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Improved understanding of magnetic signatures of basaltic lava flows and cones with implication for extraterrestrial exploration

Amanda Arlensiú Ordóñez Cencerrado (1), Rolf Kilian (2), and Marina Díaz-Michelena (1)
(1) INTA, Torrejón de Ardoz, Spain (arlensiuoca@inta.es), (2) University of Trier, Trier, Germany (kilian@uni-trier.de)

Large areas of Mars and other celestial bodies are covered with basaltic lava flows and their associated craters. Depending on the individual cooling history and related single versus multi-domain status of the magnetites, as well as the global magnetic field characteristic during crystallization, such rocks could be characterized by very distinct remanent and induced magnetic signatures. Thus, a characterization of analogue craters and lava flows on Earth, and the creation of a database of their distinct magnetic parameters is of key importance for the near future exploration of planetary surfaces like Mars and the Moon. For example, three potential landing sites of the ExoMars 2020 mission include such geological scenarios. Complete on ground measurements of their distinct magnetic properties would also allow information about the characteristics of the early Martian magnetic field.

As case study in the former context we selected a small crater (56°07' S, 69°42' E), which represents an agglutinated spatter cone, and its surrounding lava flows within the Pali Aike Volcano Field in Patagonia. Although the chemical composition of the basalts formed along and outside of the crater is similar, distinct local cooling, outgassing and crystallization histories are likely to produced huge differences in the magnetic signatures.

With the objective to achieve a better interpretation of future more extended on ground geophysical characterization on board planetary vehicles, we performed a profound magnetic characterization of the Pali Aike crater including:

• magnetic surveys with scalar, vector and gradiometric measurements providing high-resolution vector magnetic maps of the crater,

• paleomagnetic data obtained from drilled oriented samples along a transect across the crater. Further laboratory data including remanence, susceptibility, coercitivity which have been also drawn in Day plots to analyse single versus multi domain status of magnetites in the basaltic ground mass,

• a petrographical and chemical characterization of the magnetites by microscope and electron microprobe,

• and a model that considers not exposed rock units and is able to explain the observed 3D magnetic characteristics. This could be transferred to other comparable planetary scenarios.

The most important results of our investigation indicate that (A) vector magnetic data of rocks with highly remanent versus induced magnetic signatures (high Königsberger ratios) provide implications for paleofield orientations, (B) magnetic anomalies of up to +8000 nT can be related to different proportions of single versus multi-domain status of magnetites which reflect the local cooling histories in different sectors of the crater and its surroundings as well as on a decimeter scale within single volcanic spatter blocks and (C) our 3-D model is able to reproduce observed surface rock magnetic signatures together with likely signatures of underlying rock units and their spatial distribution.

In the near future the above described results should be provided by a magnetic multisensor instrument (combining vector and different susceptibility data as well as local demagnetization histories) which is recently developed in our NEWTON EU project in advance to its inclusion on board rovers to planetary missions.