TIME OF FORMATION OF RAMGARH CRATER, INDIA - CONSTRAINTS FROM GEOLOGICAL STRUCTURES. S. Misra[1], A. Dube[1], P. K. Srivastava[1]and H. E. Newsom[2], [1]Dept. of Geology and Geophysics, Indian Institute of Technology, Kharagpur- 721 302, India (saumitramisra@yahoo.co.in), [2]Institute of Meteoritics, MSC03 2040, University of New Mexico, Albuquerque, NM 87131, USA (newsom@unm.edu).

Introduction: Among the four impact craters known in India, the ring-like structure at Ramgarh (centered at 25° 20′N, 76° 37′E) with a diameter of ~5.5 km is the least well established as an impact crater [1]. The structure is formed in consolidated sediments that include flat-lying sandstone, shale along with minor limestone of the Neoproterozoic Vindhyan Supergroup [2]. The structure is suggested to be a meteorite impact crater by many workers [3-13] though some questions exist [14]. The evidence favoring an impact origin are (a) shape of the crater [1, 15], which is similar to Arizona Crater, USA [16], (b) occurrence of a small central peak inside the crater [1, 11], (c) multiply striated joint surfaces in quartzite occurring on crater's rim [11], (d) possible PDFs in quartz grains under microscope [11-13], (e) occurrence of magnetic spherules both inside and outside of the crater, and on crater's rim [5, 12, 17], and (f) high abundances of Co, Ni, and Co/Cr and Ni/Cr ratios of these spherules [17].

Only limited studies of satellite imagery [1, 11, 15] and geological structure [5, 11, 12] of Ramgarh Crater exist. No detailed study is available relating the geology of this crater to the regional deformation of the target rocks. Existing structural maps of this crater [2, 18, 19] are also different from each other. Moreover, no information exists on the time of formation of this crater. We have, therefore, examined in detail the available remote sensing images of this crater and conducted field observations to understand the time of formation of this crater in relation to regional geology and deformation of the target-rocks.

Field observations: During our geological field work in November'2007 (S.M. and A.D.), we mostly concentrated on the central peak inside the crater, the deformation of sandstone along the crater rim and fault systems transecting the crater.

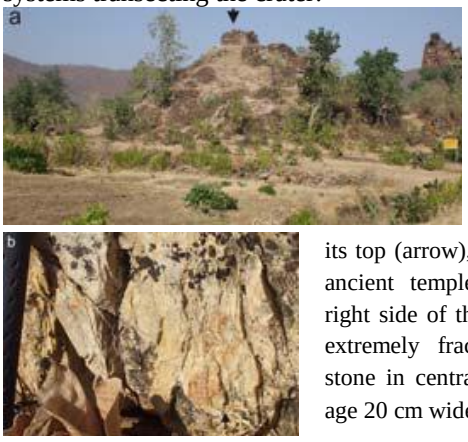

Fig.1. (a) View of ~6m central uplift, with an ancient temple on its top (arrow), and another ancient temple at the far right side of the image; (b) extremely fractured sandstone in central uplift (image 20 cm wide).

The central uplift [1, 11] is a small conical shaped peak situated at the central part of the crater beside Bandewra Temple (25°19.9′N, 76°37.5′E) and has a present height of ~6m (Fig. 1a). This peak consists of sandstone having more than one set of fracture, among which NE-SW trending fracture dipping moderately toward SE is most prominent (Fig. 1b). The sandstone on the crater's rim shows gentle to moderate titled beds around the crater's rim dipping away from the crater (average ~42°, 15-67°, number of data ~200) in most of the cases, with a few relict exposures showing subvertical to vertical dips particularly along the northern portion of the crater's rim (Fig. 2).

Fig. 2. Relict exposure of sandstone on the crater's rim at north showing vertical dip (shown by arrow).

Remote sensing imagery: High spatial resolution (~15m) panchromatic band of Landsat 7 imagery of Ramgarh Crater and its surroundings acquired on October 22, 1999 (GLCF, 2007) [20] was used besides our field observation in the present study (Fig. 3). SRTM DEM was draped over panchromatic image to reconstruct 3D view of the crater. Multi-spectral VNIR bands of ASTER (LPDAAC, 2007) [21] sensor were also used as reference in our analysis.

Geology of crater: The Ramgarh Crater is a rectangular shaped feature with a prominent, more or less continuous, raised rim all along its periphery that rises ~ 250 m above the surrounding and dips outward with angles between 20-40° from the rim crest (Fig. 3). The N-S extension of the crater's rim is ~1.4 times of its E-W extension. The crater is in a more degraded state compared to Arizona and Lonar Crater [22], which is indicated by the presence of relict/reworked ejecta within a very limited zone (~770 m) on the flank of the crater's rim (Fig. 3). Analysis of SRTM DEM image shows that only the crater's rim is standing on the ground with a thin cover of ejecta blanket around it.

