INCOMPATIBLE TRACE ELEMENT FRACTIONATION IN IMPACT-MELTS OF LONAR CRATER, INDIA- EVIDENCE OF DIFFERENTIAL IMPACT MELTING OF TARGET DECCAN BASALT. S. Misra[1] and H.E. Newsom[2], [1]School of Geological Sciences, University of KwaZulu-Natal, Durban-4000, South Africa (misras@ukzn.ac.za). [2]University of New Mexico, Institute of Meteoritics, Department of Earth and Planetary Sciences, Albuquerque, NM 87131, USA (newsom@unm.edu).

Introduction: Lonar lake, India [1, 2] is one of the few known terrestrial asteroid impact craters that is fully excavated in ~65 Ma old Deccan Trap basalts [3], and thus comparable to those craters formed on rocky planetary bodies in our Solar system having basaltic crusts [4]. Lonar crater is relatively young in age (~52 ±6 [5] or 656±81 ka [6]) and was formed by an oblique impact of a chondrite that hit target from the east [7, 8].

Lonar impactites include cm-sized impact-melt, and mm- and sub-mm sized spherules [1, 2, 7]. Geochemical fractionations between target basalt and Lonar impactites have been previously noted [9, 10]. The impactites, which have various aerodynamic to irregular shapes and range in size from mm to 10 cm, show slight to moderate enrichment of As, Rb, Zr, Sb, Cs, Th and U over target basalt [11]. Because impact melts may be common on many planetary surfaces, understanding the processes involved in their formation is important. The larger melts and impact melt spherules may have had a different origin, with the melt bombs solidifying on the surface, in contrast to the small melt spherules, which solidified in the atmosphere. In the present work we have studied trace element fractionation between target basalt and impact melt bombs.

Sampling and experimental procedures: Two samples of target basalts (L-9, 14) were collected from crater rim (i.e. from fourth flow, ~40 m thick [10]); an additional sample, which is perhaps the freshest basalt sample, was collected from a wall ~5 km west of crater as a reference. Impact-melt bomb samples (L-60c, 60d, 90; SG-1, SG-2) were collected from within ejecta at the southeast of crater rim.

Trace elements (Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Th and U) were analyzed by ICP-MS (ELAN DRC II, Perkin Elmer, USA) at National Geophysical Research Institute, Hyderabad, India. The accuracy and precision of analyses with reference to International rock standard JB-2 were better than ±5% for nearly all of the elements. However, Sc and Co data are not considered in present work because rock samples were pulverized to fine powder by tungsten-carbide ring mill that might cause contamination [12].

Petrography of impact melt: Under the microscope, our impact-melt bomb samples consist of alternate layers of brown coloured melt and relatively thin layers of opaques (magnetite) (Fig. 1a). The melt-rich part is sometimes extremely vesicular. Thin layers rich in magnetite are also present within the melt-rich part and alternate in smaller scale with melt rich layers, and they altogether show schlieren structure (yellow box). The Back Scatter Electron image shows some new features, which are present mostly close to the vesicular surface of the impact-melt bombs as follows (Fig. 1b): (i) the impact-melts show presence of micro-xenocrystic components (box 1), (ii) development of radiating crystals around vesicle (box 2), (iii) concentration of minute opaque crystals (box 3), and (iv) devitrification of glass to minute radiating crystals (box 4). The inner part of the melt bomb, however, is clean and homogeneous.

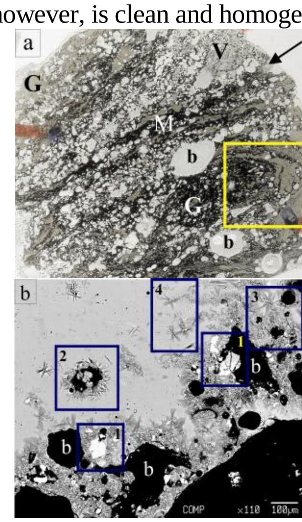

Fig. 1. (a) Photomicrograph of a thin section of an impact melt bomb (width ~24 mm) showing layering (arrow), (b) BSE image of impact melt bomb, abbreviations: G- glass-rich part, V- vesicle-rich part, M- opaque (magnetite)-rich part, b- gas bubble.

Geochemical data: Chondrite normalized plot of fourteen REEs shows that impact-melt bombs are definitely enriched in La (~1.5 times in average), Ce (1.4), Pr (1.3) and marginally in Nd (1.2) (Fig. 2a). The impact-melt bombs show more REE fractionation (La/Yb_N 4.5) compared to target basalt (3) and that is dependent on LREE (Ce_N) content of the impact-melt (Fig. 2b). The average impact- spherule [10] (3.5) shows intermediate status. There is no HREE fractionation between target basalt and impact-melt bomb (Gd/Yb_N 2).

As seen in the incompatible trace element spidergram, our impact melt bomb samples show significant average enrichment in Cs (~2.4), Rb (3.7), Ba (1.8), Th (1.5) and marginally in Sr and U (1.3) over target basalt (Fig. 3). In contrast, the average impact spherule [10] overlaps the composition of the impact-melt bomb. Among the other trace elements, impact-melt bombs only show moderate enrichment in Cr (1.3). **Discussion:** Our incompatible trace element data are similar to other results [11]. The new observations are enrichment in LREE, Ba and Sr in the impact-melt bombs over target basalt. As these elements are not sensitive to local weathering (except Sr), enrichment of these elements in impact-melt bombs could have genetic connotation.

