ROCK MAGNETIC EVIDENCE OF ASTEROID IMPACT ORIGIN OF RAMGARH STRUCTURE, INDIA.

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Introduction: Among the four known asteroid impact craters in India, the Ramgarh structure, Rajasthan state, northwest India, is the only known impact-crater looking structure [1] that is excavated on flat-lying sedimentary rocks including sandstone, shale and minor limestone of upper Vindhyan Supergroup [2]. The target-sandstone of Bhandara Group is found to be ~1000 Ma old [3]. The Ramgarh structure has a rim-to-rim diameter of ~2-3 km in E-W; having a rectangular shape with a prominent, more or less continuous raised rim all along its periphery that raises ~250 m above the surroundings, and its N-S diameter is ~1.4 times of its E-W extension [2, 4]. The structure is suggested to be an asteroid impact crater by many workers [4-11], though some controversy exists [12]. The possibility of an asteroid impact origin of this structure was strengthened when the magnetic spherules reported from the soil inside the structure [2] were found to contain high Fe_2O_3 (upto ~83 wt%), Ni (~4000 ppm), Co (~7000 ppm) with high Ni/Cr (average ~4, range 0.06 to 32) and Co/Cr (~10, 0.06-58) ratios [13].

In the present work, we report for the first time the magnetic properties of two sets of magnetic particles/spherule samples collected from the soil on the crater rim at southeast (Type a), and the other set from within the finer fraction of reworked debris lying outside of the rim of this structure to the northwest (Type b). The type 'a' spherules (R-80) are reddish brown in colour, spheroidal in shape, and of relatively large size of ~ 7 mm diameter. The type 'b' spherules (R-71) are of same colour but vary in size from spheroidal to angular, and of relatively small size range of ~ ≤ 2 mm. Our study mostly includes measurements on Natural Remanent Magnetization (NRM), Isothermal Remanent Magnetization (IRM) and Saturation IRM (SIRM) and its decay. The rock magnetic study of Ramgarh spherules/particles is possible because these samples have average total Fe_2O_3 is ~34 wt%, which is nearly double to that of Lonar spherules [13, 14].

Experimental procedures: Each of the four sub-samples of weight between ~0.03 and ~0.8 gm from each sample set was tightly packed inside an 8 cc cylindrical plastic container. The NRM was measured by an AGICO JR-6 Dual Speed Spinner Magnetometer in the high speed mode. SIRM was imparted in a 1T steady field by a Molspin Pulse Magnetizer followed by its subsequent measurement on a Molspin Spinner Magnetometer. Progressive demagnetization of SIRM and NRM intensities was carried out using a D-2000 A F Demagnetizer (ASC Scientific)

Natural Remanent Magnetization: Our measurements showed that the NRM values of the Ramgarh samples are very high ranging mostly between 8 and 19 Am^{-1}, except relatively low value of 0.2 Am^{-1} for one sub-sample of R-80. Similarly, high NRM values (2-17 Am^{-1}) are also observed for additional type 'a' samples collected from re-worked debris from outside the crater rim. The NRM values of type 'a' and 'b' samples are relatively much higher compared to those of the target-sediment of Upper Bhandara sandstone of 0.008-0.02 Am^{-1} from Rajasthan area [3]. High NRM values of Ramgarh spherules/particles are comparable to those of the shallow impact-melt sheet occurring at the center of Chixulub impact crater, Mexico (4-5 Am^{-1}) [15] on 3-6 km thick sediments of carbonates and evaporates overlying metamorphic basement [16], or the highly shocked granite target-rocks of the Vredefort impact crater, South Africa (average 16.2 (2-17 Am^{-1}) [17], or experimentally shocked diabase samples at 4.5-35 GPa [18].

REM ratio: NRM/SIRM ratio (referred to as REM) is indicative of the magnetic field that existed during the formation of sample under investigation, a ratio of ~1% is indicative of the Earth magnetic field [19]. For the Ramgarh samples we get a range of very high SIRM values between 1.5 and 235Am^{-1}, and REM ratios between 0.073 and 1.46 (between 7 and 145%) for most of the samples. Though lightning was suggested to be one of the causes for high REM value (above 10%) of the samples under study [19], high REM values of Ramgarh spherules/particles now occurring over an area of ~20 sq. km., or more may probably be interpreted due to the existence of a strong magnetic field during their formation.

