Geophysical Research Abstracts,
Vol. 11, EGU2009-8014-2, 2009
EGU General Assembly 2009

Permafrost and Periglacial Activity Distribution and Geothermal Anomalies in the Chachani and El Misti Volcanoes (Southern Peru)

D. Palacios (1), N. Andrés (2), J. Úbeda (3), and J. Alcalá (4)

(1) Dept. AGR y Geografía Física. Universidad Complutense, Madrid, Spain (davidp@ghis.ucm.es), (2) Dept. AGR y Geografía Física. Universidad Complutense, Madrid, Spain (nuriand@ghis.ucm.es), (3) Dept. AGR y Geografía Física. Universidad Complutense, Madrid, Spain (joseubeda@ghis.ucm.es), (4) Dept. AGR y Geografía Física. Universidad Complutense, Madrid, Spain (jalcalar@ghis.ucm.es)

The El Misti volcano (16˚17′ S, 71˚24′ W, 5.822 m) is considered one of the most potentially catastrophic in America. Its crater is 18 km from the centre of Arequipa (2335 m a.s.l.), a city with more than 800,000 inhabitants whose population has doubled over the last 20 years, spreading out over the volcano's sides and gullies in many new settlements, less than 12 km away from the crater. Although the last significant eruptive period occurred in 2300-2050 BP, during the last five thousand years the recurrence period for eruptions has been 500 to 1500 years (Thouret et al. 2001). The last eruption occurred between 1440 and 1447 AD, although it was low-intensity. The crater currently has fumarolic activity. The volcano does not show any signs of having supported glaciers or any periglacial form in the past.

The Chachani volcanic complex (16˚11' S 71˚31' W, 6.057 m a.s.l.) lies 18 km northeast of El Misti and 22 km from the centre of the city of Arequipa. The complex is made up of several volcanic cones and domes. The date of the most recent eruption is unknown, and no current or recent eruptive activity has been recorded or detected (Paquereau et al. 2006). The complex probably supported glaciers during the Little Ice Age, although there are none at present. Geomorphological evidence shows that glaciers during the Last Glacial Maximum were very extensive, with some of their feet reaching an altitude of 4000m. Rocky glaciers up to 1800 m long can be found inside some of the cirques. The PichuPichi Complex (16º 25' 25"S 71º14'27", 5650 m a.s.l.), 22 km E of El Misti, supported substantial glaciers during the Last Glacial Maximum, with a minimum foot altitude of c.4000 m, and like the Chachani, has numerous rock glacier formations in its cirques.

The aim of this paper is to ascertain whether the lack of glacial or periglacial geomorphological evidence on the El Misti volcano is due to its destruction from subsequent volcanic activity, or because it never existed. In the latter case, considering its altitude and the conditions in the extinct Chachani and Pichupichu volcanoes nearby, that no evidence is available could be due to the action of geothermal heat, as this is an active volcano.

With this aim, three thermal stations were established on El Misti, at altitudes of 4780, 5438 and 5740 m, consisting of an air temperature sensor and a ground temperature sensor, installed at a depth of 20 cm. When possible, a third sensor was installed in the ground at a depth of 40 to 100 cm. Three stations were also installed on the Chachani volcano, at altitudes of 4871, 5013 and 5352 m, with the same orientation where possible, and with the same sensor types and positions. Data was collected during the period 2004-2008.

Results obtained for the Chachani volcano during the four complete years for which data is available are fairly uniform, despite the occasional failure of some sensors. For the air temperature, the 0ºC mean annual temperature (MAAT) isotherm is situated at around 5000 m altitude, and the -2ºC isotherm, which we consider the limit of probable permafrost (Palacios et al. 2007), at around 5300 m. At 5352 m, permafrost was not detected at a depth of 40 cm, with 78 days above 0ºC, although it may exist and may be detectable using a deeper probe. The daily temperature range is always very wide, with an average daily range of around 8ºC and a maximum daily range of up to 20ºC. The number of days where the temperature oscillates above and below 0ºC (freeze-thaw cycles) is practically nil at an altitude of 4870 m (between 0 and 75 cycles/year), and maximum at 5013 m (around 200 cycles/year). It then decreases as the altitude increases, with fewer than 150 cycles/year at 5352 m.

