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Introduction: Magnetic anomaly in terrestrial craters could be studied both with measured magnetic fields above impact structures and with laboratory investigation of magnetic properties of the original and altered rocks. Geophysical modeling is used to determine the sources of magnetic anomalies [1, 2, 3] by interpreting fields at the surface. However, this modeling does not consider impact demagnetization [4]. Here we present an extended analysis of the magnetic anomaly over the well-studied Bosumtwi crater (Ghana, 10.5 km in diameter), including numerical modeling of the crater formation and developing a magnetic anomaly model based on simulated parameters and crater drilling data.

Complex Crater Anomalies: The crater-associated magnetic anomaly is characterized by a weakened magnetic field, with sporadic positive anomalies that are often associated with a central uplift, if any [5]. During a high-velocity impact, shock waves are formed in the impactor and target, resulting in evaporation, complete destruction of the impactor, ejection of its substance (compression stage), the formation of a cavern in the target (the transient crater, excavation stage), which is then modified into a shallower final crater of a larger diameter and with a rim (modification stage) [6].

The magnetic rock minerals, shocked and heated by the impact, cool below the Curie temperature and acquire thermo-remanent magnetization. The preexisting magnetization of minerals may reduce or disappear under the action of a shock wave. The solidified melt and breccias acquire an increased magnetic susceptibility and remanent magnetization [2].

"Magnetic Cavity": Impact demagnetization of target rocks is caused by the passage of a shock wave. Partial demagnetization occurs already at pressures of several GPa [4]. Target rocks subjected to impact loads more than 3.5 GPa are considered in our simulation as demagnetized. These rocks and the crater cavern are named here as “the magnetic cavity”.

Previously results of modeling the Bosumtwi crater formation were published in [7]. Detailed numerical modeling of the Bosumtwi formation was used to study impact metamorphism in boreholes drilled near the central uplift [8]. In this work, new modeling with the SALEB code [9] was done to clarify the distribution of shock pressures in target rocks under the crater and to estimate the demagnetization zone.

Fig. 1 shows the model crater profiles, obtained with the Tillotson equation of state (EOS) [10, 6].

Fig. 1. Profiles of two model craters (solid curves) compared to the observed profile of Bosumtwi crater [8]. On the left side results are shown of an impact with the velocity of 10 km/s (diameter of a spherical impactor D_{proj} ≈ 0.72 km), on the right side - with the velocity of 20 km/s (D_{proj} ≈ 0.5 km), obtained with the Tillotson EOS for granite: the density 2600 kg/m^3, modulus of compressibility A and Tillotson's parameter B have equal values A = B = 44 GPa [10, 6]. Two bold vertical bars mark the locations of drilled boreholes LB-07A and LB-08A [8]. The vertical stretch of the figure is 4:1.

Fig. 2. Isobars of maximum shock pressure under model craters after impacts of 10 km/s (the left panel) and 20 km/s (the right panel). The distances and depth are expressed in km.

Method for Calculating Magnetic Field: The medium is considered as a set of magnetic dipoles with known properties. The magnetic field induction is described by the equation for a point dipole ([11, eq. 3]. At first, the magnetic field of the target without the crater is calculated, then the magnetic field after the
formation of the crater is defined, the difference of these fields is determined as the magnetic anomaly associated with the crater.

**“Magnetic Cavity” Anomaly:** The profiles of the “magnetic cavity” were plotted at pressure level of 3.5 GPa. The chosen model variant is shown on the right panel of Fig. 2. Its depth is 2.9 km, and the final radius is 3.6 km. The remanent and inductive magnetization inside the cavity are equal to zero. The magnetic susceptibility of the target rock is $10^{-4}$ SI [12].

Fig. 3 a,b. Magnetic anomaly (nT) of the magnetic cavity (a), magnetic field of the target and the magnetic cavity (nT), regard to the local geomagnetic field (b). Fig. 3a shows a negative magnetic anomaly formed by the magnetic cavity. The -2 nT anomaly lies mainly within the crater diameter. The picture of the anomaly is shown at a height of 70 m above the surface of the target. The magnitude of the magnetic anomaly in the target rocks depends on the magnetic properties: the greater the magnetization, the more pronounced the anomaly. Fig. 3b shows the picture of the magnetic field of the “magnetic cavity” in the target rocks with the target field. The magnetic field was calculated relative to the local field (6°30’26” N 1°24’24” W, inclination is -12.0, declination is -6.0, the field is 32500 nT).

**Calculated Bosumtwi Magnetic Anomaly:** In this modeling typical values of the magnetic susceptibility and remanent magnetization of the target rocks and the samples from the boreholes were used [12]. The magnetic susceptibility of the target rock $10^{-4}$ SI is assumed, the remanent magnetization is equal to zero. The rocks in the crater, interpreted as impactites begin at a depth of -280 m, the lake level is at -50 m. It was assumed that all volume inside the crater at depths from 0 m to -280 m does not have magnetic properties. “Impactites 1” are described as a layer 200 m thick from a depth of -280 m within a radius of 3.1 km. Their remanent magnetization is equal to 0.037 A/m. “Impactite 2” lie at a depth of -375 m, have a thickness of 3 meters. Their remanent magnetization is 3 A/m. This layer is modeled as a ring, as such samples were found in the borehole LB-07A and not found in the borehole LB-08A closer to the crater center. The inner and outer radii of the ring are 0.5 km and 1.7 km.

The measured values of the Bosumtwi magnetic anomaly over the south - north radius were shown in Fig. 3 [3]. In Fig. 5 this profile (the gray curve) and the calculated profile (the black curve) are compared.

Fig. 4 a,b Magnetic anomaly (nT) created by the combined effect of the “magnetic cavity” and impactites at the 0 m level (a) and at the -50 m level, (b).

The measured magnetic anomaly is several tens of nT, which is close to values obtained in the simulations. The general behavior of the curves (minimum with a local maximum in the center) are quite close. The asymmetry of the experimental curve maybe caused by heterogeneity of the target rocks [3], which was not taken into consideration in the simulations.

Fig. 5. Measured (gray) and calculated (black) magnetic anomalies of Bosumtwi (nT).

**Conclusions:** The numerical modeling of the crater formation process and the construction of a magnetic anomaly model based on the simulated parameters and crater drilling data are presented. The complex model shows good agreement with direct measurements.

**References:**