The crater's rim is discontinuous at the southwest and displaced by a set of NE-SW dextral strike slip faults (2 in Fig. 3). The dextral movement along this fault is also understood by displacement of the Kul

River channel at northeast of the crater. The trace of palaeochannel of this river still exists. The rim crest is also transected by many radial deep notches and they belong to various fault systems (Fig. 4). One of them is an E-W sinistral fault that displaces the rim outward at the southeast (labeled "4" in Fig. 3). These E-W trending faults are also seen to have transected the western rim of the crater and are perhaps the youngest because they appear to transect the most prominent NE-SW fault and other faults on the crater. Two additional fault systems trending N-S and NW-SE are present on the crater's rim. Non-radial nature of these faults suggests that they may not be related to cratering mechanisms. In addition, the trends of these faults are very similar to the four sets of joints on Vindhyan sediments observed in the Rajasthan sector at Chittorgrah area ($24^{o}53'$N, $74^{o}37'$E)[2], which are E-W/ vertical or 80^{o}N, N-S/ vertical or 45-65^{o}W, NE-SW/ vertical, and NNW-SSE/ vertical. In fact, NE-SW and NW-SE trending joints are very common on the target-rock sediments around the crater. These observations indicate that the cross-cutting faults on the Ramgarh Crater are more related to the Vindhyan tectonics rather than any impact process. Their transecting nature suggests that these faults must have post-dated the formation of Ramgarh Crater. Excessive post-impact faulting perhaps helped the erosion of ejecta around the crater.

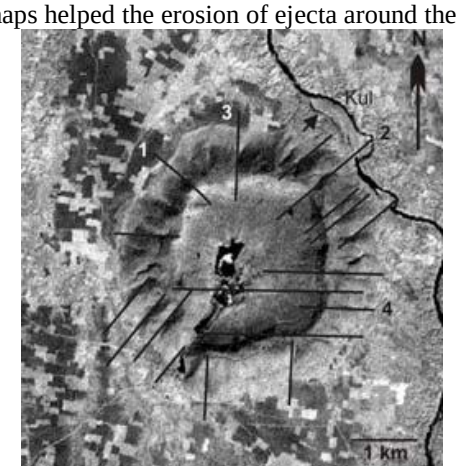

Fig. 3. Panchromatic band Lanndsat-7 grey shed image of Ramgarh Crater. Different sets of fault transecting the crater's rim are shown in black lines labeled 1, 2, 3 and 4 respectively. Black arrow in northeast shows paleochannel of Kul River. The main river Parbati is at north of the crater.

Time of formation of Ramgarh Crater: Studies on remote sensing images of greater areal extent shows that the Ramgarh Crater is situated on the old course of river Parbati, which is indicated by the presence of NNW-SSE paleochannel of this river at south of this crater. Studies of ASTER image also show that the Parbati and other two main rivers to its east and west are flowing though sub-parallel channels indicating the presence of a NW-SE mega-fracture system in this area on Vindhyan [2]. Deviation of river channel of Parbati around the Ramgarh Crater suggests this structure post-dated the formation of this mega-fracture system, which most likely had strong bearing on the rectangular shape of this crater. The cross-cutting relationship of this crater with E-W fracture system, on the other hand, indicates that this structure pre-dates the formation of this fracture system. So it can be concluded that Ramgarh Crater was perhaps formed in between the development of NW-SE mega-fracture system on Vindhyan and its subordinate deformation by E-W fracture. Further studies are in progress.

Fig. 4. The trace of E-W fault seen on the eastern rim of Ramgarh Crater (no scale).

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References: [1] Grieve R. A. F. et al. (1988) *LPI report 88-03*, 1-89. [2] Prasad B. (1984) *Geol. Suv. India Mem*., 116, 1-107. [3] Crawford A. R. (1972) *Nature*, 237, 96. [4] Balasundaram M. S. and Dube A. (1973) *Nature*, 242, 40. [5] Ahmed N. et al. (1974) *Curr. Sci*., 43, 598. [6] Dietz R. S. and McHone J. (1974) *Meteorites*, 2, 329-333. [7] Rakshit A. M. (1974) *Geol. Surv. India Unpub. Rept*. [8] Bhandari N. et al. (1976) *PRL*, Ahmedabad, India, 57p. [9] Khan A. J. (1980) *Geoviews*, 7, 173-179. [10] Nayak V. K. (1984) *Proc. 71st Indian Sci. Congr*., 22-23. [11] Master S. and Pandit M. K. (1999) *Meteoritics & Planet. Sci.* (suppl.), 34, 4. [12] Sisodia M. S. et al. (2006a) *J. Geol. Soc. India*, 67, 423-431. [13] Sisodia M. S. et al. (2006b) *J. Geol. Soc. India*, 68, 563. [14] Reimold W. U. et al. (2006) *J. Geol. Soc. India*, 68, 561-563. [15] Murali A. V. et al. (1990) *LPSC, 21*, 821-822. [16] Nayak V. K. (1997) *Conf. on Large meteorite impacts and planetary evolution*, LPI, abs. no. 6048. [17] Misra S. et al. (2008) *39th LPSC (submitted)*. [18] Ghosh S. and Das D. P. (1999) *Geol. Suv. India Unpub. Rept*, 20p. [19] IRS LISS II FCC, IRS Application appraisal card: 001. [20] GLCF (Global Land Cover Facility) (2007), Link: http://glcf.umiacs.umd.edu/index.shtml. [21] Land Processes Distributed Active Archive Center (LPDAAC, 2007), Link: http://edcdaac.usgs.gov/main.asp [22] Grant J. A. (1999) *International J. Impact Eng*., 23, 331-340.