GEOCHEMISTRY OF TEXTURALLY DIFFERENT FRACTIONS OF PIPLIA KALAN EUCRITE AND LOHAWAT HOWARDITE. A. Basu Sarbadhikari, M. S. Sisodia and N. Bhandari; PLANEX, Physical Research Laboratory, Ahmedabad 380009, India (E-mail: amitbs@prl.res.in)

Introduction: Howardite, eucrite and diogenite (HED) meteorites represent the largest clan of achondrites and are presumably derived from a differentiated asteroid 4-Vesta [1]. Lohawat howardite (fall, 1994) and Piplia Kalan eucrite (fall, 1996) contains texturally and compositionally different components in their main masses. Earlier studies reported preliminary petrography and geochemistry of these meteorites [2-4]. Since both of the achondrites appear to have originated in the differentiated like 4-Vesta or other similar asteroids, we have now carried out a more detailed chemical study of texturally distinct fractions to understand their petrogenesis. Here we report trace elements, especially the REE systematics, of different fractions.

Methodology: Textural and mineralogical diversity in thin- and thick-sections of these two meteorites was identified from petrographic observations. This helped in distinguishing and subsequently separating different fractions from the main mass. Major-elements in the bulk samples and different fractions were analyzed using Cameca SX-100 EPMA at PRL. Trace element concentrations were measured using a quadrupole ICP-MS (Thermo-X series2) at PRL. The rock-powder standards were terrestrial basalts (BCR-2 and BHVO-2) from the USGS and meteorite sample (Allende) from the NMNH, Smithsonian.

Petrography and Trace Element Composition: Earlier studies indicated that Piplia Kalan eucrite is an equilibrated, monomict, non-cumulate basalt [2]. Two main lithologies are observed, coarse-grained (ophitic) and fine-grained. The lithic clasts (60–80 vol%) are embedded in a brecciated matrix [2, 3]. Pyroxene and plagioclase are the dominant mineral phases; while the accessory phases are Cr-spinel, ilmenite, sulfide (troilite) and Fe-metal. Pyroxene and plagioclase composition ranges between $Wo_{0-48}En_{27-38}$ and An_{85-91}, respectively.

Lohawat is a polymict breccia howardite. It consists of a mixture of eucritic, diogenetic, and groundmass "regolith" materials [4]. Eucritic clasts are composed of basaltic pyroxene and plagioclase phases, similar in petrography and geochemistry to those of the Piplia Kalan eucrite. The diogenetic clasts are composed of more Mg-rich (up to Mg# 79) and Ca-poor pyroxenes than the eucritic clast pyroxenes. Groundmass is composed of fayalitic olivine, Cr-spinel, ilmenite and Fe-metal. Impact-melt clasts and possible carbonaceous chondrite fragments are also present in the groundmass [4].

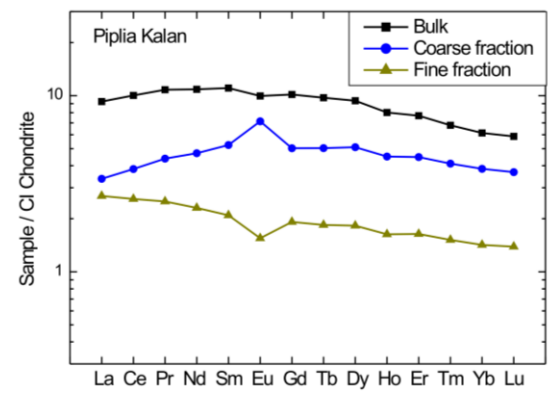

Fig. 1: REE abundances of bulk sample, and coarse and fine fractions of the eucrite Piplia Kalan. Normalization values are from Anders and Grevesse (1989).

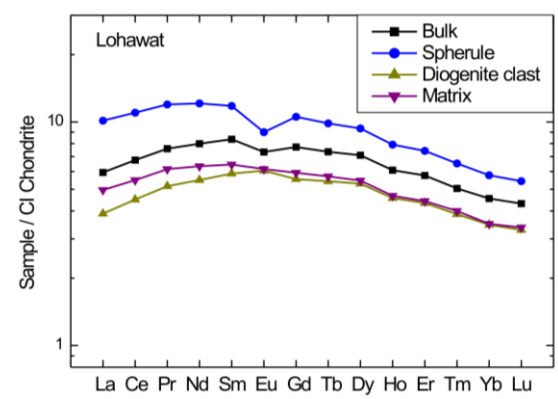

Fig. 2: REE abundances of bulk sample, and spherule, diogenite clast and groundmass of the howardite Lohawat. Normalization values are from Anders and Grevesse (1989).

