THE CUMULATE AND BASALTIC EUCRITE: COMPARATIVE GEOCHEMISTRY WITH TERRESTRIAL MORB AND IMPLICATIONS TO IGNEOUS HISTORY. D. RAY, A. D. SHUKLA and S. GHOSH. Physical Research Laboratory, India (dwijesh@prl.res.in).

Introduction: Howardite, Eucrite and Diogenite (HED) clan of achondritic meteorites constitute the most abundant achondrite class and are thought to have derived from a differentiated asteroid, 4Vesta [1,2]. The cumulate eucrites are basically deep seated, medium to coarse grained gabbros, whereas basaltic eucrites are fine to medium grained, pigeonite-plagioclase basalts, often resembling terrestrial basalts and recently connected to Vestan crust. It can be argued that reasonable time differences exists between asteroidal volcanism vis-à-vis the terrestrial modern volcanism, however, basaltic eucrite is found geochemically similar to terrestrial Mid-Ocean Ridge Basalt (MORB) [3]. In this communication, we present new trace element data of Indian cumulate eucrite (Vissannapeta) and different lithologies of basaltic eucrite (Piplia Kalan) in order to identify the igneous process(es). Our aim is further to understand source characteristics of eucrite using terrestrial MORB as a reference.

Database and Analytical Techniques: Geochemical data for cumulate and basaltic eucrites were compiled from Mittlefehldt (2014) [4]. Global MORB data were collated from Petrological Database of Ocean floor. Trace element analyses of Indian eucrites were carried out using Inductively Coupled Plasma Mass Spectrometer (ICP-MS, Thermo XSeries II) at Physical Research Labortaory, India. BHVO-2 was employed for calibration and also run as unknown sample to check the accuracy and precision of the analyses. The accuracy and precision is always found better than 5% for most of the trace elements.

Geochemistry: Reports on first fall, petrography, cosmogenic nuclides and noble gases on Vissannapeta and Piplia Kalan have been already complied and discussed elsewhere [5,6]. In MgO versus Al_2O_3/TiO_2 plot, majority of cumulate and basaltic eucrite fall within the terrestrial MORB field, however, eucrite compositions display relatively a higher and variable Al_2O_3/TiO_2 ratio (5-35) as compared to MORB (Fig. 1a). In CaO/Al_2O_3 versus Al_2O_3/TiO_2 plot, cumulate eucrite, basaltic eucrite and terrestrial MORB altogether show a tight cluster and average CaO/Al_2O_3 mostly cluster around 0.8 (Fig. 1b). In Chondrite normalized trace element spidergram, Vissannapeta cumulate eucrite shows typical depleted pattern with positive Ta, Sr, Eu and negative Nb anomalies (Fig. 2). In contrast, Piplia Kalan trace element concentration is more akin to E-MORB composition, except there are noticeable depletions in Zr and Hf. Individual clast of Pipilia Kalan also shows uniform trace element pattern and more or less follow the bulk compositional trend (Fig. 2).