Alternating Field Demagnetization **(AFD) of SIRM and NRM:** The SIRM decay curves for type 'a' and 'b' samples are uniform in shape (Fig. 1) and show a steady concave decay with ~80% demagnetization of intensity within 40mT demagnetization level (Fig. 1). IRM acquisition shows that most of the remanent magnetization is acquired within 100 mT with a coercivity of remnance < ~30 mT. These magnetic features together with high SIRM indicate the presence of low coercive multidomain ferro(i)magnetic minerals in these samples, which is in accordance with our early microprobe data (i.e Fe, Co, Ni) [13].

Depending on the shapes of the NRM decay (Fig.2), the samples can be classified into three groups, viz.: (a) those gently decaying from low NRM values of ~2 to 7 Am^{-1}, (b) those decaying steeply from high NRM values of ~14 to 17 Am^{-1}; in these two cases normal NRM decay begins at ~10 mT (Fig. 2a), and (c) samples collected particularly from the crater rim (type ‘a’) show a general increase of NRM upto 35 Am^{-1} with increasing demagnetisation level upto ~30-40 mT, followed by a sharp decrease in NRM intensity up to 80 mT. The decay patterns become flat with further increase of AF field (Fig. 2b).

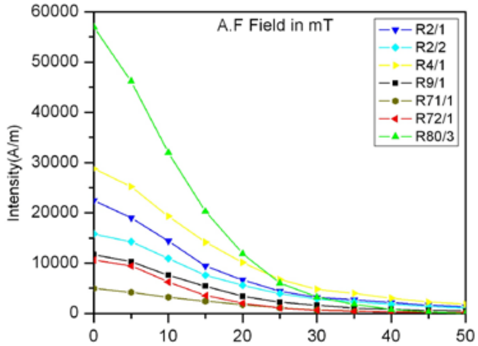

Fig. 1. AF Demagnetization of SIRM of magnetic spherules from Ramgarh structure, India.

Discussion: Our preliminary observation on iron-rich Ramgarh particles/spherules [13] shows that these samples have very high NRM (~2-19 Am^{-1}) and high REM ratio (up to 1.46) indicating the presence of a high magnetic field during their formation, much higher than the ambient Earth’s magnetic field (~40 Am^{-1}). When coupled with early observation on field, petrography and geochemistry [4-11,13], our rock magnetic data further strengthen the possibility of an impact origin for the formation of Ramgarh structure. The increase of initial NRM intensity (Fig. 2b) may only be explained by the presence of a secondary soft component, which apparently be acquired due to shock metamorphism by asteroid impact. The role of the impact was to create a high magnetic field during the formation of the Ramgarh structure, which perhaps covers an area more than ~20 sq. km. during its formation. The origin of high magnetic fields during impact have been studied for some time [20-21]. An amplified field could result from a plasma cloud generated by the impact interacting with the Earth’s magnetic field [20,22], or less likely, shock magnetization [23-24].

As evidence accumulates for impact origin of the Ramgarh structure [25], this study suggests that Ramgarh materials may provide new data to study the magnetic field phenomena associated with impacts.

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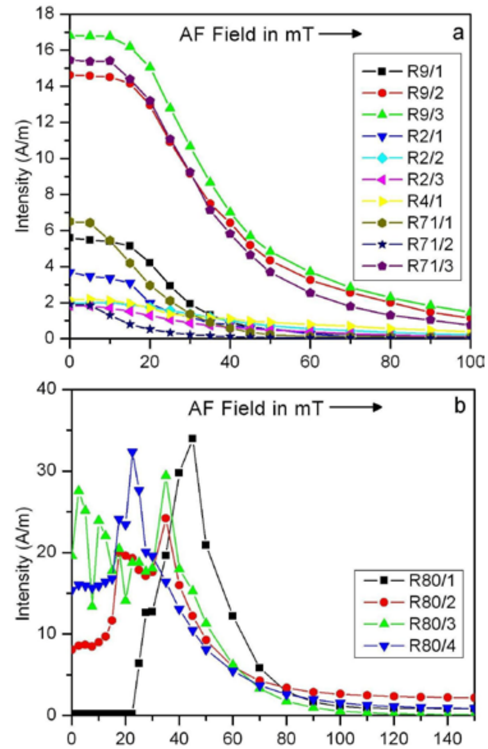

Fig. 2 (a, b). AFD of NRM of magnetic spherules from Ramgarh structure, India.

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