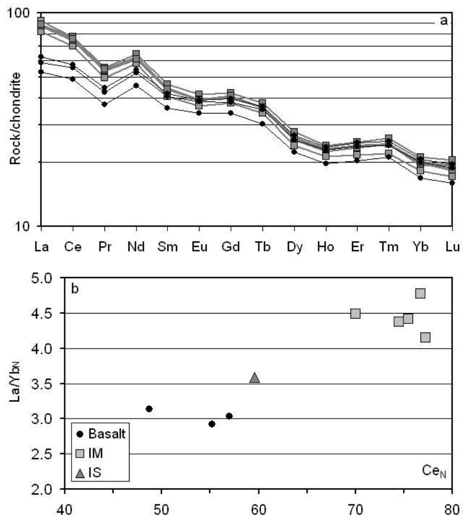

Fig. 2. Chondrite-normalized REE plots of Lonar samples, abbreviations: IM-impact melt, IS-average spherule [10].

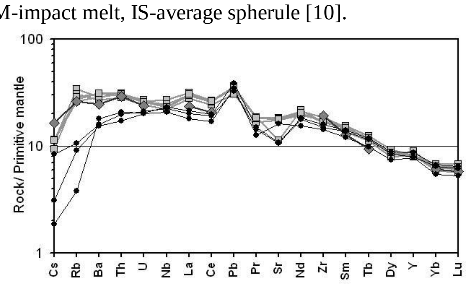

Fig. 3. Incompatible trace element spidergram of Lonar samples (our Pb data shown in figure only to show relative enrichment), symbols as in figure 2.

The major CIPW normative minerals of average target basalt and impact-melt bomb (type 'c' glass [10]) are given in table 1. The impact-melt is relatively enriched in q (~80%) and or (63%), and depleted in di (28%). The normative or molecule must be present within plagioclase because no potash-feldspar mineral is seen in target basalt under microscope. This compositional difference between target and impact-melt has several possible explanations. The differences can perhaps be best explained by plagioclase-dominated partial melting of target basalt [13, 14], with an enrichment of early melting plagioclase in the melts. Plagioclase-dominated melting of target could also enrich the impact-melt bombs in SiO_2 because microprobe analyses showed that plagioclase melts were relatively enriched in SiO_2 (~2.5 wt%) in the highest stage of shock metamorphism compared to unshocked plagioclase [13]. The low normative ab in impact-melt (Table 1) suggests possible vaporization of Na into impact plume. Melting and mobilization of an interstitial low melting temperature mineral phase could also lead to enrichment of incompatible elements in the melts. The near absence of phosphorus-bearing minerals in the Lonar basalts makes testing this chemically difficult. Relative enrichment of volatile K in Lonar impact-melts has been attributed to 'potassium metasomatism' [11]. It could also be due to plagioclase-dominated melting of target basalt during impact because plagioclase is the major source of incompatible elements K, Rb, Sr, Ba, Cs, LREE and Th [12,15] in basaltic rocks; during melting process these elements get enriched in impact-melts. Enrichment of plagioclase and/or other low-temperature melting component of target rocks is plausible as melting of plagioclase begins in the third stage of shock metamorphism, where pyroxenes were only highly fractured and opaques showed some alteration on grain boundaries, but were not severely changed, even in the highest stage of shock relict pyroxene and opaque were also present in the melt [13].

Table 1. Major CIPW normative minerals of average target basalt and impact-melt, most of data from [10] and few personal data.

Normative minerals	Target basalt (nos. 19)	Impact-melt (nos. 6)
Quartz (q)	5.91	10.65
Anorthosite (an)	20.89	24.63
Diopside (di)	15.10	10.87
Sphene (spn)	5.04	5.04
Hyperthene (hy)	8.20	8.56
Albite (ab)	25.47	20.73
Orthoclase (or)	2.24	3.66
Hematite (hm)	16.01	14.81
	98.86	98.95
Plagioclase (ab+an)	46.36	45.36

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References: [1] Nayak V. K. (1972) *Earth Planet. Sci. Let., 14, 1-6.* [2] Fredriksson K. et al. (1973) *Science*, 180, 862-864. [3] Hofmann C. et al. (2000) *Earth Planet. Sci. Let., 180, 13-27.* [4] Newsom H. E. et al. (2001) *Astrobiology*, 1, 71-88. [5] Sengupta D. et al. (1997) *Revista de Fisica Aplicada e Instrumentacao*, 12, 1-7. [6] Jourdan F. et al. (2010) *41st LPSC*, abs. no. #1661. [7] Misra S. et al. (2009) *Meteor. Planet. Sci.*, 44, 1001-1018. [8] Misra S. et al. (2010) *GSA Bull.*, 122, 563-574. [9] Strobe W. B. et al. (1978) *Meteoritics*, 13, 201-208. [10] Osae S. et al. (2005) *Meteor. Planet. Sci.*, 40, 1473-1492. [11] Son T. H. and Koeberl C. (2007) *GFF*, 129, 161-176. [12] Rollinson H. R. (1996) *Longman, England*, 352p. [13] Kieffer S. W. et al. (1976) *7th LPSC*, 1391-1412. [14] Ghosh S. and Bhaduri S. K. (2003) *Ind. Min.*, 57, 1-26. [15] White W. M. (2008) *John-Hopkins University Press, USA*.