In the present study it is observed that Piplia Kalan is characterized by a relatively flat-REE pattern, ~10xCI-chondrite with slightly descending trend towards the HREE ~6xCI-chondrite (**Fig. 1**). Interestingly, the coarser fraction of this eucrite demonstrates a positive Eu-anomaly, while the finer fraction shows a negative Eu-anomaly. From LREE to MREE (La to Dy) the coarser and finer fractions are the mirror images of each other. The HREE trends,

however, in the bulk, the coarse and the fine fractions are sub-parallel.

REE-trend in the Lohawat howardite displays a broad convex-up pattern in the range of 4-8xCI-chondrite with a small negative Eu-anomaly (**Fig. 2**). The glassy spherules are the most enriched in REEs (~ 10xCI-chondrite) amongst the different fractions and show a relatively large negative Eu-anomaly. The diogenite clasts are relatively least enriched in REEs (3-5xCI-chondrite) with no Eu-anomaly. Groundmass of Lohawat is intermediate in REE-composition between the bulk and the diogenite clasts in the LREE region, but closely matches in MREE to HREE (Eu to Lu) trend.

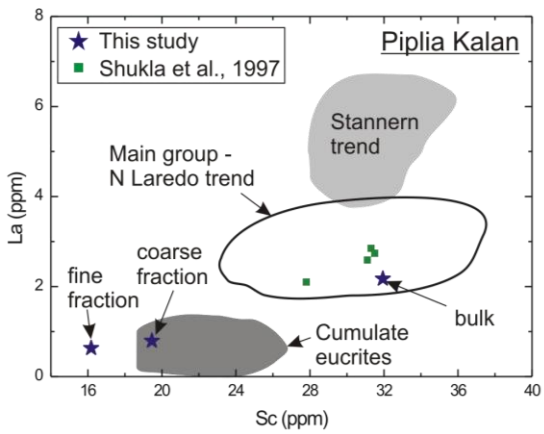

Fig. 3: Sc vs La plot of different group of eucrites, after [5]. Whole rock composition of Piplia Kalan is plotted at the Main group N Laredo trend, while both the fine and coarse fractions are plotted at or near the field of cumulate eucrites. Please note the mass balance of the addition of fine- and coarse-fractions is not equated to the bulk, which presumably has contribution from impact spherules.

Discussion: The variation in REE compositions together with textural diversity in the Piplia Kalan eucrite indicates possible chemical heterogeneity through different petrogenetic processes. Earlier study [2], based on similar major and few minor element data among texturally different fractions stated that they formed co-genetically in a shallow intrusive body. It is to be noted that the differences or similarities in the trace-elements are good indicators of the heterogeneity in the source region, while the major-elements generally signify the fractionation effects during the course of melt crystallization as magma leaves the source region.

The Sc and La content of Piplia Kalan is in the range of the Main group - N Laredo eucrites (**Fig. 3**), while both the coarse and fine fractions are within or near the range of the cumulate eucrites. Interestingly earlier result reported Piplia Kalan as a non-cumulate eucrite [2]. The strong positive Eu-anomaly of the coarser fraction (**Fig. 1**) probably indicates contribution from plagioclase. The mirror image symmetric trend of the LREEs and MREEs of the coarse and fine fractions must be mutually related during their process of crystallization. The higher abundance of REEs in the bulk composition of Piplia Kalan compared to that in the coarse and fine fractions can be attributed to the contribution from the impact spherules, which were observed in trace amount in the thin- and thick-sections of this meteorite. For instance, Lohawat howardite has abundant impact spherules that have contributed considerable amount of REEs in the main mass (**Fig. 2**).

Almost parallel and similar REE-trend between the bulk and groundmass of the Lohawat howardite (**Fig. 2**) is because of contribution from the "regolith" materials. However, a feeble negative Eu-anomaly in the bulk data indicates influence of glassy spherules observed in abundance in this howardite. The diogenite clasts, which consist mostly of high-Mg, low-Ca pyroxenes, are highly depleted in LREE, compared to the bulk and other fractions, representing an early-crystallizing cumulate. Further study based on in-situ trace, isotope and bulk isotope systematics will be attempted to comprehend the petrogenetic processes involved at the source of the HEDs.

References: [1] Drake M.J. (2001) *MAPS*, *36*, 501-513; [2] Shukla A.D. et al. (1997) *MAPS*, *32*, 611-615; [3] Bhandari N. et al. (1998) *MAPS*, *33*, 455-461; [4] Sisodia M.S. et al. (2001) *MAPS*, *36*, 1457-1466; [5] Yamaguchi A. et al. (2009) *GCA*, *73*, 7162–7182.