THERMAL EVOLUTION OF PRIMITIVE ACHONDRITE PARENT BODIES

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Introduction: Acapapulcoites and winonaites belong to the group of "primitive achondrites". They were heated to significantly higher temperatures than type 6 ordinary chondrites (ca. 900°C), often exceeding the silicate solidus (ca. 1100°C), although evidence for silicate differentiation is absent in most cases. These achondritic meteorites should have formed earlier than ordinary chondrites, at a time when more ^{26}Al was available to generate the very high temperatures. Due to the presence of abundant metal in both types of meteorites their equilibration can be dated with the Hf-W chronometer. This chronometer was applied to the two acapulcoites Monument Draw and Dhofar 125 and the resulting ages are compared with published age constraints for chondrites and winonaites [1].

Results: Non- and weakly magnetic fractions of all analyzed acapulcoite separates from the two samples define a combined Hf-W isochron with an initial $^{182}W/^{184}W$ of -3.1 ± 0.3 ε- units and a slope corresponding to an age of 4.6 ± 1.4 Myr after CAIs (using $^{182}Hf/^{180}Hf = (1.01 \pm 0.05) \times 10^{-4}$ for Allende CAIs [2]). A Hf-W isochron for similar mineral fractions for winonaites yielded a much younger age of 14.5 ± 2.8 Myr [1]. A comparison of the Hf-W age with published Pb-Pb and Ar-Ar ages of the acapulcoites implies cooling rates of about 100°/Myr between the closure temperatures of the Hf-W and Ar-Ar systems. This is faster than cooling rates for the H5 and H6 ordinary chondrites [3]. The winonaites and IAB meteorites yield cooling rates from 5 to 100°/Myr for the same temperature interval.

Discussion: The Hf-W age for acapulcoites is similar to maximum ages of ~ 4-5 Myr after CAI formation obtained for other differentiated meteorites (D`Orbigny angrite 4.3 ± 1.3 Myr [4]; eucrites 4.3 ± 1.4 Myr [5] and IAB silicates 2.9 ± 2.2 Myr [6]). However, the acapulcoite age is slightly older than Hf-W ages reported for H5 and H6 chondrites (6.0 ± 0.9 Myr and 9.6 ± 1.0 Myr [3]) that were not melted during thermal overprint.

Assuming an internal heat source for these parent bodies, this marked age difference in peak temperatures most likely reflects a higher ^{26}Al content in the acapulcoite parent body compared to the H-chondrite parent body. The apparent age cluster for solidification of the most ancient differentiated meteorites of around 4-5 Myr most likely marks a minimum age required for ^{26}Al being the driving force for asteroid differentiation. If thermal peaks were reached at a later time, as for example in the H-chondrite parent body, internal heating was insufficient to trigger melting and efficient metal-silicate separation. The younger Hf-W isochron for winonaites (14.5 ± 2.8 Myr [1]), on the other hand, clearly highlights the role of impacts as a driving force for parent body differentiation and metamorphism later than 5 Myr.

References: [1] Schulz T. et al. 2007. [2] Burkhardt C. et al. 2007. [3] Kleine T. et al. 2008. [4] Markowski A. et al. 2007. [5] Kleine T. et al. 2004. [6] Schulz T. et al. 2006.