DERIVING THE KEY PROPERTIES OF THE ACAPULCOITE-LODRANITE PARENT BODY WITH NUMERICAL MODELS.

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Introduction: The acapulcoites and lodranites (AL) are rare groups of primitive achondritic meteorites that originate from a common parent body[1-3] and are compositionally related to ordinary chondrites. ALs are especially interesting because they experienced partial melting and only minor melt segregation[4-7]. Thus, unravelling their origin contributes to the understanding of the initial differentiation stage of planets objects. In this study we investigate the thermal and structural evolution of the parent body of the acapulcoites and the lodranites using models that consider compaction, partial melting as well as metal-rock differentiation. We compare the calculations with the metamorphic temperatures, the differentiation degree and the thermo-chronological data. We obtain a set of parameters that fits the thermo-chronological data for the AL-clan. Our models provide estimates of the size, formation time, orbit of formation, nature of the precursor material and internal structure of the AL parent body.

Model: We calculated the thermal evolution of the parent body considering radioactive heating, temperature- and porosity-dependent parameters, and compaction of porous material. Calculations have been performed using two models described in detail in [8-10]. The models solve a 1D heat conduction equation in spherical symmetry considering heating by short- and long-lived radionuclides, temperature- and porosity-dependent parameters, compaction of porous material, and melting. Moreover, differentiation of a Fe core and silicate mantle by porous flow as well as magmatic heat transport and convection at melt fractions ≥50% are considered. In addition, a genetic algorithm for parameter optimization is included.

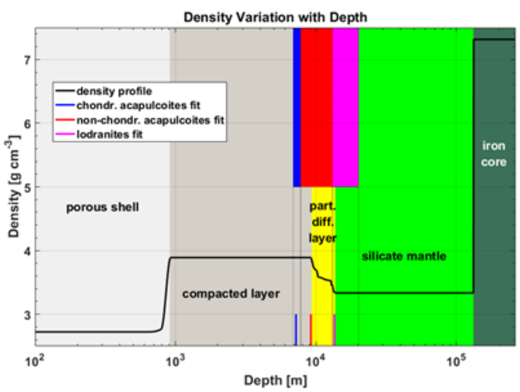

Figure 1: Density variation with depth after compaction and differentiation of the parent body. The unsintered shell (light grey) has a density of ≈2.7 g cm^{-3}, the layer at the depth of ≈1-9 km is compacted but not differentiated (dark grey) with a density of ≈3.9 g cm^{-3}. It is followed by an ≈4 km thick partially differentiated layer (yellow) where the density decreases to the mantle density of ≈3.3 g cm^{-3} due to iron depletion. The silicate mantle (light green) stretches to a depth of ≈132 km where the density jumps to ≈7.3 g cm^{-3} in the core (dark green). The layers that contain chondrule-bearing acapulcoites (blue), chondrule-free acapulcoites (red) and lodranites (pink) are indicated with the colors and dotted lines. The depths at which the data were fitted are indicated by the short lines with respective colors.

Results: The models were compared to the observed maximum metamorphic temperatures and thermo-chronological data available. An optimized parameter set which fits to the data for the cooling histories of the meteorites was determined. Since the obtained maximum temperatures were higher than the metal solidus, we calculated the differentiation of the optimum fit body. These calculations confirm the fits obtained and provide additional information about the interior structure of the parent body. These results indicate differentiation in the interior and small-scale melt migration at shallow depths. The resulting structure shows a fully differentiated metallic core and silicate mantle, a partially differentiated layer, and an undifferentiated shell that was once partially molten in its deeper part. The degree of differentiation of the burial layers derived is consistent with the meteoritic evidence.

Conclusions: Our results indicate a larger radius (≈270 km) and an earlier formation time (≈1.6 Ma) of the acapulcoite-lodranite parent body than typical estimates for ordinary chondrites' parent bodies (<130 km and >1.8 Ma[11]), consistent with a stronger thermal metamorphism. The optimum fit of the initial temperature of ≈250 K suggests a formation closer to the Sun as compared with the ordinary chondrites (≈180 K[11]). The burial depths of ≈7-11 km support excavation by a single impact event. The differentiated interior indicates that these meteorites could share a common parent body with some differentiated stony and iron meteorites (see [12] for details).

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