



## **The Little Ice Age glacier maximum on Pico de Orizaba volcano (Mexico) constrained through in situ cosmogenic produced $^{36}\text{Cl}$ and lichenometry**

Jesús Alcalá Reygosa (1), Lorenzo Vázquez Selem (2), Irene Schimmelpfennig (3), Néstor Campos (4), and Aster Team (3)

(1) Facultad de Filosofía y Letras, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 Ciudad de México, Mexico, (2) Instituto de Geografía, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 Ciudad de México, Mexico, (3) Aix Marseille Univ, CNRS, IRD, INRA, Coll France, CEREGE, Aix-en-Provence, France, (4) Departamento de Geografía, Universidad Complutense de Madrid, Spain

Several studies performed in mountains worldwide have reported consistent glacial advances in agreement with the Little Ice Age (LIA), a relatively cold event that occurred between 1450 and 1850. However, the dates of glaciation during the LIA are not well-constrained in Mexico where the research has been focused on Iztaccíhuatl. This inactive ice-capped stratovolcano presents voluminous and well-preserved moraines at 4,500 m asl, known as Ayoloco moraines in local terminology, that are not covered by the pumice layer from Popocatepetl volcano dated at  $\sim 1$  ka. Therefore, these moraines have been associated with the LIA, the most significant cold event of the last millennium. Furthermore, the moraines of Ayoloco have been dated with lichenometry and the ages indicate two maximum advances in phase with the LIA. To verify if other glaciers of Mexico experienced glacial advances during the LIA, we applied two dating methods in three successive moraines on Pico de Orizaba ( $19^{\circ} 04' \text{ N} / 97^{\circ} 15' \text{ W}$ ; 5,675 m asl), situated at a similar altitude as the moraines of Ayoloco on Iztaccíhuatl volcano. One method is in situ produced cosmogenic  $^{36}\text{Cl}$  dating and the other is lichenometry based on the measurement of the biggest thalli of the species *Rhizocarpon geographicum* using a growth rate of 0.23 mm/year determined on Iztaccíhuatl.

The results derived from in situ cosmogenic produced  $^{36}\text{Cl}$  dating indicate that the outer moraine has an age between  $0.9 \pm 7.9$  ka and  $0.40 \pm 0.38$  ka. These ages have high uncertainties due to the low amounts of  $^{36}\text{Cl}$  and the high concentrations of  $^{35}\text{Cl}$  ( $> 300$  ppm) in the sampled rocks. However, the  $^{36}\text{Cl}$  nominal values suggest that the moraines were built in the last millennium, likely during the LIA. This hypothesis is confirmed through lichenometry because the oldest thallus leads to an age of  $\sim 270$  years, suggesting that the moraine might have formed during the minimum thermal of the LIA (Maunder solar minimum). Moreover, the oldest thalli found in the recessive moraines lead to an age of  $\sim 180$  and  $\sim 130$  years, respectively, tentatively in agreement with the Dalton solar minimum. The ages of glacial advances obtained on Pico de Orizaba coincides with those on Iztaccíhuatl, suggesting a synchronic response of the glaciers in Mexico during the LIA.

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