GEOCHEMISTRY OF GLASSY ROCKS FROM RAMGARH STRUCTURE, INDIA. S. Misra[1], D. Panda[2], D. Ray[2], H. Newsom[3], A. Dube[4] and M. S. Sisodia[5], [1]SAEES, University of KwaZulu-Natal, Durban-4000, South Africa (misras@ukzn.ac.za), [2]Physical Research Laboratory, Ahmedabad- 380009, India (dwijesh@prl.res.in), [3]Institute of Meteoritics, University of New Mexico, New Mexico 87131, USA (newsom@unm.edu), [4]P147/3, Janak Road, Kolkata-700029, India, [5]Department of Geology, J. N. Vyas University, Jodhpur-342 033, India.

Introduction: The ring-like Ramgarh structure in the southeast Rajasthan (centered at 25°20′N, 76°37′E) [1], which has an outer diameter of ~4 km and a rim height of ~250 m above the surroundings, is formed on the extensively flat sedimentary terrain of the Neoproterozic sandstone (dominant rock type), shale and minor limestone of the Lower Bhander Group of the Vindhyan Supergroup of central India [2]. This rectangular shaped structure could be the third best candidate of asteroid impact craters in India, although confirmative evidences are slow in coming [3-6]. Our study during the last half a decade has documented some features, e.g. closely spaced (<10 µm) planer fracture (PF) in quartz; spherules with accretionary lapilli, similar to those found at Ries crater, Germany, having high average Ni [7, 8] etc., which perhaps have strengthened arguments in favor of asteroid impact origin of the Ramgarh structure.

In our previous abstract, we reported some glassy objects recovered from the alluvium of the Ramgarh structure [8]. These glassy rocks have either highly vesicular or ropy appearance on their surfaces. In our present work, we report our preliminary observation on the internal morphology and geochemistry of these glasses.

Analytical techniques: The polished thin sections of the glassy materials were made at SAEES, University of KwaZulu-Natal, Durban, South Africa. The microprobe (Cameca SX-100) analyses were carried out at the Planex, Physical Research Laboratory, Ahmedabad, India. All the analyses were undertaken at 15 keV accelerating voltage, 15 nA sample current, and 1µm beam size with PAP correction. Quantitative analyses of major oxides and some trace elements (Cr, Co, Ni) were attempted during our study. High sample current (80 nA) along with long peak counting times up to 50s were used to reach detection limits of trace elements with low concentrations. Our detection limits of trace elements with reference to the NIST 610 standard [9] are as follows: Cr- 107 ppm (uncertainty 6%), Co-132 ppm (5%) and Ni- 150 ppm (8%).

Experimental data: An irregular shaped vesicular glassy rock sample (R-AD-11) of ~5 cm diameter (figure 2a in [8]); collected from the alluvium at the western part of the crater just outside the rim of the structure; is amorphous, highly vesicular and shows vitreous luster in hand specimen. Under microscope, the rock contains subrounded to subangular xenocrysts of quartz grains containing fractures within a vesicular brownish matrix. The BSE image of the matrix shows porphyritic texture where subhedral prismatic crystals (c) without any preferred orientation are embedded in a glassy melt (m) (Fig. 1a).

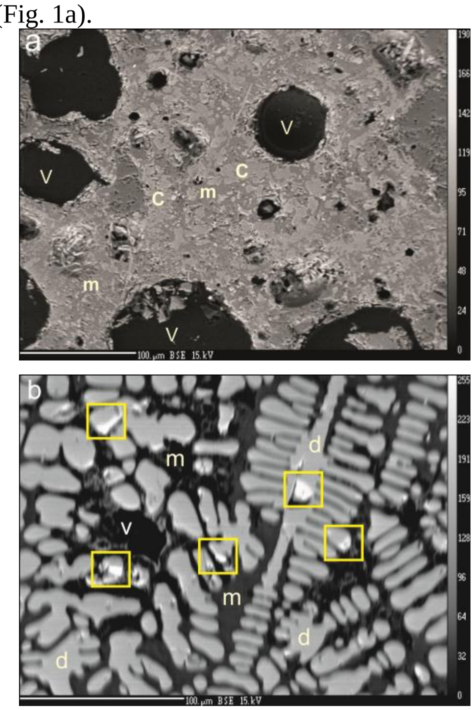

Fig. 1. BSE images of (a) vesicular glass (R-AD-11) showing prismatic crystals {c} within a melt {m} with vesicles {v}, (b) another glassy sample (R-82) showing dendritic structure of magnetite {d} within silicate melt {m}with vesicles {v}, note presence of native iron {in box} with magnetite.

The average bulk chemistries of the crystal and melt in the matrix are shown in Table 1. Both the phases show considerable variations in bulk compositions dominated by SiO_2, Al_2O_3, CaO and FeO. The apparent low totals of these two phases could be either due to activity of volatiles during their formation [8] or the presence of iron in ferric state. The composition of the crystals is not clearly known, could be between oligoclase and andesine in terms of SiO_2 (~61 wt%) [10], although it contains high iron, perhaps as Fe^{3+} replacing Al, and CaO (12%) and too low Na_2O (~0.55%). The low SiO_2 of the glassy matrix is similar to basaltic melt. Co and Ni could be the important trace element constituents of crystal and melt respectively and both of the elements vary in abundance upto ~700 ppm.

