RADIOGENIC Pb IN MUONIONALUSTA TROILITE AND THE OLD AGE OF THE IVA ASTEROID.
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Introduction: The ages of core segregation in the parent asteroids of iron meteorites have been variably assessed, notably by the 187Re–187Os technique [1], and the extinct radioactivities of 107Pd–107Ag [2, 3] and 182Hf–182W [1, 4, 5]. Because the latter chronometer suggests that iron meteorites formed within a few Ma of Allende CAIs, we set out to date these bodies using the Pb-Pb chronometers. Although iron meteorites have been found to contain the least radiogenic Pb in the Solar System, some of them contain Pb radiogenic enough to justify an investigation of their chronological potential [6, 7].

The IVA group is of magmatic origin and particularly depleted in volatiles [8]. Muonionalusta is an octahedrite find, which contains very large inclusions of troilite [9]. The presence of stishovite indicates that it has been heavily shocked, presumably during the 0.4 Ga old event associated with the shower [10].

Techniques and Results: Large chunks (1.5 – 3.1 g) from two large (> 5 cm) troilite inclusions from two separate slabs were first analyzed on an Element 2 LA-ICP-MS at Rice University. High levels of Fe, Ni, Cr, and Cu were found. The samples were then repeatedly leached in 0.5N and 1N HNO3 and 50% HF. The resulting residues were dissolved in concentrated HNO3. Lead for all leachates and residues was separated on an anion-exchange resin using 1N HBr and 6N HCl. The chemistry blanks were < 20 pg. Lead from the leachates and residues was analyzed on a Nu Plasma HR MC-ICP-MS in Lyon using standard bracketing, and TI to monitor the instrumental mass bias. Typical internal uncertainties on Pb isotope ratios are about 50-100 ppm.

The Pb isotope compositions, and therefore the U/Pb ratios, are quite variable from one sample split to another. All samples contained only very little Pb compared to, for example, Canyon Diablo. HF leachates were found to be systematically anomalous. A first slab, referred to as ML1, contains troilite with highly radiogenic Pb that forms an array in the ‘reverse’ 204Pb/206Pb and 207Pb/206Pb vs [204Pb/206Pb] isochron plots. A second slab (ML2) was found to contain only radiogenic Pb in comparison with ML1 and the isotope compositions do not define useful alignments.

Discussion: We calculated the least-square straight lines using a new code based on lognormal error distributions to avoid considering error ellipses that would ‘dip’ into the domain of negative isotopic ratios and therefore heavily bias error assessments. An alignment of 12 points from different troilite chunks of ML1 corresponds to an apparent 207Pb*/206Pb* age of 4.563±0.0005 Ga (Fig. 1). The different troilite chunks by themselves give ages (4.563-4.567 Ga) mutually consistent within error bars. One of these ages, for which the uncertainties due to disequilibrium in the U series and the U isotope composition are factored in, is particularly precise (4.565±0.0005 Ga) with an MSWD of 1. Oddly enough, the high U/Pb ratios of all the troilites are accompanied by very low Th/U ratios (~0.14). The non-radiogenic end-member is not dominated by Canyon Diablo-like primordial Pb but by terrestrial Pb. Some parts of the troilite inclusions are extremely well preserved, while others are shocked and hence may have been more permeable to Pb contamination.

The results presented here indicate that the core of the Muonionalusta IVA parent body segregated within 3±2 Ma of planetary accretion, which is marginally consistent with evidence from the 107Pd–107Ag chronometer [3]. In contrast, this time interval is somewhat longer than the mean age of IVA obtained relative to CAIs by the 182Hf–182W system [1, 4, 5]. There is no support for the young ages of 4.456 Ga found for the IVA group by the 187Re–187Os technique [1].

Figure 1. Inverse isochron plot of 12 leachates (L) and residues (R) for a troilite inclusion in the Muonionalusta iron meteorite. Three different splits (R, R1, R2) were analyzed. N0.5 and N1 stand for 0.5N and 1N HNO3, respectively, CN for concentrated HNO3. The HF leachates systematically fall off the line and are not shown. The three splits give individual ages from 4563 to 4567 Ma with the most precise age of 4.5651±0.0005 Ga (5 points) for ML1-R2.