TERTIARY–QUATERNARY MAGMATISM WITHIN EUROPE — THE ROLE OF MANTLE PLUMES

M. WILSON

Department of Earth Sciences, Leeds University, Leeds LS2 9JT, United Kingdom

Whenever large volumes of basaltic magmas are emplaced within continental plates their petrogenesis tends, in general, to be attributed to adiabatic decompression within ascending mantle plumes. Such plumes are now widely accepted as an integral part of the mantle convection system, although their ultimate source and geometry remains a subject for debate. Most authors agree that they must originate from thermal boundary layers in the mantle, either the 670 km discontinuity or the core mantle boundary (D" layer). On the basis of the trace element and Sr–Nd–Pb isotope geochemistry of mid-ocean ridge (MORB) and oceanic island (OIB) basalts, mantle plumes appear to have distinctive geochemical fingerprints which may be expressed in terms of the mantle end-members HIMU, EMI and EM II. The HIMU end-member, defined on the basis of its elevated $^{206}Pb/^{204}Pb$ ratio (> 20), may be the time-averaged product of the recycling of oceanic crust into the deep mantle throughout much of Earth history. The EM I and EM II end-members could reflect recycling of pelagic and terrigenous sediments respectively.

Lithospheric extension, induced by far field stresses, does not, in general, appear capable of generating significant volumes of magma unless the mantle lithosphere is volatile rich (metasomatised), stretching factors (b) are extremely high (> 3) or the underlying mantle asthenosphere is anomalously hot. The thermal boundary layer (TBL) at the base of the lithosphere appears to play a crucial role in the petrogenesis of the magmas.

Tertiary–Quaternary alkali basalts, basanites and melilitites with HIMU-like Sr–Nd–Pb isotope and trace element characteristics occur at widely scattered localities throughout western and central Europe (Massif Central, Rhenish Massif, Bohemian Massif, Iberia), the Mediterranean, northern and central Africa and in the Eastern Atlantic ocean. Magmatic activity commonly occurs as small volume monogenetic centres, scattered necks and plugs and fissure controlled plateau basalts. Rarer central volcanic complexes (e.g., Cantal and Mont Dore in the Massif Central) include more differentiated magmas which can be related to processes of magmatic differentiation in sub-volcanic magma chambers. Although magmatism initiated locally in the Early Paleocene, the major phase of activity occurs in the Neogene (10–5 Ma) with a subsidiary peak between 4–2 Ma. Activity locally continues to a few thousand years BP.

The magmatism is spatially and temporally associated with the Late Cretaceous–Cenozoic convergence of Africa-Arabia with Eurasia which resulted in the progressive closure of oceanic basins in the Mediterranean domain and ultimately the collision of the Alpine orogen with the southern passive continental margin of Europe. There appears to have been an intermittent build-up of horizontal compressive stresses in the foreland, transmitted from the Alpine and Pyrenean collision fronts. Phases of compressional deformation occurred during the Late Paleocene, Late Eocene–Early Oligocene, Late Oligocene–Early Miocene and Pliocene. The main magmatic phases appear to occur during periods of stress relaxation, although the correlation is by no means perfect. The Eocene and younger compressional deformation of the northwestern Alpine foreland is broadly synchronous with the evolution of the Cenozoic rift system of Europe, which initiated in Middle Eocene–Early Oligocene times.

The major volcanic regions (e.g., Massif Central, Rhenish Massif) are associated with domal basement uplifts with a wavelength of 200–500 km. A recent seismic tomographic experiment across the French Massif Central has demonstrated that basement uplift and magmatism are associated with the upwelling of a discrete “hot-finger” or diapir from a layer deeper than 300 km within the upper mantle. Similar features are inferred to occur beneath the other Cenozoic volcanic fields. They may reflect the convective destabilisation of a zone of anomalous asthenospheric mantle with HIMU characteristics induced, at least in part, by the Alpine–Pyrenean collision.