

**GEOCHEMICAL AND MINERALOGICAL CONSTRAINTS ON THE COMPOSITION OF THE PARENT PLANETESIMAL FOR THE ACAPULCOITE AND LODRANITE SUITE OF METEORITES.** P. Layak and N. Rai, Department of Earth Sciences, Indian Institute of Technology Roorkee, India ([playak@es.iitr.ac.in](mailto:playak@es.iitr.ac.in), [n.rai@es.iitr.ac.in](mailto:n.rai@es.iitr.ac.in))

**Introduction:** The most fundamental process in the evolution of different rocky bodies in the solar system includes the transformation from primitive nebular aggregates to differentiated bodies with a well-defined metallic core surrounded by silicate mantles. Chondrites and planetary samples like basalts and iron meteorites represent the two extremes observed in meteorite records, representing the crust derived through partial melting of the silicate, and the metallic core that segregated from the silicate part. On the other hand, meteorites such as achondrites (e.g. Acapulcoites, Lodranites etc.) represent the intermediate stages in the physical and chemical processes of asteroidal differentiation extremely well. The acapulcoite-lodranite (AL) clan, which represents the prototypical primitive achondrite group defines partial differentiation in an asteroid. Acapulcoites and lodranites (ALs) are primitive achondrites which are derived from a common parent body owing to its similarities in mineral compositions,  $^{39}\text{Ar}$ - $^{40}\text{Ar}$  ages, CRE ages and O-isotope signatures [1-5].

The petrogenesis and thermal evolution of acapulcoites and lodranites establishes that they have been formed from a chondritic precursor which experienced localized partial melting and melt extraction accompanied by thermal metamorphism [1,6]. As a result, their study provides clues to some of the earliest stages in the physical and chemical processes of asteroidal differentiation. In spite of the detailed petrogenetic history of the AL parent planetesimal, its original composition still remains an unsettled question.

Estimating the bulk compositions of planetary bodies is challenging given the limited constraints that are available. In case of the Earth, the bulk composition of its mantle (66% of the total planet) is considered to be well constrained because of the availability of the mantle xenolith samples supplemented by geophysical constraints [7]. In this study, we aim to predict the bulk composition for the Acapulcoite-Lodranite Parent Body (ALPB) from a host of meteorite compositions.

**Approach:** Here, we have considered a few parent body contenders for the acapulcoite-lodranite suite of meteorites (based on the works of [1-6, 8-9]). This included chondritic meteorites viz. ordinary (H) chondrites, Carbonaceous Bencubbinites (CB),

Carbonaceous Renazzo (CR), Rumuruti (R) and Kakangari (K) chondrites, as possible representatives of building block material for the AL-suite.

We have used a range of criteria including mineralogy, density, comparison of bulk composition of A-L meteorites with model compositions derived using thermodynamic and experimental petrology data, trace element systematics for lithophile and siderophile elements, modal abundance of minerals, and oxygen isotopes, to shortlist the most plausible parent body composition for the A-L suite of meteorites.

**Results & Discussion:** The results are derived after consideration of several criteria which include mineral phases and their compositions, densities, bulk composition of the modelled ALs derived from thermodynamic and experimental petrology data, trace element abundances and O-isotopes. Some of the main findings obtained so far have been listed below:

**Mineralogy:** Mineralogy in ALs comprise of olivine, opx, Ca-px, plagioclase along with metallic Fe-Ni, troilites, chromites and phosphates [1, 4, 5, 6, 10, 11, 12]. Our results demonstrate that all 5 starting compositions generate olivines, orthopyroxenes, whitlockites and feldspars as observed in AL silicates.

**Bulk composition of ALs:** The bulk composition of modelled acapulcoites obtained for H, CB, CR, K and R chondrites compositions lie within  $\pm 2\sigma$  of actual acapulcoite samples. On the other hand, except R chondrites, all four compositions result in modelled lodranites that lie within  $\pm 2\sigma$  of actual lodranites. There is an observed mismatch between the low MgO content in R chondrites (~22 wt.%) compared to the lodranites (~29.7 wt.%), which rules out R chondrite composition as an ALPB contender.

