

NOBLE GAS ISOTOPES: TRACERS OF IMPACTOR SIGNATURES IN LONAR IMPACT GLASSES.

S.V.S. Murty* and P.M. Ranjit Kumar, PLANEX, Physical Research Laboratory, Ahmedabad-380009, India, E-mail*: murty@prl.res.in

Introduction: Lonar impact crater, situated in Buldhana district of Maharashtra, India ($19^{\circ}58'N$, $76^{\circ}31'E$) is one of the two known impact craters on earth in basaltic terrain [1,2]. The age estimate for the formation of the Lonar Crater is variable, ranging generally from 50 to 650 Ka by various dating methods [3,4]. At Lonar, two types of impact glasses have been reported, based on geochemical and morphological features: Lonar tektite-like glass and Lonar vesicular glass [5]. Identifying the impactor helps in the understanding of the crater formation process (dependence of the crater morphology on the nature of projectile and the target rock) and possibly the nature, origin and flux of the impactor material. Earlier attempts have focused on geochemical and/or isotopic signatures in the impact melt breccias/glasses as tracers for identifying the impactor. In particular, siderophile elements (Co, Ni, PGEs) and Os and Cr isotopic ratios have been successfully used in the identification of the impactor [6]. Based on the observed crater dimensions, physical properties of target and bolide and scaling relations, the impactor of Lonar crater has been speculated to be an iron, stony-iron or chondritic meteorite of diameter 70m, 86m and 120m respectively [7]. Several earlier attempts to look for impactor signatures in Lonar glasses have been unsuccessful, but recently, geochemical investigation of impact spherules has led to the conclusion that 12 to 20% of chondritic impactor has survived in them [8]. Here, we present the noble gas results from Lonar glasses to demonstrate the potential of noble gas isotopes as unmistakable tracers in the identification of meteoritic signatures in them.

Samples and experimental procedures: Two types of glasses have been identified around the Lonar crater, 'tektite like glasses' with regular shapes and high (~67 wt. %) SiO_2 content, and irregularly shaped 'impact glasses' with low (~51 wt. %) SiO_2 content [5]. In this study, we have analysed 3 tektite like and one impactite like glasses from Lonar, and two samples of Phillippinite tektite for all the noble gases, by stepwise pyrolysis, using standard procedures [9]. While the initial analyses have been carried out on VG1200 Micromass, mass spectrometer, a recently commissioned 'NOBLESSE' mass spectrometer has been used to study two Lonar glasses, before analysing any meteoritic samples on this system, for unambiguous confirmation of the findings from VG1200.

Results: Noble gases are inert and volatile and their concentration depends upon temperature-pressure conditions prevailing during the glass formation.

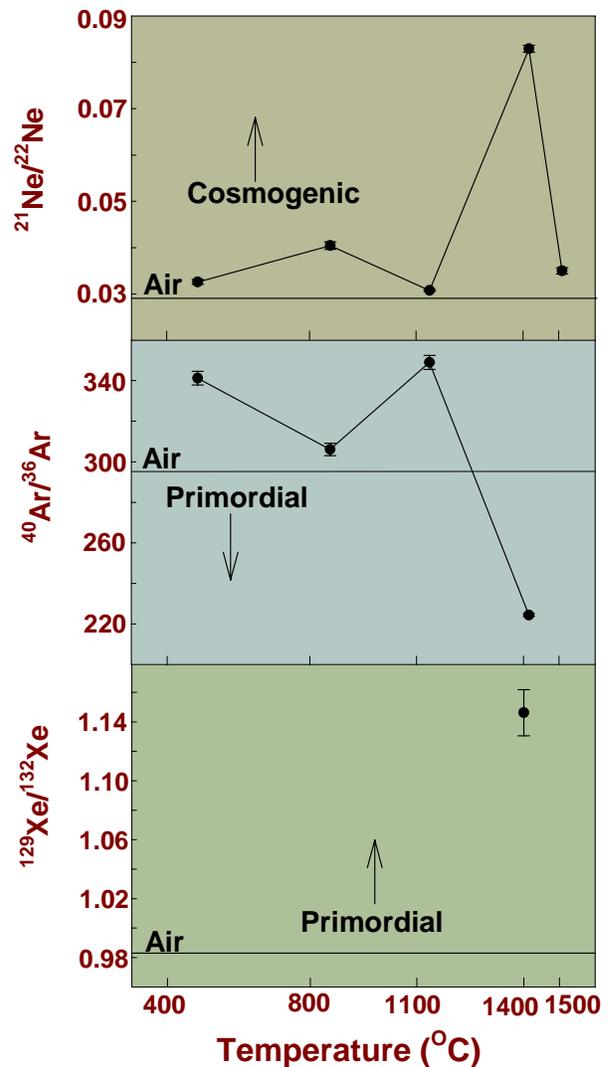


Figure 1- Release pattern of $^{21}\text{Ne}/^{22}\text{Ne}$, $^{40}\text{Ar}/^{36}\text{Ar}$ and $^{129}\text{Xe}/^{132}\text{Xe}$ ratios observed during pyrolysis of Lonar tektite-like glass. The 'Air' values and shifts expected from meteoritic component are also indicated by arrows.

