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Predicting the block-and-ash flow inundation areas at Volcán de Colima (Colima, Mexico) based on the present day (February 2010) status

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ABSTRACT

Maps of areas potentially affected by block-and-ash flows and associated ash clouds are here presented for the Volcán de Colima. TITAN2D 2.0.1 code has been used to simulate block-and-ash flows using as an input volume that of the actual summit dome (assessed at 2×10^6 m^3), while the Energy Cone model has been used to delimit the possible inundated area from associated ash clouds. Both Merapi- and Soufriere-type block-and-ash flows were generated using different basal friction angles and maintaining fixed the volume and the internal friction angle. The setting of the input parameters takes into account some flow characteristics, such as the stepwise aggradation of different pulses that piled up to form the total thickness of the block-and-ash flow deposits. The outputs of the computational routines are reported as two maps describing the total thickness of the final deposits. They predict that thick deposits will engulf the ravines descending from the main cone to the west, south and southeast, with expected maximum runouts between 4.5 and 7 km. The associated ash clouds have slightly longer runouts, and the model predicts they will inundate some higher grounds that are not affected by the concentrate underflows. The presented maps represent useful tools for managing the current block-and-ash flow hazard at Volcán de Colima.

1. Introduction

Pyroclastic density currents (PDCs) are hot, gravity-driven currents of solid volcanic particles and gas, which travel at high velocity (e.g. Carey, 1991; Druitt, 1998; Freundt and Bursik, 1998; Branney and Kokelaar, 2002; Sulpizio and Dellino, 2008), and can cause near-complete destruction of widespread areas (Tilling and Lipman, 1993). Since 1783 more than 50,000 people have been killed by PDCs (Tanguy et al., 1998). Their hazard is related to their temperature, particle concentration, missile content, dynamic pressure and ability to inundate and bury the environment under thick deposits. The interaction between the PDCs and the pre-existing natural and urban topography can strongly influence the currents behaviour and dispersion (e.g. Fisher, 1990, 1995; Gurioli et al., 2002, 2005; Baxter et al., 2005; Sulpizio and Dellino, 2008), complicating the assessment of the related hazards. Even in distal locations the PDCs can still be very hot (e.g. Zanella et al., 2007; Sulpizio et al., 2008), have high velocity (e.g. Dellino et al., 2008) and have particle concentrations above asphyxiating levels (e.g. Baxter et al., 1998). Therefore, PDCs pose a serious threat to human life and property. All these features rank PDCs amongst the most devastating of all natural phenomena. For these reasons the assessment and mitigation of the PDC hazard is one of the main topics of present day volcanology.

The assessment of the areas impacted by past PDCs is one of the prime ways for providing spatial information required in territorial planning and emergency management. This follows the assumption that areas previously impacted by PDCs are likely to be affected again in future eruptions (e.g. Baxter et al., 1998; Nakada, 2000; Spence et al., 2004; Gurioli et al., in press). However, the use of geological information on PDCs deposits for delineating the area that could be potentially inundated by future PDCs (e.g. Crandell et al., 1984; Wolfe and Pierson, 1995; De la Cruz-Reyna and Carrasco-Núñez, 2002; Petterson et al., 2003; Mastrolorenzo et al., 2006; Di Vito et al., 2009) poses some problems in the estimation of the area actually affected by pyroclastic deposition. This is because geological data generally encompass various eruptions, each of them eventually affecting a limited portion of the volcano and with different preservation in the geological record, and do not take into account the present day morphology.

To consider all the areas affected in the past by PDC deposition as potentially subjected to inundation in the future would be a conservative approach, which takes into account all the eruptive dynamics and intensities that have occurred in the past. This method has the advantage of delimiting dangerous areas for Civil Protection purposes. However, it poses serious problems when dealing with the

