

NUMERICAL MODEL OF A GENETIC LINK BETWEEN THE ACAPULCO AND Y791493 PRIMITIVE ACHONDRITES. II: IMPLICATIONS TO THE ORIGIN OF ACAPULCOITES AND LODRANITES

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Abstract. Acapulcoites and lodranites could have formed from a common precursor by partial melting up to ~15 % of it. The mineralogical and chemical properties of acapulcoites point to retention of the partial melt in its source region(s), while those of lodranites require removal of the earliest portions of partial melt. In the system modeled by [1], at melting degrees less than ~20%, Mg/(Mg+Fe) ratios in residual olivine and orthopyroxene coexisting with metal *decrease* as the melting proceeds, allowing lodranites to be formed as residua from the partial melting of more magnesian acapulcoites.

The thermodynamic model studied by [1] allows lodranites to be produced from Acapulco by partial melting their source region, followed by the removal of a portion of the melt and addition of small amounts of Fe metal. Apparently the acapulcoite/lodranite parent body contained a partially molten region(s), in which melt and metal moved in opposite directions. Textural and petrofabric studies of the Y791493 lodranite suggest it was formed "in the presence of strong magmatic laminar flow" [2]. The degree of melting required is >6 wt.%, but more likely ~15 %. The latter value is required to explain the Fe/Mn and Mg/(Mg+Fe) ratios of Acapulco olivines. To produce the Y791493 lodranite from the same precursor material, a more complicated history is required (Table 1 in [1]): primary residue (M_{Lod}) formed by removal of the first ~5% of melt (M_{part}) then needs to be melted by an additional ~10% (M_{mLod}). For the Acapulco composition, the calculated temperature at which 15% partial melting is achieved (1257°C) is close to the temperatures estimated from oxygen isotope thermometry (1300-1400°C, [3]) and metal compositions (1400-1500°C, [4]). The model requires that acapulcoite and lodranite source regions were melted to similar degrees, but the former retained all melt generated within the residue while the latter lost ~85% of the first melt formed (which comprised <~6 wt.% of the total mass of precursor material). Later melt formed in the lodranite source regions was retained with the residue, and ultimately crystallized there.

What happened to the partial melt that was lost from the lodranite source regions? These incompatible-element-rich melts could have been pyroclastically ejected from the parent body altogether, forming Na, Al-rich chondrules or other objects in space [5], or they could have migrated to undepleted precursor material, ending up in the acapulcoites themselves. The enrichment of Acapulco and ALH81261 in REE, especially LREE [6-8], relative to chondrites could be achieved by the addition of small amounts of a melt enriched in incompatible elements. The addition required would not significantly change the bulk mineralogy of acapulcoites, except by increasing their plagioclase contents (as has occurred in the ALH78230, EET84302 and ALH81261 acapulcoites [9-12]). [13] suggested partial melts were lost from lodranites by explosive volcanism. This mechanism could work at low degrees of partial melting, until volatiles (mainly S) were exhausted from the source region. Fe_{sulf} has not been included in the model [1]; if sulfur were removed as a gas rather than as a constituent of Fe-Ni-S-rich melt, the loss of ~1.8 wt.% S from the source region would be equivalent to the addition of ~3 wt.% metal to the residue, which is required by the model of [1]. Thus the removal of S-rich gas or fluid along with silicate melt can be seen as an alternative mechanism of differentiation in the lodranite source region(s).

One of the most important results of our model calculations is the discovery that at degrees of melting <20 wt. %, Mg/(Fe+Mg) in olivine and orthopyroxene equilibrated with melt and metal in the source region *decreases* as melting proceeds (Fig. 1). This resolves an apparent discrepancy between the silicate mineral chemistries of lodranites and acapulcoites [14]: lodranites with Mg/(Mg+Fe) ratios lower than those of acapulcoites can be the solid residua left after partial melting of the latter. Our calculations also suggest that the composition of olivine - *i.e.*, its Fe/Mn and Mg/(Mg+Fe) ratios - are an important source of information about the igneous history of acapulcoites and lodranites, and one that does not depend upon the sections studied petrographically being highly representative. The olivine compositions of both meteorites modeled

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plot along the calculated melting curve in Fig. 1, indicating that these meteorites could represent different stages of partial melting of the same precursor material. The importance of the Fe/Mn ratio in silicates coexisting with metal as an indicator of redox conditions and metal/silicate fractionation in achondrite source regions has also been noted by [15,16].

Application of our model to other members of the acapulcoite/lodranite group is limited by the scarcity and incompleteness of published data. The few data on olivine chemistry shown in Fig. 1 suggest that both the degree of melting and fO_2 might vary slightly within the source region(s). Minor differences between calculated and observed chemical and mineral compositions may be attributable to small variations in fO_2 and/or melting degree, but this cannot be tested until more members of the acapulcoite/lodranite group are included into the model. Only samples having thoroughly characterized chemical and mineral compositions can be included in our model calculation, in order to compare the model with 'nature.' The one meteorite that meets these criteria is the acapulcoite Y74063 [17]. The bulk analysis of Lodran [18] does not include SiO_2 , which is extremely important in model calculations. While the bulk chemical composition of Y77081 is available [19], the lack of data on mineral chemistry makes it difficult if not impossible to compare the modeled and real mineral assemblages.

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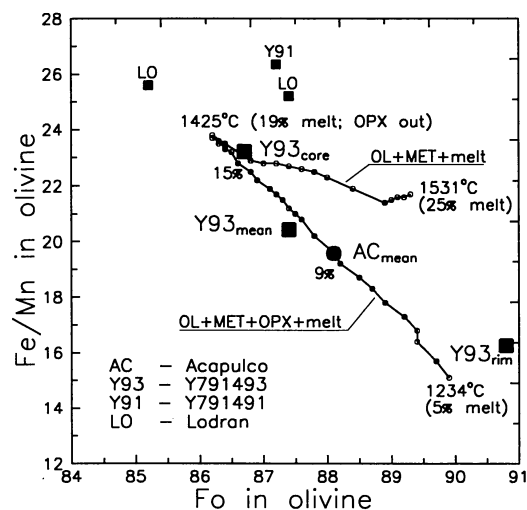


Fig. 1. Variations in olivine composition during partial melting of 'model' lodranite [1]. Open circles are calculated values, with 0.5% melting degree increments. Filled circle: Acapulco olivine [6]; filled squares: lodranites - Y791493[2], Lodran [9,20] and Y791491 [9]. As melting proceeds, Fo content decreases, and Fe/Mn ratio increases, until orthopyroxene is exhausted in the residue; after that the trend reverses. Data for meteorites included in the model (Acapulco and Y791493) plot along the calculated line, suggesting that olivine compositions were established during the melting stage of their evolution. Deviation of the most magnesian rim compositions from the calculated line may be caused by subsolidus reequilibration [2]. Deviations of other lodranites from the calculated trend may result from variation of the degree of melting and/or oxygen fugacity in the lodranite source region(s).