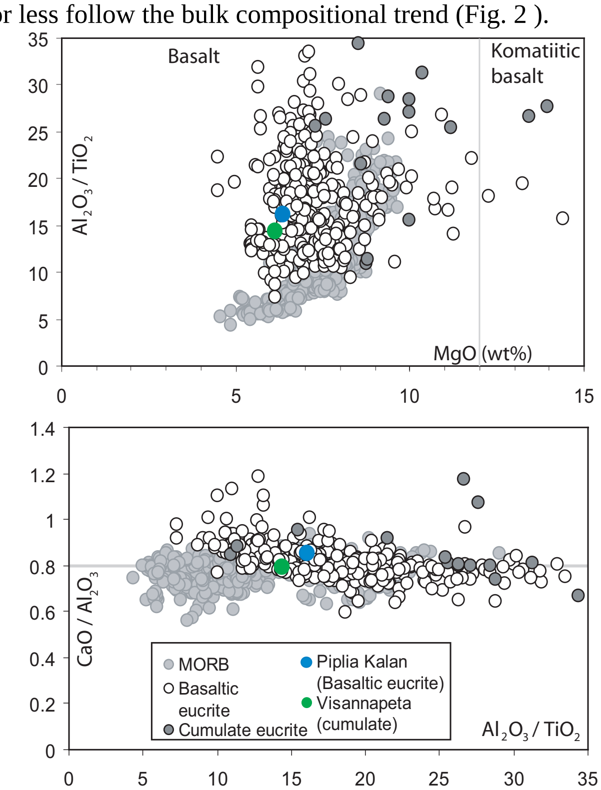

Fig. 1. Al_2O_3/TiO_2 versus MgO (wt%) and CaO/Al_2O_3 plots showing cumulate eucrite, basaltic eucrite along with Piplia Kalan and Vissannapeta eucrite.

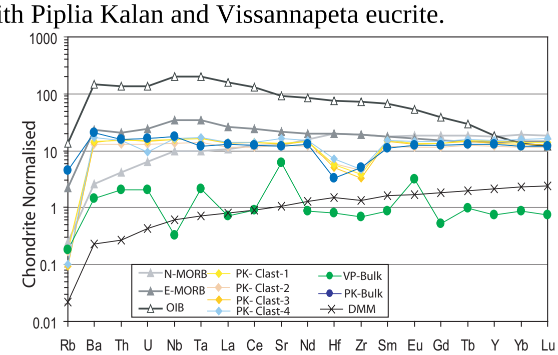

Fig. 2. Chondrite normalized trace element spidergram. Chondrite data after McDonough and Sun (1995) [7].

The chondrite normalized REE pattern of Piplia Kalan like other basaltic eucrites exhibits relatively flat LREE (La/Sm_N:1.15), HREE (Gd/Yb_N:1.04) without any Eu anomaly (Eu/Eu*~1.07). In contrast, the Vissannapeta like other cumulate eucrites shows flat

LREE (La/Sm_N: 0.82), slightly depleted HREE (Gd/Yb_N:0.61) and a typical positive Eu anomaly (Eu/Eu*~ 4.7) (Fig. 3). Moreover, based on REE abundances, Piplia Kalan is ~15 times more enriched as compared to Vissannapeta.

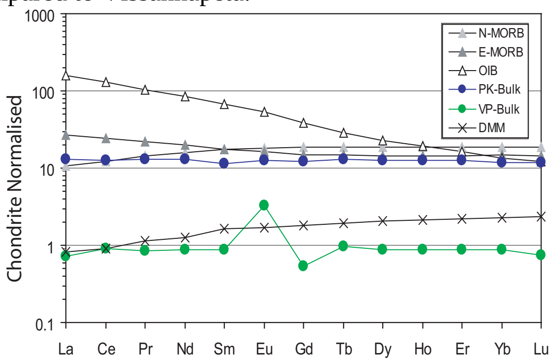

Fig. 3. Chondrite normalized rare earth element spidergram of Piplia Kalan (PK) and Vissannapeta (VP). Normalised data after McDonough and Sun (1995) [7]. Depleted MORB mantle (DMM) data from Workman and Hart (2005) [8].

In igneous identification plot (after [9]), incompatible trace element ratio (Zr/Y) changes substantially with a steeper slope, as the least compatible element (hence Zr) increases (Fig. 4). The MORB-like geochemical characters are more well demonstrated in incomatible trace element ratios (Y/Nb versus La/Sm) plot. Piplia Kalan and the basaltic eucrite composition fall close to the Mid-Atlantic Ridge Transitional MORB (MAR T- MORB). Interestingly, terrestrial MORBs show a curvilinear trend while cumulate and basaltic eucrite fall along the mid way of the curve, similar to T-MORB (Fig. 5).