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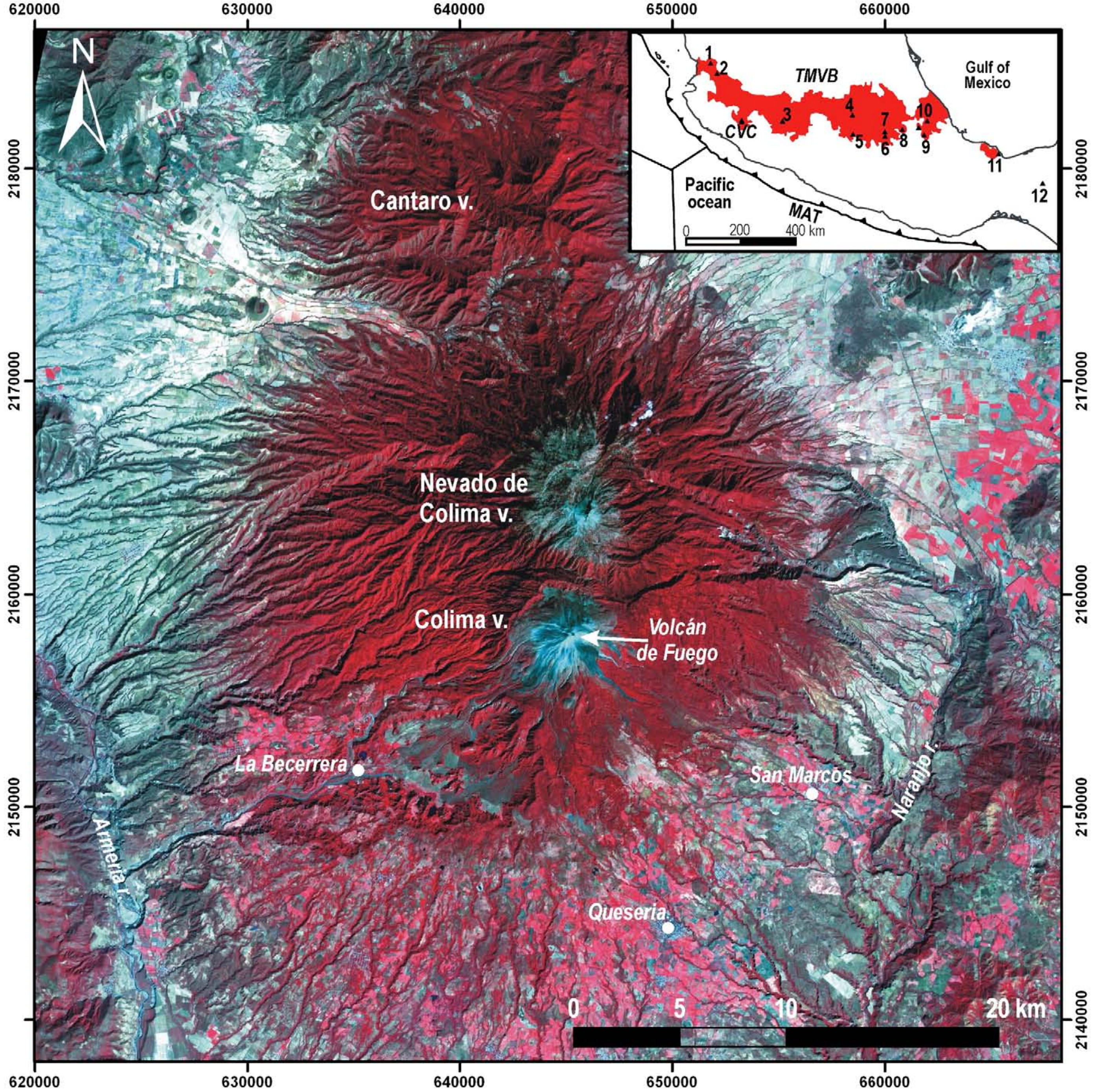

Fig. 1. ASTER image (4, 5 and 7 bands in RGB combination) showing the Colima Volcanic Complex (CVC), which consists of the Cantaro, Nevado de Colima and Volcán de Colima volcanoes. The inset shows a sketch map of the Trans-Mexican Volcanic Belt with the location of the CVC and other active volcanoes: 1: San Juan; 2: Ceboruco; 3: Tancitaro; 4: Jocotitlán; 5: Nevado de Toluca; 6: Popocatépetl; 7: Ixtaccíhuatl; 8: La Malinche; 9: Pico de Orizaba; 10: Cofre de Perote; 11: San Martín; 12: El Chichón.

ranking of the different zones for PDC inundation, and for prioritising their evacuation in case of a volcano crisis. In order to maximize the efficiency of Civil Protection plans and to limit the negative feedback on the local economy, hazard zonation must be based on different eruptive scenarios with associated probability of occurrence. In other words, hazard zonation needs to cover all possible eruption intensities and dynamics, but the state of the volcano indicates the most probable event to be considered for short-term risk management. The ranking procedure is particularly efficient for concentrated PDCs, like block-and-ash flows (BAFs) from dome explosion or collapse, which can be easily channelled into the existing drainage network. For this reason, the use of statistically constrained semi-empirical methods that deal with the motion and deposition of granular-dominated flows (e.g. Widiwijayanti et al., 2009) and computer codes (Savage and Hutter, 1989; Takahashi and Tsujimoto, 2000; Denlinger and Iverson, 2001; Iverson and Denlinger, 2001; Patra et al., 2005; Sheridan et al., 2005; Kelfoun et al., 2009) can be more appropriate for identifying the potential areas of inundation and for delineating hazardous zones.

Fig. 2. a) ASTER image (RGB composition of 123N VNIR bands) showing the distribution of block-and-ash flow deposits used for setting the simulation parameters; b) aerial view of the present day summit dome (Photograph taken on 20th February 2010 by J.C. Gavilanes-Ruiz).