PETROGENESIS AND GEOCHEMISTRY OF FALL HED METEORITES

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Introduction: To understand the petrogenesis of eucrites and howardites, petrographic, mineralogical, and bulk compositional analyses were performed on four Fall HEDs, which include three monomict eucrites (Lakangaon, Piplia Kalan, and Vissannapeta), and a howardite (Lohawat). Textural features and bulk compositions indicate that Lakangaon and Piplia Kalan are basaltic eucrites, while Vissannapeta is a cumulate eucrite consistent with earlier studies ([1][2][3][4]).

Methods: Petrographic studies of thin and thick sections were conducted using a Field Emission EPMA (FE-EPMA; JEOL JXA 8530F Plus, Japan) using a 15 kV accelerating voltage and 15 nA sample current at PRL. For the bulk major and trace element composition, approximately 10 mg of sample powders were dissolved using inorganic acids and elemental concentrations were measured using a quadrupole ICP-MS (Thermo Scientific X-Series II) at CEaS, IISc.

Results: Lakangaon and Piplia Kalan are majorly composed of pyroxene (shows exsolved texture) and plagioclase with SiO_2 polymorph, ilmenite, troilite, and chromite as accessory phases. Five grains of zircon were found in the Lakangaon sample; some of the zircons were associated with ilmenite, while others were isolated. The composition of the mineral phases, as measured using the EPMA, are very similar for Lakangaon and Piplia Kalan. Vissannapeta is a heavily brecciated eucrite dominated by plagioclase and orthopyroxene. SiO_2 polymorph and chromite are the accessory phases. Spherical grains of troilite as inclusion in exsolved pyroxene grain were also detected but in extremely limited quantities. Lohawat, being a howardite, exhibits diogenitic, basaltic, as well as cumulate eucrite clasts.

Abundant rod- and bleb-shaped, finely disseminated inclusions (as small as ~ 0.2 x 0.05 µm in size) can be observed in pyroxenes as well as plagioclase of Lakangaon and Piplia Kalan; this texture is known as ”clouding in pyroxenes and plagioclase”. Because these inclusions are too small to be characterized using the EPMA beam, an approach to identify these phases using the K-means clustering algorithm on the BSE images has been executed. This algorithm helps to label different phases based on their gray values, irrespective of the size of the phase. It was found that the pyroxenes from Lakangaon are solely clouded with troilite, whereas the pyroxenes from Piplia Kalan are clouded with ilmenite. The plagioclase from Lakangaon and Piplia Kalan are majorly clouded by pyroxenes (both augite and pigeonite), although some very rare occurrences of tiny chromite inclusions were detected.

Bulk major and trace element compositions of Lakangaon and Piplia Kalan overlap with the MG-NL (Main Group – Nuevo Laredo) trend of basaltic eucrites, based on incompatible vs compatible element plots (for e.g. La vs Sc, TiO_2 vs FeO/MgO). The enriched REE abundances of both these samples (~10-14 x CI) show a relatively flat pattern with a slight negative anomaly (Eu/Eu* = 0.78 and 0.92, respectively). Lohawat also shows a similar pattern (Eu/Eu* = 0.72) but with significantly depleted concentrations (~ 4-5 x CI) as compared to Lakangaon and Piplia Kalan. Vissannapeta, on the other hand, is extremely depleted in LREE abundances (~0.2-0.3 x CI) but shows relative HREE enrichment (~0.5-0.6 x CI) with a huge positive Eu anomaly (Eu/Eu* = 7.03). The Ni content can be used to classify the samples into very low (< 1 ppm), low (1-5 ppm), intermediate (5-10 ppm), and high (> 10 ppm) Ni categories [5]. Piplia Kalan can be classified in the low Ni category, whereas Lakangaon, with slightly more Ni content, makes it to the intermediate Ni category. Vissannapeta contains 30 ppm of Ni, which is high and anomalous for monomict eucrites. Lohawat also belongs to the high Ni category (16 ppm), consistent with the presence of H5 chondrite clasts [6].

Conclusions: Based on the textural evidences , Lakangaon and Piplia Kalan exhibit type 5 and type 7 of the degree of thermal metamorphism of basaltic eucrites, respectively, while Lohawat displays different degrees of thermal metamorphism (type 1, 3, 5, and 6) in different clasts [7][8]. Based on a Ni/Co vs Ni plot, Vissannapeta is plausibly contaminated by CM/CR chondrite by up to 0.37% (by applying mass balance constraints on mixing between average CM and average cumulate eucrite). Eucrite petrogenesis explored through a partial melting perspective based on REE concentrations reveals that the REE composition of Vissannapeta can be formed as a residue when the CI precursor undergoes 21% partial melting. In the case of basaltic eucrites Piplia Kalan and Lakangaon, REE compositions can be generated through a two-stage model where the CI precursor undergoes 33% and 44% partial melting followed by 84% and 90% fractional crystallization, respectively.

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