POSSIBLE PLANAR FRACTURES, COESITE, AND ACCRETIONARY LAPILLI FROM RAMGARH STRUCTURE, INDIA: NEW EVIDENCE SUGGESTING AN IMPACT ORIGIN OF THE CRATER. P. K. Das[1], S. Misra[2], H. E. Newsom[3] and M. S. Sisodia[4], [1]Indian Institute of Geomagnetism, Navi Mumbai-410218, India (pkdasdkl@gmail.com), [2]School of Geological Sciences, University of KwaZulu-Natal, Durban-4000, South Africa (misras@ukzn.ac.za), [3]University of New Mexico, Institute of Meteoritics, Albuquerque, NM 87131, USA (newsom@unm.edu), [4]Department of Geology, J. N. Vyas University, Jodhpur-342005, India (sisodia.ms@gmail.com).

Introduction: The Ramgarh structure of southeast Rajasthan, India (centered at 25°20′N, 76°37′E) with a diameter of ~5.5 km has been a candidate impact site for many years, but confirmation has been slow in coming [1]. The structure is formed on flat-lying sedimentary rocks including sandstone, shale along with minor limestone (Bhander Group) of the Neoproterozoic Vindhyan Supergroup [2]. The structure is suggested to be an impact crater by many workers [3 and references therein]. Evidences favoring an impact origin are: (a) crater's shape [1, 4, 5], which is similar to Arizona crater, USA [6]; (b) occurrence of impact spherules, diaplectic glasses within the soil inside the structure [3]; (c) occurrence of mm-sized magnetic particles in soil both inside and outside the crater, and on crater's rim [3, 7, 8]; (d) high abundances of Co, Ni, and Co/Cr and Ni/Cr ratios of these spherules [8]; and (e) very high natural remnant magnetization (NRM) and REM of these particles (~8-19 Am^{-1}) [9].

One of the main problems in accepting Ramgarh as an impact crater is the lack of well documented microtextural evidences of shock metamorphism from this structure. Workers have described Planar Deformation Fractures (PDFs) in quartz within sandstone from Ramgarh [10, 11, 12], but authenticity of these observations remains questionable [13]. In the present study we report Planar Fractures (PF)-like structure in some quartz grains in sandstone from the crater rim, and X-ray Diffraction (XRD) analyses of magnetic spherules recovered from the soil inside the structure [8].

Experimental procedures: The XRD analyses on magnetic spherules were carried out at the CRF, Indian Institute of Technology, Kharagpur, India, using an X'PertPRO PANalytical machine (Model no. PW3040/60) using a Cu target and Ni filter, operated at 30 mA current and at 40 kV. The samples were scanned for 10-140° 2θ range with a scanning speed of 0.0533° 2θ/s. The precision of analyses was examined with a Si-disc standard, which is better than ±0.03° 2θ.

Petrographic observations: The sandstones exposed around the rim of the Ramgarh structure show dips between ~45 and 78°, which gradually decrease to values between 20 and 30° at the outer slope of the structure at lower altitudes, and to 5 to 15° at the foot of the outer rim [2]. The samples for petrographic observations were collected from the exposed sandstones at the rim of the structure.

A sandstone sample collected from the eastern rim of the crater contains quartz grains that show a set of planar cleavages. The distance between successive cleavages is ≤20 μm (Fig. 1a). The sandstone sample from the southeastern rim also shows possible PF with spacing between successive cleavages <10 μm (Fig. 1b) and almost all of the planner fractures are parallel.

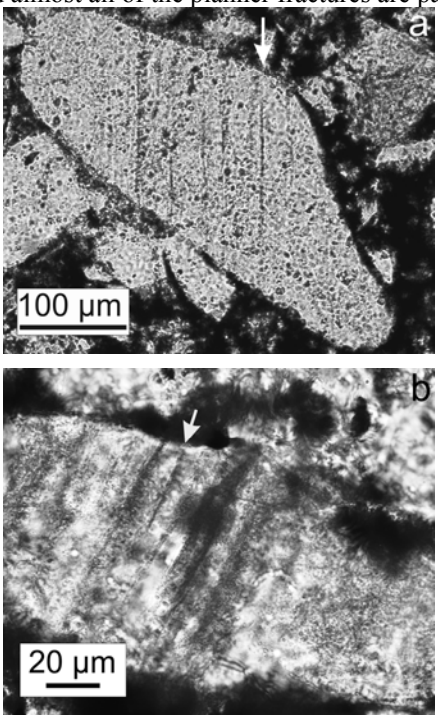

Fig. 1. Photomicrographs of quartz grains in sandstones collected from rim of Ramgarh structure, showing development of well defined, very closely spaced (<20 μm) parallel fractures visible only in high magnification (200-500x).

