LEAD-LEAD CONSTRAINTS ON THE TIME SCALE OF EARLY PLANETARY DIFFERENTIATION.
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Introduction: The U-Pb isotope system provides unparalleled chronological resolution in the determination of absolute ages of events occurring in early solar system history. Proper comparison of these absolute ages with the relative chronologies emerging from studies of now-extinct nuclides such as ^{26}Al, ^{53}Mn, and ^{182}Hf requires identification of fixed time points in the evolution of materials in the early solar system.

U-Pb Model Ages: Single stage model ages are commonly calculated for U-Pb analyses by subtracting an estimate of the initial Pb isotopic composition of the solar system, usually defined by the Pb in sulfides from the Canyon Diablo meteorite. For minerals with high U-Pb ratios, such as chondritic phosphates [e.g. 1] and the pyroxenes from angrites and eucrites, the assumption that the non-radiogenic Pb in these minerals has the isotopic composition of Canyon Diablo Pb is questionable. First, most meteoritic materials show clear evidence of contamination with terrestrial Pb introduced during terrestrial weathering. For example, leaching experiments on "clean" mineral separates from eucrites and angrites show that more than 90% of the Pb in the separates commonly is easily removed by leaching in dilute acids. Furthermore, the Pb removed by leaching usually has the isotopic composition of modern terrestrial Pb [2,3]. Secondly, if the meteoritic minerals resided in a whole rock characterized by high U/Pb, as is the case for eucrites and angrites, later recrystallization of the mineral, or continual Pb diffusion during a prolonged cooling history, would lead to incorporation of radiogenic, not primitive Pb. Both of these phenomena lead to single-stage U-Pb model ages that overestimate the true age of crystallization of the mineral.

Pb-Pb Systematics: The ^{207}Pb-^{206}Pb systematics of meteorite whole rocks and minerals allow independent evaluation of the problem outlined above. The oldest materials in the solar system are generally assumed to be the calcium-aluminum rich inclusions in carbonaceous meteorites. Indeed, the Pb-Pb systematics of CAI's from the Allende meteorite [4] provide the oldest age (4.566 Ga) of any meteoritic material. However, the line passing through the Allende CAI data on a plot of ^{207}Pb/^{206}Pb vs. ^{204}Pb/^{206}Pb falls to the unradiogenic side of Canyon Diablo Pb. This indicates that, if this age is valid, the Allende CAI's, formed from a source with a Pb isotopic composition distinct from that of any other meteoritic material. Allende CAI's thus must have formed either in a different part of the solar nebula than other meteoritic materials, or included a significant component of non-solar Pb during their formation. The latter case introduces the possibility that the Allende CAI age may date an event that precedes solar system formation and thus should not be used as a marker for intra-solar system events.

In contrast to the Allende CAI Pb data, chondrules in Allende provide a Pb-Pb age of 4.560 Ga with an initial Pb consistent with Canyon Diablo Pb [5]. Data for phosphates from the St. Severin chondrite [1,4] fall along the same Pb-Pb line as do pyroxenes from the angrites Lewis Cliff 86010 and Angre dos Reis [3] and the Angre dos Reis phosphates [4]. This line corresponds to an age of 4.559 Ga, within error of that of the Allende chondrules, suggesting that 4.559 – 4.560 Ga may mark the initiation of igneous processing of materials in the solar system.

Mineral Pb-Pb isochrons for eucrites tend towards significantly younger ages and a wider spread in ages. Ages obtained for eucrites range from 4.540 Ga age for Juvinas [6] through several noncumulate eucrites with ages between 4.52 and 4.51 Ga [2]. Cumulate eucrites give concordant Pb-Pb and Sm-Nd ages that range from 4.484 to 4.399 Ga, significantly younger than obtained for the noncumulate eucrites [2]. This relatively wide range in ages indicates a prolonged history of igneous activity in the early solar system, even on the relatively small parent planetesimal(s) of the eucrites. Whether the young ages of the cumulate eucrites reflect endogenous igneous activity or impact melting remains an open question.

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