmann, S., Leyk, H.-J., Meyer, R., Lippolt, H. J., and Viereck-Götte, L., in press., Two distinct Miocene age ranges of basaltic rocks from the Rhön and Heldburg areas (Germany) based on 40Ar/39Ar step heating data. Chemie der Erde – Geochemistry. Available online at: www.sciencedirect.com/science/journal/00092819

Meyer, R., Abratis, M., Viereck-Götte, L., Mädler, J., Hertogen, J. and Romer, R.L., 2002, Mantelquellen des Vulkanismus in der thüringischen Rhön. – Beiträge zur Geologie von Thüringen, 9, 75-105.