Some considerations about the April 2007 eruption at Piton de la Fournaise suggested by InSAR data.

J.-L. Froger (1,2,3), A. Augier (1, 2, 3), V. Cayol (1, 2, 3) and T. Souriot (1, 2, 3)

(1) Clermont Université, UBP, LMV, BP 10448, F-63000 Clermont-Ferrand

(2) CNRS, UMR 6524, LMV, F-63038 Clermont-Ferrand

(3) IRD, R 163, LMV, F-63038 Clermont-Ferrand

J.L.Froger@opgc.univ-bpclermont.fr

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INTRODUCTION

From 30 March to 1 May 2007, Piton de la Fournaise experienced one of its major eruptive crises of XXth and XXIth centuries. The large and complex ground displacements that occurred during this event and in the following months were recorded both by the radar ASAR on board of the European satellite ENVISAT and by the radar PALSAR on board of the Japanese satellite ALOS. In this paper we describe how the ASAR and PALSAR InSAR data provide new insights on the processes acting during the April 2007 events.

InSAR DERIVED CO-ERUPTIVE DISPLACEMENTS

From three ASAR and two PALSAR interferograms spanning the March-April 2007 eruption we have inverted the EW and vertical co-eruptive displacements. On the resulting displacement maps, four main signals are visible (Figure 1) :

- The entire western part of Central Cone is affected both by eastward and downward displacement indicating a centripetal subsidence with a maximum of about 50 cm at the north western rim of Dolomieu crater.

- At the eastern flank of the central cone, the displacement maps reveal a large inflation axis that extends NS on about 4 km from the Faujas Cône to the Langlois Cône. The horizontal component indicates a total opening of about 20 cm to the North and up to 45 cm to the South while the vertical component map exhibits a maximum uplift of about 25 cm on the south-eastern flank of the Central Cone. At its southern end, the axis divides in two N150° branches. The easternmost branch coincides with the location of the March 30 eruptive fissure, suggesting that the whole NS uplift axis was produced by the March 30 intrusion.

- To the East of the Central Cone, the Grandes Pentes are marked by a large displacement pattern. On the horizontal component map, the pattern covers a roughly triangular area of about 4.5 × 4 km^2, indicating a global eastward displacement with a maximum up to 1.4 m. The vertical component map shows a more complicated pattern, with a global subsidence of the Grandes Pentes, up to 33 cm, intersected in its central part by an uplift reaching 37 cm. These observations suggest the superimposition of a large wavelength downslope sliding of the entire Grandes Pentes, except its southern part, and a shorter wavelength uplift of its central part.

- At the SE base of the Grandes Pentes, a N125-130 subsiding axis is clearly visible on the vertical component map, with a maximum displacement of 28 cm downward. Its SE end points at the location of the 2 April eruptive fissure suggesting that the subsidence is directly related to the magma migration from the central cone area to the place of the 2 April eruption.

InSAR DERIVED POST-ERUPTIVE DISPLACEMENTS

We calculated EW and vertical post-eruptive displacements from 167 ASAR and 11 PALSAR interferograms spanning different time intervals between May 2007 and

September 2008. The resulting displacement maps show that the ground displacements continued at least one year after the end of the eruption, with an exponentially decreasing intensity, both at the Central Cone and in the Grandes Pentes (Figure 2).

- The entire Central Cone is affected by a centripetal subsidence that gives a nice symmetrical displacement pattern on the horizontal component map with a maximum eastward displacement of the western flank of 19 cm. On the vertical component map, the displacements pattern is concentric with a maximum value of about 25 cm downward. The displacement wavelength suggests a relatively shallow source bellow or within the cone. Comparison of the co- and post-eruptive displacements on the western flank of the Central Cone shows a very slight decrease of the displacement wavelength. This observation suggests either the activity of a unique shallow deflating source, with a slight rising of the deflating centre or the coexistent activities of a deep and a shallow deflating sources, the second one continuing deflating alone during the post-eruptive period.
- The Grandes Pentes are marked by a large trapezoidal displacement pattern indicating a general downslope sliding. It coincides partly with the large wavelength downslope sliding recorded on the co-eruptive interferograms. However, the co-eruptive and post-eruptive displacements patterns differ in some respects. First, the ratio between horizontal and vertical components is inverted with more than 30 cm of vertical displacement downward for a maximum of 12 cm of horizontal displacement to the East. Second, one does not observe the superimposition with the shorter wavelength uplift of the central Grandes Pentes that was evidenced during the co-eruptive period. This observation suggests that the inflation of the central Grandes Pentes is due to a transient process, active only during the co-eruptive period while the large wavelength downslope sliding continued a long time after the end of the eruption. A last difference arises from the evident structural control of

the post-eruptive displacements that does not appear so manifest in the case of the co-eruptive displacements.