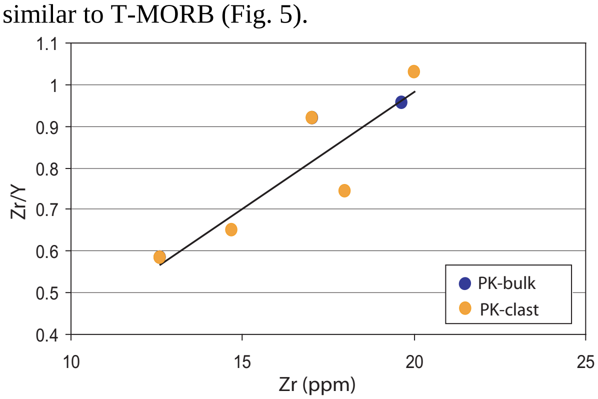

Fig. 4. Process identification plot (after White 2008 [9]). Ratio of incompatible trace element (Zr/Y) versus least compatible element (Zr).

Discussions: The classification scheme of MgO, CaO/Al_2O_3 and Al_2O_3/TiO_2, more commonly used for terrestrial komatiitic rocks (after [10]), is equally useful to classify the planetary basalt and asteroidal basalt due to remarkable similarity with MORB composition.

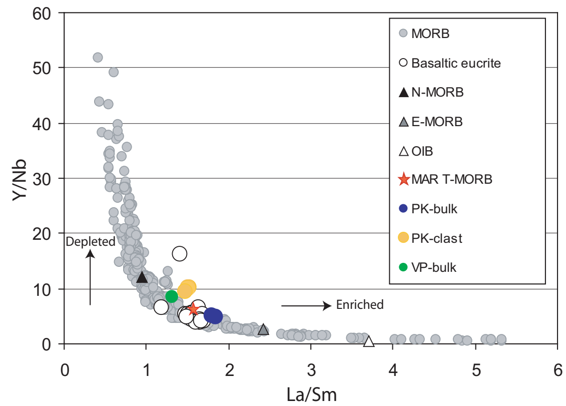

Fig. 5. Incompatible trace element ratio plot of Piplia Kalan, Vissannapeta eucrite and Global MORB.

We argue that basaltic eucrite geochemically falls in between depleted N-MORB and enriched E-MORB as reflected in the incompatible trace element ratio and furthermore it is confirmed by the curvilinear mixing trend of MORB data. The overlapping composition of Piplia Kalan and MAR T-MORB suggests for an MORB-like source melt in asteroidal mantle.

In process indentification plot, Piplia Kalan (including the individual clast) favours partial melting dominated processes instead of crystal fractionation. This is also supported by uniform and flat REE patterns. This clearly provides an indiaction of serial magmatism rather than whole-mantle magma melting. The source of cumulate Vissannapeta is truly depleted (compared with DMM), while positive Sr and Eu anomalies are preferably related to plagioclase accumulation.

The petrogenesis of basaltic eucrite is indeed perplexing. The whole-mantle magma ocean model recently being debated and therefore partial melting or incomplete melting could be a more realistic process yield eucrite magma, however, further studies are ongoing to prove this point.

References

[1] McSween Jr. H.Y. et al. (2013) *Meteorit. Planet. Sci., 48,* 2090-2104. [2] McCoy T.J. et al. (2014) *Chemie der Erde-Geochem.*, in press. [3] Shukla A.D. et al. (2015) 46th *LPSC, abstract no. 1356.* [4] Mittlefehldt D.W. (2014) *Chemie der Erde-Geochem.*, in press. [5] Ghosh S. et al. (2000) *Meteorit. Planet. Sci., 35,* 913-917. [6] Shukla A.D. et al. (1997) *Meteorit. Planet. Sci., 32,* 611-615. [7] McDonough W.F. and Sun S.S. (1995) *Chem. Geol., 120,* 223-253. [8] Workman R. and Hart S.R. (2005) *Earth Planet. Sci. Lett., 231,* 53-72. [9] White W.M. (2008) Geochemistry In: Encyclopedia of Earth Sciences, Macmillan, New York (online version) [10] Sproule R.A. et al. (2002) *Precamb. Res., 115,* 153-186.