Plume-like instabilities in the upper mantle beneath Europe: their possible origin
ILP Task Force 8: PLUME Project

Marjorie Wilson
Institute of Geophysics & Tectonics, School of Earth & Environment, Leeds University, LEEDS LS2 9JT, UK

The distribution of Tertiary-Quaternary volcanic provinces within Europe is broadly correlated with the location of a zone of high-velocity material within the Transition Zone at the base of the upper mantle (410-660 km depth), inferred to represent an accumulation of subducted slabs of oceanic lithosphere (Wilson & Downes, 2006; Lustrino & Wilson, 2007). Many of the major volcanic fields are located around the periphery of this velocity anomaly, coincident with the distribution of finger-like, slow velocity anomalies in the upper mantle, imaged by local seismic tomography experiments (e.g. Eifel, Massif Central; Ritter et al., 2001). These anomalies have widely been considered to represent thermally anomalous "hotspots" or mantle plumes, some 100-150 ˚C hotter than the ambient upper mantle. However the absence of any evidence for a positive thermal anomaly at Transition Zone depths argues strongly against this. Indeed the Transition Zone is seismically fast – reflecting both the presence of high-velocity basaltic materials and, possibly, lower than ambient mantle temperatures.

An alternative explanation for these plume-like structures in the upper mantle is that they are the products of localised fluid streaming from the top of the Transition Zone. According to this model water is concentrated in the base of the upper mantle by subduction processes during the Africa-Eurasian collision where it is stored in high-pressure mineral phases (cf Hirschmann, 2006). Periodic fluid release from the top of the Transition Zone (410 km), triggered by metamorphic breakdown reactions, causes partial melting in the overlying mantle. Small degree partial melts of melilitic composition then rise towards the surface, causing further melting as they approach the base of the lithosphere. Localised extension within the lithosphere further enhances the degree of melting in some areas, producing the range of nephelinites, basanites and alkali basalts observed.

Davies & Bunge (2006), however, have proposed a model in which intra-plate "hotspots" like the Eifel and Massif Central could be a dynamic response to subduction and slab detachment during the Alpine collision; they call these features "splash" plumes. Whilst this is undoubtedly an interesting idea, it is difficult to explain both the chronology of the volcanism and its distribution in terms of such a geodynamic process. In contrast, the fluid-release model provides an attractive generic explanation for intra-plate alkaline magmatism in regions which have experienced an earlier phase of subduction e.g. Europe, eastern China, western USA.

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Fig.1: Location of Tertiary-Quaternary volcanic fields in relation to a zone of inferred subducted slabs in the Transition Zone (410-6660 km depth)