Volcanism synchronous with mantle exhumation at the axial zone of a fossil slow spreading ocean: evidences from the Chenaillet ophiolite (Franco-Italian Alps)

Françoise CHALOT-PRAT

chalot@crpg.cnrs-nancy.fr
CNRS/CRPG - Nancy University, BP20, F-54501 Vandoeuvre les Nancy

The mechanisms checking together emplacement of volcanoes, mantle and gabbro exhumation and ocean enlargement at the axial zone of a slow spreading ocean are poorly understood. In order to better assess how they could be linked, a detailed mapping of a fossil ocean-floor structure, preserved from alpine tectonic and metamorphism, was performed in the Chenaillet unit (Franco-Italian Alps)(Chalot-Prat & Coco, submit.). In parallel a geochemical sampling of basalts was carried out to constrain the observed space and time relationships between volcanoes and to decipher the periodicity of replenishment of reservoirs. The results are as follows:

From its overall dimensions (segment of 3-5 km in width on 30 km^2), the morphology and topography of the volcanic complex (numerous narrow ridges, 200 m to 1 km in length on 100 to 500 m in width, 100 to 600 m above the oceanic floor with steep slopes), the global architecture of the volcanic complex (several strings of micro-segments forming composite volcanoes at their junction; pseudo-symmetry of volcanic strings), the dimensions of composite volcanoes (700-1500 in diameter on 100-300 m high, some hundreds of volcanoes), the dimensions and internal structure of single volcanoes (3-15 m in diameter on 3-30 m high), the Chenaillet unit would be a witness of an axial zone of Atlantic type, similar to a volcanic abyssal hill or a 4th order segment in the Reykjanes Ridge. On both sides of this volcanic hill, large zones of exhumed basement strewed with rare volcanoes attest for the discontinuity of eruptive zones as in any internal rifts of slow spreading oceans.

The basaltic cover of the volcanic hill is only up to 50 m thick and overlays a basement of serpentinized peridotites and gabbros. The top of this basement is convex upward below the composite volcanoes. It is underlined by a tectonic breccia horizon (10 cm to 5 m thick) attesting for the existence of a detachment fault zone responsible for the basement exhumation at the seafloor (Chalot-Prat & Manatschal, 2002). Clasts of dolerite, found within the fault zone, indicate that the basement exhumation had to be active during and even after emplacement of volcanoes.

On the volcanic hill, stair- and comb-type volcanic systems check the distribution of separate volcanoes. Both types of systems are built on rather steep slopes, and everywhere the higher the volcano, the younger it is relative to the others.

In the stair-type (up to 600 m of height difference between base and top on up to 2 km in length), each step is formed with a stacking of several pillow and tube tongues fed from fissural conduits located at the root of each step (Fig. 1). This system would form by uplift, step by step fracturation of an already exhumed basement, and magma injection along the fissures once formed.

The comb-type, the most widespread system on the volcanic hill, consists in a number of alignments of conic volcanoes on a steep slope (50 to 200 m of height difference between base and top on 100 m to 1 km in length) (Fig. 2). For each volcano (3-15 m in diameter on 3-30 m high), the tube and pillow distribution implies that it was built on a slope. The central feeder dyke, vertical or most often steeply inclined up- or down-hill, is located at the crossing of two directions, oblique (*tooth*) and parallel (*line*) to the *branch* of the comb. Towards its base, each feeder-dyke appears frequently curved up- or down-hill, and seems uprooted above the detachment fault zone. On each tooth, the higher the volcano, the younger it is relative to the others, while along a same line, eruptions are coeval as proved by rhythmic variations of chemical compositions of basalts from one line to another. This also means that the branch of the comb superposed to a deep fracture which served as main magma conduit for the comb system.

All these observations suggest that these “in line” volcanoes formed on the ridge of a basement in uplift, at the crossing between a steeply dipping major fracture (main conduit) and a set of shallow parallel fractures (secondary conduits). Once formed, volcanoes were dragged away and down on a travelator to give place to new volcanoes and so on. This travelator consisted in a new basement (mantle or gabbro), the top of which was underlined by a detachment fault. This detachment fault formed at depth and was nothing else than the main fissural conduit which canalized the magma up to the surface. Thus the building of comb systems was synchronous with an enlargement of the basement surface. Besides, and it is an important point, most comb structures are pseudo-symmetric on both sides of narrow ridges (same dipping of feeder-dykes, but teeth with different directions and length). This evidences that the exhumation process occurred in opposite directions, synchronously but not at the same rate as observed at any mid-oceanic ridge axis.

From the major and trace element data on basalts within a same system (comb or stair), the basalts appear to be related by both partial melting and fractional crystallization trends. The fast alternation between partial melts and their differenciates suggests that the main magma conduit was rooted within a frequently fed small reservoir. Nevertheless the regular recurrence of partial melts within a same comb could also suggest that the detachment fault rooted within the asthenospheric mantle source.

Thus at the axial zone of a Mid-Oceanic Ridge, volcanic eruptions would trace the emergence of detachment faults, themselves closely associated with lithospheric matter stretching and transfer up to the sea floor.

Figure 1: sketch of a stair-type volcanic system (in Chalot-Prat et al, submit.)

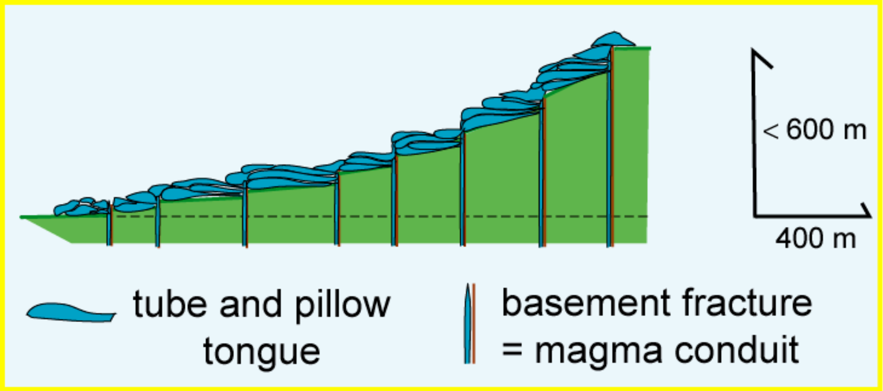

Figure 2: sketch of a pseudo-symmetric comb-type volcanic system (in Chalot-Prat et al, submit.)