ROCK-MAGNETIC PROPERTIES OF DRILL CORE LOC-9 FROM THE LOCKNE CRATER, SWEDEN. I. Melero Asensio1, F. Martín-Hernández 2, J. Ormø3, 4Centro de Astrobiología (Ctra. Torrejón-Ajalvín km.4, Torrejón de Ardoz, Madrid, Spain), 2Universidad Complutense de Madrid (Avda. Complutense s/n, Madrid, Spain).

Introduction: The Lockne crater is a 456 Ma old marine-target impact structure. It is concentric with 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 some metavolcanites occur at the southern part of the crater. The basement target rocks also include several tens of meters thick, near horizontal dolerite sills. These are of special interest to this study.

The Lockne crater has been subject to several geological and geophysical studies [1] including magnetic modeling based on aeromagnetic data [2]. The magnetic modeling was restricted to the use of only measured values of the induced magnetization (i.e. magnetic susceptibility) for the geological bodies in consideration. Remanent magnetization as a contribution to the total signal was ignored for simplicity based on scientific argumentation. Here, we provide a precise analysis of the rock magnetic properties, including characterization of the magnetic phases and identification of them for samples 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.

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 obtained with this instrument up to a maximum field of 500 mT. A Matlab routine has been developed in order to compute the magnetic parameters derived from the Coercivity Spectrometer measurement. The slope of the hysteresis curve after saturation of the ferromagnetic phases represents the paramagnetic susceptibility and has been measured as a proxy for the identification of changes in the rock matrix. IRM acquisition curves allowed the identification of the different magnetic fractions depending on the field at which saturation is reached [3]. The derivative of the IRM acquisition curves allows the evaluation of the coercivity spectra computed using the software developed by Kruiver et al (2001) [4]. In this method, normal statistical distributions are obtained where the center point of each normal distribution is an indicator of the population average coercivity and its standard deviation is an estimation of the spread of the magnetic population variation. Different features of each normal distribution indicate fractions with different properties; due to the same composition, but different characteristics such as magnetic domain state, coercivity, or due to differences in composition. Additionally, 15 chips were taken from samples of every lithology 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 temperature of the magnetic phases. The temperature characterization at which magnetization is lost provides a guide toward the identification of their nature. Finally, a compositional analysis has been made from one magnetic extract by means of Scanning Electron Microscopy Energy-dispersed X-ray (SEM-EDX).

In order to obtain more mineralogical detail 10 thin sections are currently being analyzed.

Results and discussions: 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 -0.1E-03[SI] and 58.2E-03[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 1E-03[SI]. The susceptibility profile as a function of depth shows a significant maximum in the range between 11 and 14m approximately.
Three different types of hysteresis loops depending on the main carrier of the magnetic signal have been observed. 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. Lack of a significant relaxation when the polarity of field is inverted indicates that superparamagnetic particles are not present. Several samples show that saturation is not reached at 500mT. The high coercivity suggests the presence of either goethite or hematite. The relaxation observed when the field is inverted suggests the presence of superparamagnetic particles. The rest of the samples show a mixed curve with a slight relaxation.

25 characteristics samples were analyzed by coercivity spectral analysis method in order to identify the presence of different magnetic populations. It is noted that one magnetic component dominates the signal in the most of the samples, especially for those with the highest susceptibilities. The dispersion parameter, or wideness of the normal distribution of coercivity, 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 not post-depositional diagenesis, hydrothermal alteration, or other rock metamorphism affecting the ejecta after its deposition.

Most of the measured samples present Curie temperature values obtained by the thermomagnetic curves in the range of 460°C to 580°C. These are attributed to magnetite and titanomagnetite with different Ti contents. Two samples show an unlocking temperature in the heating curve around 100°C that indicates the presence of goethite. Moreover, one sample presents a local maximum centered around 500°C in the heating curve that we attribute to the presence of pyrite. Pyrite is a paramagnetic mineral but it can have associated ferromagnetic phases of iron sulphate.

We prepared a Day plot that summarizes the hysteresis parameters depending on the domain state of the titanomagnetite particles [5]. When the magnetization ratios are represented in a Day plot 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.

The compositional analysis by SEM-EDX indicates the clear presence of Ti and Fe which reveals the titanomagnetite existence as it was already suggested by the magnetic analysis.

Conclusions: The ferromagnetic phases found in LOC-9 core are mainly magnetite/titanomagnetite and goethite. A paramagnetic fraction has been detected, that we determined to be pyrite. It could be associated with ferromagnetic fraction most likely iron sulphates. Moreover, the Day plot shows the presence of pseudo-single domain particles near the ground surface parts of the ejected basalts. These phases have to be studied in more detail because they can potentially carry a stable remanent magnetization that should be taking into account in the interpretation of future more detailed magnetic models of this section of the crater rim.

The magnetic phases observed based on thermomagnetic curves do not support the presence of magnetite and the coercivity spectra does not show a large dispersion parameter associated to populations affected by alteration. This suggests that the observed magnetic signal of the ejecta already existed before the ejecta emplacement. Altogether, this means that the emplacement of this part of the rim ejecta occurred en masse, possibly aided by the shallow, near horizontal distribution of the dolerite sills allowing the excavation flow to split up relatively large and intact blocks along the rock contacts.


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