DISCUSSION - INTERPRETATIONS

Central Cone

The persistence of the centripetal subsidence at Central Cone during at least one year after the end of the eruption suggests that the displacements do not result from purely elastic process.

At least three alternative processes can be put forward to explain this behavior:

- The magma reservoir that feed the April 2007 eruption undergoes continuous deflation during the months following the end of the eruption, either by compaction or draining of the magma remaining within it, or by thermal contraction of the surrounding wall rocks.
- The rock column located between the Dolomieu floor and the roof of the magma reservoir is an intensely altered and brecciated medium, that behaves as a visco-poro-elastic body, damping in time the relaxation of central cone that occurred in response to the instantaneous change in shape of the topography induced by the Dolomieu collapse.
- The Dolomieu collapse triggers the large opening of a previously pressurized hydrothermal system resulting in its draining, massive immediately after the collapse and decreasing gradually in intensity in the following weeks and months.

Grandes Pentes

The origin of Enclos Fouqué - Grandes Pentes - Grand Brûlé structure has been discussed for a long time. The proposed interpretations range from classical caldera collapse to recurrent seaward landslides. It should be noticed however, that before our study, all the interpretation proposed for this structure were derived from indirect observations. Here, for the first time, thanks to the InSAR data, we provide direct evidences of a large active seaward sliding affecting the eastern flank of Piton de la Fournaise. This large flank motion seems obviously related with the intense magmatic activity occurred during the March-April 2007 eruption. However the way the two processes are related is still unclear. Two main scenarios can be proposed:

- The March 30 intrusion in the eastern flank of Central Cone triggered the Grandes Pentes sliding. In this scenario, we suppose, on one hand, that the sliding occurs on some basal decollement level (e.g. altered and or brecciated level) and, on the other hand, that it favoured in some way the magma migration from the Central Cone area to the 2 April eruptive fissure area.
- The Grandes Pentes sliding is triggered by the magma migration from the Central Cone area to the 2 April eruptive fissure area. In this scenario, the short wavelength uplift in the central part of Grandes Pentes, visible on co-eruptive vertical displacements map, could mark an intrusion that failed propagating up to the surface. This intermediate intrusion could have play the rule of a discontinuity on which the sliding of Grandes Pentes initiated.

The influence of the Grandes Pentes sliding on the stress state of the whole edifice and particularly of the magmatic reservoir host rock is an interesting issue that still needs to be addressed. It could have significant consequences, in particular, on the location and style of injections from the magmatic reservoir (dyke propagating from the roof, sill propagating from the sidewall). The Dolomieu collapse could have also been influenced by significant change in the edifice stress state and could have contributed, in return to modify again this stress state.

Figure 1. Co-eruptive displacements draped on the shaded DEM. a) EW component, contour level interval is 0.1 m; b) vertical component, contour level interval is 0.05 m; AEF : 2 April 2007 Eruptive Fissure; CC : Central Cone; EF : Enclos Fouqué; FC : Faujas Cone; GB : Grand Brûlé; GP : Grandes Pentes; LC : Langlois Cone; MEF : 30 March 2007 Eruptive Fissure. Coordinates are in km UTM (40 zone South).

Figure 2. One year post-eruptive displacements draped on the shaded DEM. a) EW component, contour level interval is 0.02 m; b) vertical component, contour level interval is 0.05 m; AEF : 2 April 2007 Eruptive Fissure; CC : Central Cone; EF : Enclos Fouqué; FC : Faujas Cone; GB : Grand Brûlé; GP : Grandes Pentes; LC : Langlois Cone; MEF : 30 March 2007 Eruptive Fissure. Coordinates are in km UTM (40 zone South).