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Geochemical monitoring of volcano unrest and multi-step magma propagation: the example of the 2007-2011 Piton de la Fournaise activity.

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The 2007 eruption represents a major event in the recent history of Piton de la Fournaise volcano because it produced: i) the most voluminous lava field (at least 0.21 km3), ii) the most intense lava fountaining activity (>200 m high), iii) the largest SO_2 plume (>230 kt), iv) the largest summit collapse (1 km wide x 0.34 km deep) and v) the main flank slip event (up to 1.4 m eastwards) ever documented at PdF. The bulk magma volume extruded during the 2007 eruption is similar to that emitted during the entire 1998-2006 period. As a whole, the volume of lavas emitted during the whole 1998-2007 cycle is remarkably close to that estimated ($\sim$0.35 km3) for the shallow plumbing system of Piton de la Fournaise. The 2007 eruptive sequence consisted of three successive phases (February, March and April). The main phase in April ended a 9 years long period (1998-2007) of continuous edifice inflation and frequent eruptive activity (3 eruptions per year on average). On the contrary, the 2008-2011 activity is associated with a trend of continuous deflation and consists of small-volume summit eruptions of moderate/low MgO magmas and frequent shallow magma intrusions. Bulk rocks, minerals, melt inclusions, matrices and very fast cooled ejecta (Pele's hairs and tears) are studied in order to assess the link between volcano unrest processes, structure of the magma plumbing system, ascent dynamics and summit caldera collapse. Melt heterogeneity demonstrate that the shallow part of PdF edifice (upper 3 km) host low-MgO (MgO: 6.2 wt%) melts with variable normative An/Di ratios and olivine content, at variable steps of evolution towards a common ternary eutectic minimum. Repeated summit collapses favor the formation of discontinuities for shallow temporary magma storage. Extrusion of shallow evolved melts is triggered by ascent of small volumes of deeper, hotter magnesian melts (MgO: up to 8.7 wt%), previously stored in the depth range 2-4 km below sea level. Finally, the good match between our petrological estimates of the potential SO_2 release and the remotely derived fluxes, together with absence of hydrothermal signature in bulk rocks and melt inclusions, rule out a significant contribution of external fluids to PdF volatile budget. Regular monitoring of magma, crystal and glass compositions is an effective strategy for monitoring and interpreting magma storage and dynamics at a very active volcano like Piton de la Fournaise.