Understanding Lunar Geochemistry beyond Procellarum KREEP Terrane from Antarctic Lunar Meteorites

Y. Srivastava[1,2], A. Basu Sarbadhikari[1], J. M. D. Day[3], and A. Yamaguchi[4],

[1]Physical Research Laboratory, Ahmedabad 380009, India, [2]Indian Institute of Technology Gandhinagar, Gujarat 382355, India, [3]Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093-0244, USA, [4]National Institute of Polar Research (NIPR), 10-3 Midori-cho, Tachikawa, Tokyo 190-8518, Japan

Sample return missions such as Apollo, Luna, and the recent Chang'E 5 have provided an invaluable understanding of the chemical and thermal evolution of the Moon. Although these missions sampled a plethora of lithologies on the Moon, all of them were brought from a region with unusually high abundances of incompatible elements (such as K, REEs, P) known as the Procellarum KREEP Terrane (PKT). Consequently, our understanding of the Moon is somewhat biased due to this restricted sampling. This work focuses on lunar meteorites, which were recovered from Antarctica, offer access to unexplored regions of the Moon. Using the lunar meteorites, we aim to understand two important processes that have shaped the Moon throughout its geological history, i.e., Volcanism and Meteoritic impacts.

We studied unbrecciated lunar meteorite A-881757, which is free from urKREEP component, along with paired meteorites Y-793169, MIL 05035, MET 01210 (together as YAMM). These samples based on their Sr-Nd isotopic characteristics classify into a relatively new basaltic rock type termed as KREEP-free basalts. The applied petrological modelling indicates these older (4.3-3.9 Ga) KREEP-free basalts were generated through low degree partial melting of a shallow pyroxene-rich mantle, distinct from later (3.8-3.3 Ga) KREEP-bearing Apollo mare basalts, suggesting a fundamental change in lunar melting processes. This further provides insights into the early thermo-chemical evolution of the Moon, and highlights the importance of KREEP-free basalts in understanding the partial melt mechanisms at the lunar interior.

Moreover, we studied highly siderophile elements in meteorites A-881757, Y 981031, Y 983885 and Y-86032, which have potentially been launched away from the PKT, and therefore provide new insights into the meteoroid impacts and volcanism that have shaped the previously unexplored lunar surfaces. The Re-Os isotope systematics and HSE abundance in A-881757 yield valuable insights into the abundance of these elements in the KREEP-free lunar mantle, while the brecciated lunar meteorites offer constraints on the HSE abundance at the lunar crust. The inter-elemental HSE ratio of lunar regolith breccia Y-86032 implies late accretion of an ordinary chondrite-type impactor, while Y 981031 and Y 983885 show fractional crystallization and metal segregation within impact melt sheets, resembling the HSE enrichment observed in terrestrial impact settings. Collectively, findings from the Antarctic meteorites, presented in this work, expand our knowledge to the Moon's geological processes and provide a more comprehensive understanding of its complex evolution history.