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Magnetic properties of the LOC-9 core, implications for the ejecta emplacement from Lockne crater (Sweden).

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1. Introduction

The Lockne crater is a 456 Ma old marine-target impact structure. It has a 7,5km wide inner crater developed in the crystalline basement, which is surrounded by a 3,5km wide brim where the crater excavation removed most of sedimentary cover rocks (mainly limestone and dark shale) before it was covered by the ejecta flap from the basement crater. The crystalline rocks of the basement are mainly granitoids, but several tens of meters thick dolerite sills are included. Here, we provide a precise analysis of the rock magnetic properties from the LOC-9 core. This is a 31,04m long and 42mm in diameter core drilled into the crystalline crater brim and ejecta flap. Thus, it provides an excellent opportunity to study the process of flap formation.

2. Methodology

Firstly, a visual core log was performed. Laboratory measurements of rock-magnetic properties were carried out in samples from various lithologies in the LOC-9 core. The magnetic susceptibility of the whole core was measured by a SatisGeo KT-6 field kappameter. 91 samples were cut from the core in order to measure low-field bulk susceptibility and 88 pieces were extracted from these samples in order to measure the magnetization in a Coercivity Spectrometer. Initial magnetization curves, hysteresis loops, acquisition of Isothermal Remanent Magnetization (IRM) curves and further back field static demagnetization curves were. A Matlab routine has been developed in order to compute the magnetic parameters derived from the Coercivity Spectrometer measurement. IRM acquisition curves allowed the identification of the different magnetic fractions depending on the field at which saturation is reached [1]. The derivative of the IRM acquisition curves allows the evaluation of the coercivity spectra computed using the software developed by Kruiver et al (2001) [2]. The derivative of the IRM curve is fitted into a series of log-normal distributions. A generic log-normal distribution is defined by the mean destructive field (a proxy of coercivity of the magnetic population), standard deviation and intensity. Each distribution is associated with a population of magnetic minerals. Differences in the physical properties of the distributions are due to either same minerals but different physical characteristics or differences in mineralogy. Additionally, 35 chips were taken from samples in order to measure thermomagnetic curves up to 700ºC with a saturating field of 1T. These measurements have been carried out in a Variable Force Translation Balance High sensitivity Magnetometer in order to determine the Curie/Neel. The characterization of the temperature at which magnetization is lost provides a guide toward the identification of their nature. Other techniques such as thermogravimetric analysis, X-ray diffraction and ICPM analysis have been used in order to support the magnetic study presented.

3. Results

The visual core log showed the ejecta flap to be mainly a brecciated basaltic rock, likely a relocated dolerite, with some blending with dark shale just at the contact between the ejecta and the more intact granitic basement. The susceptibility values obtained along the core by the field kappabridge range between $-0{,}1\cdot10^{-3}$[SI] and $58{,}2\cdot10^{-3}$[SI]. Negative susceptibility values correspond to a diamagnetic material occurring in the crystalline basement below the flap. Most of the susceptibility values of the whole core fall in the interval between 0 and 10^{-3}[SI]. The susceptibility profile as a function of depth shows a significant maximum in the range between 11 and 14m approximately. These high values are consistent with the susceptibility values measured in Åsby dolerite in previous studies [3].

Three different types of hysteresis are obtained. Type A) corresponds to hysteresis loops dominated by the paramagnetic and by diamagnetic fraction. Type B) is dominated by both paramagnetic and ferromagnetic fractions and Type C) is dominated by ferromagnetic fraction. The obtained values of coercivity and the field at which saturation is reached suggest the presence of magnetite/ titanomagnetite fraction.

Three typical curves are obtained from the IRM acquisition curves. Some samples reach saturation at about 250mT and this suggests the presence of magnetite/titanomagnetite. Several samples show that saturation is not reached at 500mT. The high coercivity suggests the presence of either goethite or hematite. Nevertheless, thermogravimetric curves do not support the presence of goethite. The third curve type is a mixture between a low coercivity phase and a high coercivity phase.

25 characteristics samples were analyzed by coercivity spectral analysis method in order to identify the presence of different magnetic populations. One magnetic component dominates the signal in the most of the samples, especially for those with the highest susceptibilities. The dispersion parameter is low, suggesting a well constrained coercivity poorly affected by alteration processes. This suggests that the process of formation of the magnetic phases related with the highest magnetic values of the core is probably not post-depositional alteration.

Most of the measured samples present Curie temperature values obtained by the thermomagnetic curves in the range of 460ºC to 590ºC. These are attributed to magnetite and/or titanomagnetite. Some samples also show the presence of pyrite and pyrrhotite. Hematite has also been identified as a phase which looses magnetization at 680ºC.

The magnetic parameters derived from hysteresis loops as a function of depth reveals a maximum value of Ms, Mrs and Hc which corresponds to the high susceptibility.

A Day plot summarizes the hysteresis parameters and classifies them according to their domain state for titanomagnetite particles [1]. When the magnetization ratios are represented as a function of the coercivity ratios, it is observed that some near surface parts of the ejecta basalt lay inside the theoretical pseudo-single domain zone with a gradual transition towards the multi-domain zone at increasing depths.

4. Discussion and Conclusions

The ferromagnetic phases found in LOC-9 core are mainly magnetite/titanomagnetite.

The Day plot shows the presence of pseudo-single domain particles near the ground surface parts of the ejected basalts. These phases can potentially carry a stable remanent magnetization that should be taking into account in the interpretation of future more detailed magnetic models of this area.

The origin of the high values of magnetic properties associated to the upper part of the ejecta flap can be interpreted by two models. The first would imply the presence of a previous body of high magnetic properties which was quickly transported to the current location in a fast mechanism fashion. The second would correspond to an intrusion dyke-type with different (and high) magnetic properties.

The magnetic phases observed based mainly on thermomagnetic curves do not support the presence of maghemite and the coercivity spectra does not show a large dispersion parameter associated to populations affected by alteration. This suggests that the magnetic signal observed of the ejecta already existed before the ejecta emplacement. Otherwise, the highest susceptibility values obtained in this study are similar to the Åsby dolerite previously measured in the area. Altogether, could means that one of the dolerite blocks located in the shear zone before the impact event took place, was relocated *en masse* from the central part of the crater to the flap where the LOC-9 core is located. However, classical paleomagnetic measurements are still required in order to clarify the most likely flap formation mechanism.

Acknowledgements

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