The data from the ground sensors shows that the mean annual temperatures from the ground thermometers (MAGTs) are slightly higher (2ºC on average) than from the air thermometers, including those at a depth of 100 cm. In particular, the 0ºC isotherm at a depth of 40 cm is situated at around 5200 m and the -2ºC isotherm at 5450 m. The daily temperature range is very low, with an average occasionally below 1ºC at 40 cm depth, and a maximum daily range below 2ºC. The number of freeze-thaw cycles shows the same height distribution as the air temperature (MAAT), although it decreases sharply with depth. E.g. at 5013 m. in the same year there can be 188 cycles in the air, 127 cycles at 20 cm depth and 2 at 80 cm depth.

Results obtained for El Misti volcano differ significantly from those for the Chachani. Air temperature (MAAT) is higher, especially at the highest altitudes, near the crater (5740 m), where the average annual temperature (MAAT) is -2ºC, and it varies greatly according to where the sensor is located inside the crater. This abnormal temperature increase is undoubtedly due to fumarolic activity, although the sensors were always placed at a distance from the fumarole openings. The daily temperature range is similar to that on the Chachani. The number of freeze-thaw cycles is greater in the central section of the mountain, as on the Chachani although slightly higher. The air sensor positioned at 5438 m registered an average of 340 cycles/year, compared to 250 at the summit or 0 at 4780 m.

The most notable trend is that the temperature of the station always increases with depth, and this is more marked the higher the altitude is. At the summit of El Misti, the mean annual ground temperature (MAGT) at 100cm depth is 7-8ºC higher than the air temperature (MAAT), but this is also apparent at the station farthest from the crater, at an altitude of 4780m, where the ground temperature (MAGT) is 5-6ºC higher than the air temperature (MAAT). Another important peculiarity of the ground temperature (MAGT) on the El Misti volcano is that freeze-thaw cycles practically disappear at any depth; e.g. at a depth of 30 cm, the 5438 m station, where the air temperature (MAAT) exceeds 350 cycles/year, records only one cycle/year. At the crater, there are 80 yearly cycles at 30 cm and none at 100 cm.

The conclusion from the results obtained from the thermometers leads to the following hypothesis: the permafrost distribution on the mountains surrounding Arequipa city starts at an altitude of 5450 m for climatic reasons, but the area of maximum periglacial activity is located in a belt between the altitudes of 4900 and 5400 m, although always at very limited depths, and is non-existent at more than 80 cm.

These climatic values are cancelled out on El Misti by substantial geothermal heat which does not only act at a few localized spots, as has been described for other volcanoes (Palacios et al., 2007): it affects the whole volcano, although naturally to a greater extent at the summit, where the crater is located. Even the air temperature is affected, but it is the ground temperature which is basically and drastically changed, eliminating any possibility of glacial accumulation or permafrost, and reducing the depth of periglacial activity to only the first few centimeters of the ground. This activity is more significant at altitudes much greater than expected from the climatic conditions.

References.-

Dornbusch, U., 2001. Modern and Last Local Glacial Maximum snowlines in the Central Andes of Peru, Bolivia, and Northern Chile. Quaternary Science Reviews 18, 63-84.

Paquereau, P.; Thouret, J-C.; Worner, G.; & Fornari, M., 2006. Neogene and Quaternary ignimbrites in the area of Arequipa, southern Peru: stratigraphical and petrological correlations. J Volc Geotherm Res, 154: 251-275.

Palacios, D.; Zamorano, J.J.; & Andrés, N., 2007. Permafrost distribution in tropical stratovolcanoes: Popocatépetl and Iztaccíhuatl volcanoes (Mexico). Geophysical Research Abstracts 9: 05615.

Thouret, J-C.; Finizola, A.; Fornary, M.; Suni, J. & Frechen. M., 2001. Geology of El Misti volcano near the city of Arequipa, Peru. Geological Society of America Bulletin, 113(12): 593-610.