Discussion

Comments on “Epiclastic deposits and “horseshoe-shaped” caldeiras in Tahiti (Society Islands) and Ua Huka (Marquesas Archipelago), French Polynesia” by Clément et al. (2003)☆

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1. Introduction

One of the main features in the evolution of oceanic shield volcanoes is the occurrence of huge landslides affecting their flanks. It is thus relevant to accurately determine the morphology, the extension and the related breccia deposits in order to constrain the conditions of sliding.

Clément et al. (2003) recently described epiclastic deposits in the north of Tahiti-Nui (Society Islands) and in the island of Ua Uka (Marquesas archipelago). They claim that it is the first time that such products are interpreted as debris avalanches resulting from a huge landslide event. However, debris avalanche products from a southern landslide have been already described by Clouard et al. (2001) to the south of Tahiti-Nui. Moreover, a large landslide event in the north of Tahiti-Nui has been previously proposed and dated (Gillot et al., 1993; Le Roy, 1994).

From the interpretation of the landslide and the related epiclastic breccia deposits described by Clément et al. (2003) in the north of Tahiti-Nui, several issues can be raised. They focus on: (1) the level and the dimension of the northern landslide; (2) the nature and facies of the breccia deposits; (3) the age of the Tahiti-Nui northern landslide; (4) the cause of the Tahiti-Nui landslides; and (5) the post-sliding evolution.

1.1. Morphological level and dimension of Tahiti-Nui northern landslide

On Tahiti-Nui, Clément et al. (2003) describe a “debris avalanche” unit which covers most of the floor of the present central Maroto depression and the bottom of the Papenoo river (Fig. 1). They present the morphological system of Maroto basin and Papenoo river as a horseshoe-shaped caldera resulting from a huge landslide. The epiclastic deposits they described contain poorly sorted breccia lava blocks (< 10 m in size) within a matrix constituted by clay and sand.

The level described by these authors, which outcrops at the surface of the central Maroto basin and Papenoo river, represents obviously a recent morphological level. Indeed, erosion is very intense in such a wet tropical climate and it has been shown that the central part of the island has experienced a vertical loss of thousands of meters over the past 500 ka (Gillot et al., 1993; Le Roy, 1994). Thus, the present geometry of the depression cannot fossilize the structural scar of a landslide generated 450 ka ago: nor its...
walls, neither its floor. The current shape of the depression, which significantly differs from those of a “horseshoe-shaped caldera”, results obviously from a recent ongoing morphological evolution.

A huge northern landslide has been previously identified and described by Gillot et al. (1993) and Le Roy (1994). Its extension is much larger than that proposed by Clément et al. (2003). It has a clear horseshoe shape. It is limited by the main E–W rift zone to the south, whereas the lateral rims are underlined by secondary concentration of dykes in the Tipaerui river to the north-west and between Tahaute river (Le Roy, 1994) and Onoheha river (Hildenbrand, 2002) to the north-east (Fig. 1). Soon after the slide, a second shield immediately built into and filled up the northern depression. Its remnants correspond today to the highest relief of the island (Aorai, Orohena and Pito Iti). This second shield construction began with a thick brecciated lava sequence. The scarp of the sliding is located between this sequence and the lavas of the first shield stage. These lavas are preserved at the base of the southern wall, i.e. along the southern bank of Vaitamanu river (Fig. 1), much higher than the present floor of the Maroto basin.

1.2. Nature and facies of the breccia deposits

Erosion of the volcanic structure of Tahiti-Nui is responsible for the development of widespread scree and mud flow deposits (Deneufbourg, 1965), such as lahars (e.g. Boutault, 1985). Surprisingly, Clément et al. (2003) do not refer to any previous study, but these units have been already recognized and mapped in most of the largest valleys (Deneufbourg, 1965; Brousse et al., 1985; Brousse and Gelugne, 1987; Brousse et al., 1990). In the Papenoo valley (Fig. 1), similar units and post-erosional valley-filling flows, dated around 200 ka (Gillot et al., 1993; Le Roy, 1994), stand at various topographic levels, indicating a multi-stage evolution. The digging of the central Maroto depression has thus occurred through a gradual and rather complex way, probably influenced by the eustatic variations of the sea-level (Becker et al., 1974).
The epiclastic deposits described by Clément et al. (2003) may typically result from the rapid dissection and erosion of the volcanic structure, induced by the intense tropical precipitation on the high and young volcanic relief. This can explain the high energy of the breccia flow deposits, which led to the confusion with large landslide deposits.

In fact, the deposits described by Clément et al. (2003) correspond to water saturated breccias with various facies including debris flows, hyperconcentrated flows and muddy streamflows (Vallance, 2000). The lithics range from metric blocks to infra-millimetric grains inside a muddy matrix. The water circulation is responsible for a cementation of the deposits. A large proportion of the blocks have clearly been rolled; there is no clear evidence of jigsaw cracks in the larger blocks, but most of them are indurated breccia blocks with small pebbles reworked in the lahar deposit (as shown in the photo, Fig. 3, in the work of Clément et al., 2003). None of the blocks are larger than a few meters.