**Trace element systematics in ALs:** The ALPB has undergone 1-4% partial melting without the loss of a metallic melt to give rise to the acapulcoites. Thus, a compositional homogeneity in terms of their bulk trace element concentration is expected between acapulcoites and H, CR, CB, CR and K chondrites. It is observed that the CI normalized values for refractory lithophiles (Al, Ca, V, La, Sm, Mg, Cr, Na and K) and siderophiles (Ru, Os, Ir, Fe, Co, Ni, Ga, As and Au) for K chondrites, H chondrites and CR chondrites lie within  $\pm 1\sigma$  of acapulcoites. But, the CB chondrites show depletion in lithophiles ( $0.4 \pm 0.1 \times \text{acap.}$ ) and enrichment in

siderophiles ( $3.4 \pm 0.2 \times \text{acap.}$ ) as compared to acapulcoites, owing to which it is ruled out from the list of possible ALPB contenders.

**Modal abundance of minerals:** The modal abundance of the silicate phases at the end of crystallization in H and K chondrites correspond well with ALs, in sharp contrast to the case of CR chondrite composition which do not provide a good match to the ALs. Therefore, CR chondrites is also exempted from the list of ALPB contenders.

**O-Isotopes:** Despite the mineralogical and geochemical similarities of the H chondrites with ALs, the O-isotope signatures for the H-chondrites and the AL suite are observed to be very different. On the other hand, the K chondrites not only satisfy the mineralogy and geochemistry criteria but their oxygen isotope signatures also overlap with the AL-suite (Figure 1).

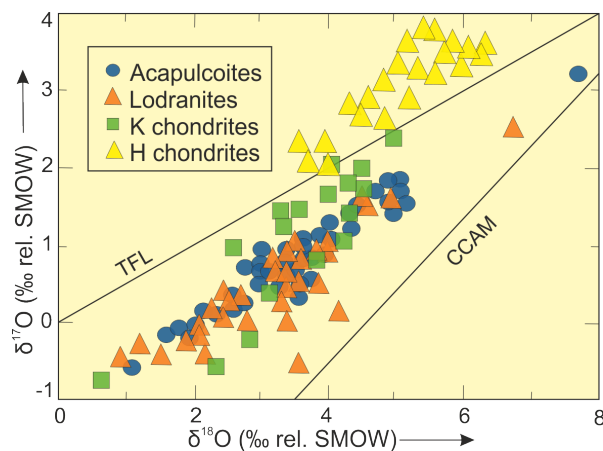


Figure 1: Bulk oxygen isotope compositions of K chondrites [13], H group of ordinary chondrites [14] and A-L suite of meteorites [5]. TFL is the Terrestrial Fractionation Line and CCAM is the Carbonaceous Chondrite Anhydrous Member Line.

**Conclusion:** Oxygen isotopes provide important constraints but in many cases the derived compositions can be non-unique as exemplified by the case of Mars, and the Ureilite Parent Body [15]. This made it necessary to satisfy other available constraints such as major element chemistry, mineralogy, modal abundance of minerals, trace element systematics for lithophile and siderophile elements, in addition to oxygen isotope signatures. From the analysis of all tentative ALPB compositions (H, R, CB, CR and K chondrites), keeping the above criteria in view, the K chondrites offer best correlations with the ALs (Figure 2). Our results suggest that the K chondrite composition appears to be the most plausible composition for the parent body that underwent low degrees of partial melting to form the AL suite of meteorites.

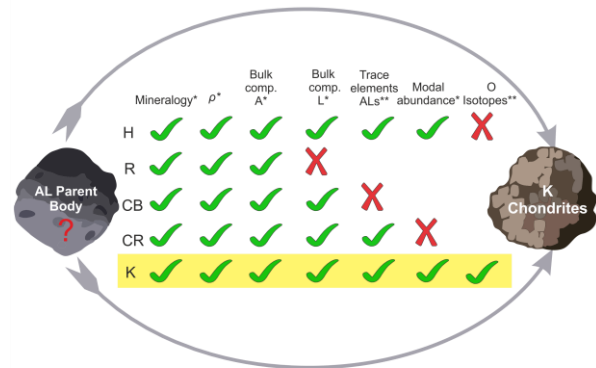


Figure 2: Summary of the findings from the comparison of mineralogy, density, bulk composition of modelled ALs obtained from thermodynamic and experimental petrology data, trace element systematics and O-isotope signatures in H, R, CB, CR and K chondrites with ALs.

\* Results based on comparison of modelled acapulcoite-lodranites (ALs) obtained from thermodynamic and experimental petrology data with actual AL samples.

\*\*Results based on comparison of samples of H, R, CB, CR and K chondrites with ALs. Here, A- Acapulcoites and L- Lodranites.

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