Hence they can be used as a tool to understand formation conditions of glasses. We have initiated this work with this objective in mind, but to our surprise, we observed clear signatures of meteoritic origin. Data obtained on some isotopic ratios that are sensitive to meteoritic signatures have been given in Table 1, for the totals of the samples. For each sample, these isotopic ratios have shown the maximum (or minimum in the case of $^{40}\text{Ar}/^{36}\text{Ar}$) value at a particular release temperature.

Table 1 – Data on some key isotopic ratios in the glass samples, from this study

Sample	$^{21}\text{Ne}/^{22}\text{Ne}$	$^{40}\text{Ar}/^{36}\text{Ar}$	$^{129}\text{Xe}/^{132}\text{Xe}$
L-T1	0.0423 ± 0.0005	330.6 3.2	1.117 0.015
L-T2	0.0314 0.0006	325.5 3.2	1.110 0.016
L-T3	0.0341 0.0003	278.9 0.1	1.006 0.004
L-IG1	0.0279 0.0003	292.7 0.5	0.9847 0.0015
P-1	0.0300 0.0006	804.0 1.9	-
P-2	0.0304 0.0012	806.4 3.7	-
Air	0.0290	295.5	0.9832

For the sample LT-1, the temperature release pattern for these three isotopic ratios has been plotted in Fig.1. Also indicated in Fig. 1 are the ‘Air’ ratios and the expected direction of shifts due to the presence of meteoritic component. At 1400°C, all the three isotopic ratios show the peak changes. On the other hand, two samples of Phillippinite tektite showed air like ratios for $^{21}\text{Ne}/^{22}\text{Ne}$ and excess ^{40}Ar of radiogenic origin that is expected from the K in the samples, confirming that the observed excesses for Lonar samples are not experimental artifacts. Since the mass spectrometer VG1200 has been used for the analysis of several meteorite samples prior to the analysis of Lonar glasses, to further rule out any memory effects, we have recently analysed two Lonar glass samples (L-T3 and L-IG1) on the freshly commissioned ‘NOBLESSE’ noble gas mass spectrometer, as the first samples. These results, shown in Table 1, reproduce the excesses, for the Lonar Tektite like samples. The Lonar impact glass sample, however, does not show the excesses.

Discussion: The noble gas isotopic compositions in the surface reservoir samples of Earth are expected to be a mixture of trapped (atmospheric) and in situ produced (radiogenic and nucleogenic) components, though the elemental ratios could show fractionations brought about by adsorption and dissolution/degassing mechanisms [11]. In addition, one might expect to find remnants of gases from the target material (depending on the degree of degassing) and in exceptional cases signatures of the impactor. It has been observed in earlier studies of tektites and impact glasses that tektites are more thoroughly degassed than the impactites [6,9,10] and radiogenic ^{40}Ar excesses due to incomplete degassing of target have indeed been identified in impact glasses [9,12]. So far there is no report of im-

pector noble gas isotopic signatures in impact glasses and the present work is first such report. Meteorites have specific trapped ($^{40}\text{Ar}/^{36}\text{Ar}$), radiogenic ($^{129}\text{Xe}/^{132}\text{Xe}$) and cosmogenic ($^{21}\text{Ne}/^{22}\text{Ne}$) isotopic compositions that are radically different from terrestrial ratios, and can not be mimicked by any known terrestrial processes. In particular, the simultaneous occurrence of these three isotopic changes can not be generated by any artifacts. It can only be explained by the presence of meteoritic component. Incorporation of a gas component from the impactor into the melt during the glass formation is difficult to envisage. It would be more likely that a solid piece of the impactor, which is either partially degassed or undegassed has been trapped in to the impact glass, resulting in the observed meteoritic signatures. As the cosmogenic ^{21}Ne in a meteorite sample is dependant on the exposure age, as well as on its depth in the pre-atmospheric size, it can not be used for quantifying the impactor amount in the analysed sample. Trapped ^{36}Ar and radiogenic ^{129}Xe are dependant on the meteorite class and its metamorphic grade. The absolute excess of $^{129}\text{Xe}^*$, calculated as $^{129}\text{Xe}^* = [(^{129}\text{Xe}/^{132}\text{Xe})_m - 0.9832]^{132}\text{Xe}_m$

due to meteoritic contribution ranges from 0.02 to 2.0 (in 10^{-12} ccSTP/g glass sample) in the samples analysed here. It may be possible to quantify the impactor material, with some reasonable assumptions, through the excess radiogenic ^{129}Xe , due to its better retention among the three meteorite specific isotopic excesses observed in the glasses.

References: [1] Nayak V. K. (1972) *EPSL*, **14**, 1-6; [2] Fredriksson K. et al. (1973) *Science*, **180**, 862-864; [3] Strozer and Koeberl C. (2004) *LPSC* **35**; [4] Jourdon F. et al., (2010) *LPSC* **41**, # 1661; [5] Murali A.V. et al. (1987) *JGR*, Supplement B4, **92**, E729-E735; [6] Mizote S. et al. (2003) *MAPS* **38**, 747-758; [7] Chakrabarti, R and Basu A.R. (2006) *EPSL*, **247**, 197-211; [8] Misra M. et al., (2009) *MAPS* **44**, 1001-1018; [9] Murty S.V.S. (1997) *MAPS* **32**, 687-691; [10] Palma R.L. et al. (1997) *MAPS* **32**, 9-14; [11] Ozima and Podosek (2001) Noble gas geochemistry, Cambridge Univ. Press; [12] Jourdon F. et al., (2007) *GCA* **71**, 1214-1231;