1.3. Age of the landslide

In order to date the event, Clément et al. (2003) use a mean K–Ar age of 565 ± 9 ka which they obtained from a lava block included in the breccia deposits, and the age of 440 ± 50 ka proposed by Becker et al. (1974) for a valley flow covering similar breccia 10 km downwards along the Papenoo river. The latter flow has been more accurately dated at 227 ± 3 ka (Le Roy, 1994).

Because pebble dating provides a maximum age for the related erosion process, the age of 565 ka is then not surprising since the main shield-building phase on Tahiti-Nui ended about 500 ka ago (e.g. Gillot et al., 1993; Hildenbrand and Gillot, 2001). The lower temporal bound inferred by Clément et al. (2003) for their landslide event relies on the hypothesis that the so-called “debris avalanches” deposits correspond to a “lahar” formation observed by Becker et al. (1974) several kilometers away, in the lower part of the Papenoo river. However, the lack of geometrical and facies continuity between the two geological units renders this assumption doubtful.

We rather think that in order to date the landslide event, one needs to sample (1) the upper flows from the volcano affected by the collapse, and (2) the base of the post-collapse activity. On Tahiti-Nui, this has been the approach followed by Gillot et al. (1993) and Le Roy (1994) to accurately date a major catastrophic northern landslide between 870 and 850 ka, i.e. 400 ka before the age proposed by Clément et al. (2003) for the landslide.

1.4. Cause of the Tahiti-Nui landslides

Clément et al. (2003) suggest that the debris avalanche occurred at the end of the shield-building stage as a consequence of the emplacement of the plutonic body which occupies the central part of the Maroto depression.

This interpretation appears rather unrealistic as the coarse-grained plutonic rocks are generated by a gentle cooling at depth, which implies the presence of a thick overlying volcanic pile. The sudden decompression due to a major landslide induces, on the contrary, a rapid and voluminous magma extrusion as discussed by Le Roy (1994).

The major northwards destructive event (Gillot et al., 1993), as well as the southern landslide (Clouard et al., 2001), have been favored by the concentration of the magmas through a main E–W rift zone. Gillot et al. (1993) and Le Roy (1994) have related this event to the presence of hundreds of dykes, which induced a strong dilatation of the primitive shield, probably triggering the two slides in opposed directions, oriented perpendicularly to the E–W rift zone. They affected the northern and the southern flanks of the primitive shield-volcano, for which the exposed activity ranges from 1.4 to 0.87 Ma (Fig. 1). Most of the northern depression was then rapidly filled by the second shield products (Fig. 1), until the erupted lavas overflowed the depression walls about 650 ka ago (Gillot et al., 1993; Le Roy, 1994; Hildenbrand, 2002). Then the flows draped the preserved slopes of the primitive shield or filled existing valleys. Finally, late lavas were extensively trapped by the southern landslide depression (Clouard, 2000; Clouard et al., 2001), about 550 ka ago (Hildenbrand, 2002).

1.5. Post sliding evolution of Tahiti-Nui

Clément et al. (2003) assume that the extension of the caldera and the landslide scar with epiclastic
breccia deposits would have been wholly preserved in their original geometry and remained at the surface since at least 390 ka, despite the intense erosional conditions prevailing on Tahiti.

We rather consider that the present Maroto basin, which cuts the main volcano-structural units, including the post-collapse northern shield, results from a recent evolution, due to the erosion. The dissection of the volcanic structure has been favored along the backward contact, between the two nested volcanoes (Le Roy, 1994) and reached the coarse-grained rocks of the magma reservoir. This explains why pebbles of these plutonic rocks are present inside the breccias.

The intrusions of the main rift zone (Gillot et al., 1993) controlled the E–W development of the present-day drainage network within the Maroto depression, as well as the E–W elongation of the Vaitamanu valley (Fig. 1). Note that downward, the main Papenoo river brutally diverts, at an almost right angle. This peculiar pattern cannot realistically be the consequence of a northward landslide process but, on the contrary, to a modification of the draining of the Maroto erosional cirque, which was first drained by the Papeihia river to the East and the Punaruu river to the West (Fig. 1). The water was thus deviated and escaped the present-day Viriviriterai and Tamanu plateaux (Fig. 1). The water was thus deviated and escaped to the north, opening the Papenoo river (Hildenbrand, 2002).

2. Conclusion

The huge landslide, which developed a horseshoe-shape structure open to the north, does exist, but with a much larger extension than reported by Clément et al. (2003): from Tipaerui river North-west to Onohheha river North-east (Gillot et al., 1993; Le Roy, 1994; Hildenbrand, 2002). The sole of the collapse appears much higher than the modern erosional surface of Maroto cirque bottom; it corresponds to the southern bank of the Vaitamanu river some hundreds of meters higher. The breccia products have been identified offshore (Hildenbrand, 2002). The landslide occurred between 870 and 850 ka ago, much earlier than proposed by Clément et al. (2003). Thus, the above arguments lead us to conclude that the interpretation of Clément et al. (2003) about the extension, the age and the cause of the northern landslide in Tahiti-Nui is not supported by geological data and does not take into account most of the geological studies previously performed on Tahiti.

This is LGMT contribution no. 50.

References


