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Magma paths at Piton de la Fournaise volcano: a synthesis of Hawaiian and Etnean rift zones

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On ocean basaltic volcanoes, magma transfer to the surface occurs along sub-vertical ascent from the mantle lithosphere through the oceanic crust and the volcanic edifice, eventually followed by lateral propagation along rift zones. We use a 17-years-long database of volcano-tectonic seismic events and a detailed mapping of the pyroclastic cones to determine the geometry and the dynamics of the magma paths intersecting the edifice of Piton de la Fournaise volcano. We show that the overall plumbing system, from about 30 km depth to the surface, is composed of two structural levels that feed distinct types of rift zones.

The lower plumbing system has a southeastward (N120) orientation and permits magma transfer from the lithospheric mantle to the base of the La Réunion edifice (5 km bsl). The related rift zone is wide, linear, spotted by small to large pyroclastic cones and related lava flows and involving magma resulting from high-pressure fractionation of ol $\pm$ cpx and presents an eruption periodicity of around 200 years over the last 30 kyrs. Seismic data suggest that the long-lasting activity of this rift zone result from a regional NNE-SSW extension reactivating inherited lithospheric faults by the effect of underplating and/or thermal erosion of the mantle lithosphere. The upper plumbing system originates at the base of the edifice in the vertical continuity of the lower plumbing system. It feeds frequent (1 eruption every 9 months on average), short-lived summit and distal (flank) eruptions along summit and outer rift zones, respectively. Summit rift zones are short and present an orthogonal pattern restricted to the central active cone of Piton de la Fournaise whereas outer rift zones extend from inside the Enclos Fouqué caldera to the NE and SE volcano flanks. We show that the outer rift zones are genetically linked to the east flank seaward displacements, whose most recent events where detected in 2004 and 2007. The lateral movements are themselves triggered by shallow sill intrusions below the east flank. We propose that the sub-vertical magma intrusions along the perpendicular summit rift zones, sill intrusions and subsequent magma injections along the outer rift zones are controlled by cycles of stress permutations. Recurrent dyke injections along the summit rift zone in an extensional stress field reduce the deviatoric stress until a switch of the axes of principal stresses and a sill intrusion. The related flank lateral destabilization restores the extensional stress field and initiates a new cycle of stress permutations.

To sum up, rift zones of Piton de la Fournaise present strong geometrical and dynamical differences. On the one hand, the lower plumbing system feeds rift zones showing striking similarities to those developed in Hawaii during the alkaline postshield stage. On the other hand, the rift zones connected to upper plumbing system and the related volcano flank movement can be compared to the eruptive and east flank dynamics of Mount Etna.