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Field investigation and modelling of a huge debris avalanche from Tancitaro Volcano (Mexico)

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The Tancitaro (3840 m) is one of the highest volcanoes of the central portion of the Mexican Volcanic Belt. It is located in the SW sector of the Tarascan corridor, where two important types of volcanoes of quaternary age are observed: a single collapsed composite volcano (Tancitaro) surrounded by a field of monogenetic cinder cones. The distribution of the cinder cones is controlled by NE-SW faults, although there are also additional faults with NNW-SSE trends along which some cones are aligned. The Tancitaro stratovolcano is located at the intersection of the NW-SE and NE-SW structures. The Tancitaro is composed of andesitic to dacitic layers. From a morphological standpoint the volcano is characterized by U-shaped, glacially incised valleys, cut by an east-facing horseshoe-shaped crater. This collapse structure (4 km wide and 5.3 km long) is related with a large fan that was deposited within the Tepalcatepec depression starting only 7 km downslope from the failure scar. The fan was primarily formed by the deposit of this huge debris avalanche (˜18 km3) and subsequently by fluvial and debris flow deposits. It is 66 km long and covers an area of approximately 1155 km2.

Field investigations on the fan area highlighted the presence of typical debris avalanche hummock morphologies in the proximal area. The hummocks are composed of structures ascribable to the so-called “block facies” seen in many other debris avalanche deposits (e.g. Capra et al., 2001). In the distal zones, blocks and megablocks, some of which are characterized by a jigsaw puzzle texture, gradually decrease in size until they disappear entirely in the most distal reaches; this portion of the deposit corresponds to the “mixed block and matrix facies” described by Glicken (1996) It was also possible to delimit a time frame for the occurrence of the Tancitaro debris avalanche by using an expeditious method of relative dating for the monogenic cinder cones of the area (Peña 1992). By combining this information with absolute dates

from nearby deposits from previous studies (e.g. Scattolin, 1996) an upper temporal limit of approximately 4000 years was established. A lower limit was ascertained from geomorphologic and climatologic information. In fact, the debris avalanche cuts glacially incised valleys that date back to the most recent glaciological period, which occurred approximately 6000 - 10000 years BP. The age of the collapse can therefore be constrained to between 4000 and 10000 years BP. The comparison between the debris avalanche of the Tancitaro and other great collapses with similar morphometric features (vertical relief during runout, travel distance, volume and area of the deposit) indicate that the collapse was most likely not primed by any type of eruption, but rather triggered by a strong seismic shock that could have induced the failure of a portion of the edifice, already deeply altered by intense hydrothermal fluid circulation. It is also possible to hypothesize that mechanical fluidization (Hungr, 1990) may have been the mechanism controlling the long runout of the avalanche, as has been documented for other well-known events. The behavior of the Tancitaro debris avalanche was numerically modeled using the DAN code (Hungr, 1995). By opportunely modifying the rheological parameters of the different models selectable within DAN, it was determined that the two-parameter “Voellmy model” provides the best approximation of the avalanche movement. The Voellmy model produces the most realistic results in terms of runout distance, velocity and spatial distribution of the failed mass. It should be noted that although the Tancitaro event was not witnessed directly, it is possible to infer approximate velocities and overall dynamic behavior from comparisons with similar events, namely the Mt. St. Helens debris avalanche of 18 May 1980.