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Monitoring the Dynamic of a Fluvial Channel after Lahar Disturbance: Huiloac Gorge (Popocatepetl Volcano, Mexico)

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Volcanic eruptions generate disturbances that affect hydrological systems (Major, 2003) by depositing large volumes of sediments in watersheds that exceed amounts common to non-volcanic river systems (Montgomery, 2005). If the eruption releases abundant melt water, the river system may respond immediately by forming hazardous flows called lahars. River system recovery following eruptive and laharic impact is an important process, but it has received little attention (Gran and Montgomery, 2005) despite the fact that Major et al. (2000) and Hayes et al. (2002) have shown that these disruptions cause long term instability and their effects persist for decades.

Lahar deposits resulting from interaction between volcanic activity and the glacier located above the Huiloac Gorge on the northern slope of Popocatepetl volcano (19º02´ N, 98º62´ W, 5,424 m), have infilled the gorge (Palacios, 1995; Palacios et al., 1998 and 2001; Capra et al., 2004; Muñoz, 2007). All of the major lahars that occurred on the volcano in 1995 (4 km), 1997 (21 km), and 2001 (14 km) have channelled through Huiloac Gorge, and have dramatically altered its morphology and dynamics through erosion and deposition.

The present study traces these changes in the aftermath of the laharic events that occurred from 1997-2001. A sector of the channel, located at 3200m-3240m altitude, of 500 m long and 15 to 20 m wide, in the mid-section of the gorge, was chosen as the control site. Precipitation is heaviest there and is most apt to trigger secondary post-eruptive lahars. ArcGis software was used to draw 6 geomorphic maps of the site showing spatial variations in the landforms for the period February 2002 – February 2008. In addition, 29 cross-profiles were made of the gorge for the same time interval, excluding February 2004. The volume of sediment eroded and deposited was calculated for each date by comparing variations in the height of the floor and banks of the gorge depicted in the cross-profile, and estimating the volume of erosion and deposition for a given time interval.

Analysis of the geomorphic variations for the period February 2002-February 2008, shows that the banks formed by lahar deposits in 1997 and 2001 at the study site receded from 48.6% to 27.4% in favor of the riverbed, and 31.0% to 52.7%, in favor of the terraces formed by secondary lahars. The time sequence for the cross-profiles depicts a general widening and infilling of the gorge floor, with greater emphasis on erosion from September 2003-February 2008 (1523 m^3as compared to 387 $m^3$of accretion).

The changes, however, were not homogeneous during the study period, due to varying rainfall patterns that cause fluctuations in runoff. This relationship became evident after comparing geomorphologic and topographic alterations and heavy precipitation (maximum/24 hrs), and variations in monthly precipitation yield and average yield for the period 1971-2000 (data provided by the Mexico's National Meteorological Service). Although both lower slope recession and lahar-induced deposition on the floor of the channel increased during the period February-October 2002, down cutting and evacuation of materials (677 m^3) greatly surpassed deposition (145 m^3). The predominance of one process in relation to another was much more acute for this period than for any other, even though it occurred during a relatively dry rainy season with below average precipitation. The explanation for this is attributed to the onset of lahar activity in January 2001 and high maximum rainfall late in the rainy season. This was

followed by a dry spell and a second very wet rainy season from October 2002 - September 2003. During this time, the slopes continued to recede in favor of the riverbed, where some down cutting and infilling occurred, resulting in a slight net gain in surface area. During the next five months of the dry season, changes in the landforms were proportionally greater, producing a substantial increase in surface area and laharic deposition formations. These features are attributed to an unusually long rainy season with above average values in October, and to atypical precipitation in the normally dry month of January.

Modifications in the surface area from February 2004-March 2006 reached 19.2%, a decrease from the previous two-year period (28.1%), which was caused by a slight increase in average precipitation in 2004 and a marked decrease in 2005. Values for erosion (620 m^3) and deposition (621 m^3) are similar for the period from September 2003 - March 2005, and the slopes receded slowly as new laharic deposits increased the level of the channel floor. The final two-year interval shows an increase in changes (31.1%) where the receding sides of the banks affected the ridges of the levees, and the floor of the channel, marked by areas of deposition and incision, became flatter and wider. The increased activity is associated with the prolonged effect of El Niño (ENSO), more rainfall during the 2006 rainy season, and below reference values for 2007 for the average wet and dry seasons. The volume of material removed and accreted was 1424 m^3 and 277 m^3, respectively.

Changes occurring in the channel to recover equilibrium in the river system included the widening and infilling of the floor, but these alterations were largely conditioned by increased water supply that triggered secondary lahars. The short interval between deposition by the primary lahar and the exceptionally heavy precipitation at the end of the rainy season, contributed to increased erosion of the gorge. The time intervals that registered below average precipitation are characterized by less surface disturbances and greater infilling of the channel floor. The opposite is true for the rainy seasons with above average values when slope erosion caused uneven deposition on the channel floor, or during the dry months that registered the most significant changes in response to episodes of exceptional heavy rainfall.

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