The other glassy rock sample (R-82, ~4 cm diameter) with vesicular surface was collected from the alluvium inside the Ramgarh structure. The BSE images on the thin section of this sample show growth of dendritic magnetite without any preferred orientation within a vesicular melt (Fig. 1b). A few fragments of native iron is associated with the magnetite, however their mutual textural relationship is still under investigation.

The melt phase of the sample R-82 is an iron and Ca-rich silicate (Table 1) and close in composition to esseneite [10]. Iron is the dominant element in magnetite. All the phases show high variation in trace element contents. The native iron shows Cr, Co and Ni in the ranges of ~240-640, 1000-2000 and 150-2700 ppm respectively. In the dendritic magnetite, Cr, Co and Ni vary between ~300-500, 200-900 and 300-500 ppm respectively. The silicate melt does not show any enrichment of Cr but it contains Co and Ni upto ~500 and 450 ppm respectively.

Table 1. Average bulk chemical compositions of crystal and melt in matrix of sample R-AD-11, and melt and magnetite in R-82, numbers in parentheses indicate number of analyses.

Sample no.	R-AD-11		R-82	
Phases	Melt (6)	Crystal (7)	Melt (6)	Magnetite (3)
SiO_2	45.99	61.29	37.58	0.14
TiO_2	0.68	0.87	0.19	0.41
Al_2O_3	18.24	14.06	9.43	0.42
FeO	5.79	4.69	23.26	92.44
MnO	0.08	0.05	0.96	0.93
MgO	2.34	1.76	0.98	0.71
CaO	15.68	12.05	23.52	0.16
Na_2O	0.68	0.55	0.47	0.03
K_2O	0.67	0.52	1.65	0.00
P_2O_5	0.21	0.30	0.80	0.00
Total	90.36	96.12	98.83	95.24

Discussion: The occurrence of isolated glassy rocks (Fig. 1) is unusual in the Ramgarh because this structure is situated in a completely sedimentary terrain with no volcanics [11]. The possibility of any anthropogenic origin of these materials can be ruled out because the historic constructions within this structure do not contain man-made bricks or any kiln cooked materials. The vesicular nature and presence of dendritic magnetite in these samples (similar to the Lonar impact-melt [12]), suggest their rapid cooling in atmosphere.

Our previous work on the spherule-like materials from the alluvium of the Ramgarh structure [8] and the present work on the glassy rocks (Fig. 1) confirm the importance of SiO_2, Al_2O_3 and CaO in their formation. These oxides were probably contributed by the sandstone, shale and limestone, now exposed in the Ramgarh structure, during their melting by some unknown process. However, the dominance of FeO in the bulk chemistry of these substances along with Co and Ni requires involvement of an external major iron-rich source, also enriched in Co and Ni, in this melting process. Our data suggest that the shales of the Ramgarh structure could be important sources of iron (FeO upto ~13 wt%) but it is poor in Ni (~40 ppm). Detail analyses of shales belonging to the Upper Vindhyan Supergroup from the Rajasthan sector also confirm that these shales have FeO <10 wt% but poor in Co (< 30 ppm) and Ni (<40 ppm) [13, also 14].

Alternatively, the fragments of native iron in the glassy rocks (Fig. 1b) containing high proportions of Co (upto ~2000 ppm) and Ni (~2700 ppm) could be extra-terrestrial in nature. A pursuable model is that an iron-rich asteroid struck and melted the Vindhyan sedimentary target by high velocity impact that formed the Ramgarh structure. The fragments of the impactor asteroid were mixed in various proportions with the impact generated Ca-Al-rich silicate melt to produce the parent liquid for the glassy rocks and spherule-like materials presently found in the alluvium of the Ramgarh structure. This mixing model satisfactorily explains the very high proportions of Ni and Co in the spherules and glassy rocks, which cannot be contributed only by melting of the Vindhyan shales. The impact origin of the Ramgarh structure is also supported by our early findings on accretionary lapilli-looking structure in spherules [7] and high natural remanent magnetization (2-19 Am^{-1}) of these particles [15]. Further studies are in progress.

Acknowledgement: S. M., M. S. S. and H. N. are grateful to Planex, ISRO, and NASA (PG & G grants) respectively for financial support for this research.

References: [1] Grieve R. A. F. et al. (1988) *LPI report 88-03*, 1-89. [2] Sisodia M. S. et al. (2006) *J. Geol. Soc. India, 67,* 423-431. [3] Crawford A. R. (1972) *Nature, 237,* 96. [4] Balasundaram M. S. and Dube A. (1973) *Nature, 242,* 96. [5] Ahmed N et al. (1974) *Curr. Sci.,43,* 598. [6] Master S. and Pandit M. K. (1999) *Meteoritics & Planet. Sci. (suppl.), 34,* 4. [7] Das P. K. et al. (2011) *42nd LPSC,* abs. no. #1294. [8] Misra S. et al. (2008) *39th LPSC,* abs. no. 1499. [9] Rocholl A. B. E. et al. (1997) *Geostandards Newsletter, 21,* 101-114 . [10] Deer W. A. et al. (1992) *Prentice Hall, London,* 696 pp. [11] Ramasamy S. M. (1987) *Rec. Geol. Suv. India, 113,* 13-22. [12] Kieffer S. W. et al. (1976) 7th Lunar Sci. Conf., 1391-1412. [13] Raza M. et al. (2012) *J. Asian Earth Sci., 48,* 160-172. [14] Paikaray S. (2008) *J. Asian Earth Sci., 32,* 34-48. [15] Das P. K. et al. (2009) 40th LPSC, abs. no. 1466.