Magnetic spherules: The morphology of magnetic spherules are described previously [8]. Our further studies (with BSE imaging and EDS analyses) show that it has a core-like structure that is composed of relatively coarse materials, which is surrounded by concentric rims composed of relatively fine-grain materials (Fig. 2, 3). The EDS analyses confirm that the core and rims of the spherules are silica-rich, also note the similar BSE signal for the particles, consistent with a relatively uniform composition (Fig. 3). The angular mineral fragments present both in the core and rim of the spherules have quartz-composition, consistent with

a sandstone target. All of the particles examined contain cores with coarser-grain quartz fragments surrounded with multiple concentric layers of fine-grain material with smaller fragments of quartz. Volcanic accretionary lapilli are defined as consisting of an aggregate of ash-size particles with concentric accretionary rims [14]. The Ramgarh particles are consistent with this definition.

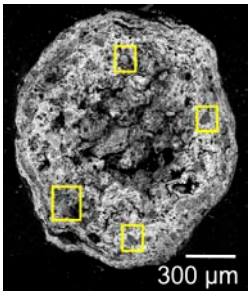

Fig. 2. BSE image of a spherical aggregate from Ramgarh structure showing concentric accretionary rims of fine-grain particles surrounding a core, and presence of angular quartz (in yellow boxes) within the spherule rim.

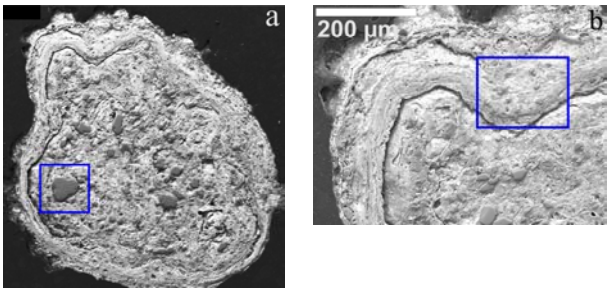

Fig. 3 BSE images of (a) a whole concretionary particle from Ramgarh showing a core containing angular quartz fragments (in box) surrounded by growth rims, (b) enlarged view of concentric growth layers containing quartz inclusions of relatively small size.

XRD data: About six magnetic spherules, recovered from the soil near the central part of Ramgarh structure [8], were mounted on a double-sided tape, placed into a small glass tray and pressed to flatness for XRD analyses. Analysis of powdered samples was not possible in this stage due to scarcity of samples.

Our preliminary XRD data show that these spherule-like substances are essentially composed of quartz (PDF no# 86-0542 [15]) (Fig. 4). These quartz fragments are likely to have been derived from the Vindhyan sandstones. The additional varieties of SiO_2 polymorphs that could be present in these spherules are coesite (83-1832), tridymite (01-0378) and cristobalite (82-1232).

Discussion: The development of intense, closely spaced planar fractures in quartz grains in sandstones (Fig. 1) is a criterion of shock metamorphism, and this type of structure is generated in a shock pressure range of ~5 to 8 GPa [16].

The concretionary particles (Fig. 2, 3) cannot be of sedimentary or hydrothermal origin because of absence of parallel growth layers (e.g. in agate) in these spherules. Alternatively, they cannot be of volcanic origin due to (a) absence of plagioclase in XRD spectra, which is an important constituent of felsic igneous rock; (b) wide range of variations of their bulk composition [8], which is not seen for any common felsic igneous rocks; (c) abundance of very high proportions of Ni (average ~ 500 ppm) in these spherules [8], which is not expected for felsic volcanic lapilli; (d) borehole samples negate any volcanic origin of Ramgarh structure [17]; and (e) no volcaniclastic layer is reported within Bhander Group [18], which could be a source of these spherules. Finally, the spherules obtained in Ramgarh structure are similar in morphology to the impact-related accretionary lapilli of Ries crater, Germany [19] and Bosumtwi crater, Ghana [20]. The impact origin of these spherules are more likely because they contain coesite, a high pressure polymorph of SiO_2, that form at a pressure range of >30 GPa [21]. Therefore, our previous observations on the shape of Ramgarh structure [5], geochemistry of the spherules [8] and their magnetic properties [9] along with our present observations suggest that the Ramgarh structure could be an asteroid impact crater. Further studies are in progress.

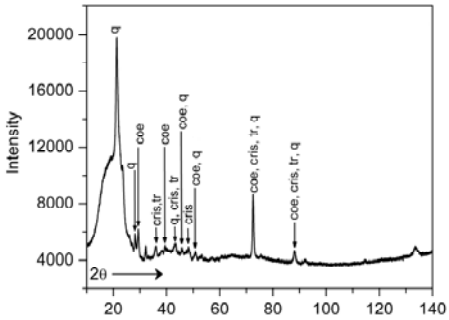

Fig. 4. The XRD spectra of spherule-like substances collected from soils inside Ramgarh structure. Abbreviations: q- quartz, co- coesite, and cris-cristobalite, tr- tridymite.

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