Solar Nebulæ

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Lodders and Fegley [1] pointed out the necessarily multiple-component origin of the Solar System. Warren [2] argued for the bimodality in ^{50}Ti, ^{54}Cr, and O nucleosynthetic anomalies exhibited by planetary materials and suggested a division between carbonaceous and noncarbonaceous sources. Such a dichtomy is also visible in the Cu and Zn isotope compositions of the same material [3]. Using a novel presentation of oxygen isotope data, we show that all the analyzed material in the Solar Nebula can be accounted for by a component mixture not unlike Warren [2]'s two component mixture but involving three components. The new orthogonnal coordinates clearly separate mass-dependent from mass-independent fractionation and unveil well-defined mixing trends. Most of the accessible material in the Solar System may be accounted for by a mixture of a non-carbonaceous (L chondrite-like), a CV and a CI end-members. Similar components are also found when other nucleosynthetic anomalies (Ti, Cr, Ni) are plotted against water content of meteorites. It is arguable that the CV component is of solar origin. The most common proportions of CV and CI components in the mixture are reminiscent of a CM composition. We suggest the approximate contributions of the noncarbonaceous sources: 90% for L chondrites, 80% for H chondrites and Mars, 70% for E chondrites, the Earth, and Moon, and 20-40% for ureilites.

A first far-reaching consequence is that the Solar System is not well mixed and that accretion time scales are shorter than nebular mixing time scales. The Solar nebula does not represent the condensation of a homogeneous cloud of gas and dust, but the accretion of a number of genetically unrelated streaks, two of which (L-type and CI) having resisted full accretion to the central star.

In a session honoring Mike Drake's immense contribution, and more specifically to this issue [4], the origin of water in planets appears essentially pinned down on that of their CI component. Several correlation plots show that water is not a rogue component of the Solar System. It is remarkably well correlated with other gaseous (C, N) and lithophile (Zn) volatiles. Even if the history of water and of the CI component in terrestrial planets are intimately related, the timing of when the components discussed in this talk were mixed is still eluding final explanation.

[1] Lodders & Fegley (1997) *Icarus* **126**, 373-394. [2] Warren (2011) *EPSL* **311** 93-100 [3] Luck *et al.* (2005) *GCA* **69**, 5351-5363 [4] Drake & Righter (2002) *Nature* **416**, 39.

Multiple age components in individual molybdenite grains

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Molybdenite occurs within a pod of unusual monazite-xenotime gneiss (MXG) that is part of a granulite-facies paragneiss in the Hudson Highlands, NY. Whereas both the paragneiss and MXG contain detrital zircon older than about 1170 Ma, only MXG has a population of irregularly zoned prismatic zircon (U-Pb age of 1036±5). This age is thought to date the formation of MXG, probably by metasomatic/metamorphic processes, rather than as a paleo-placer. Subsequent events at about 1010, 985, and 920-880 Ma formed rims on zircon, xenotime, and monazite in MXG.

Re-Os geochronology of multi-grain fractions composed of unsized, coarse, and fine molybdenite yielded dates of 950.5 ± 2.5, 953.8 ± 2.6, and 941.2 ± 2.6 Ma, respectively. These dates are not recorded by co-existing zircon, xenotime, or monazite. SEM-BSE imagery of molybdenite in thin section and as separated grains reveals that most molybdenite grains are composed of core and rim plates that are approximately perpendicular. Rim material invaded cores, forming irregular contacts that probably reflect dissolution/reprecipitation.

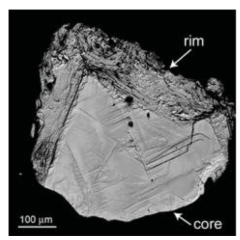

Figure 1: molybdenite grain showing core and rim.

Microanalysis for Re-Os geochronology of small volumes within individual grains was not attempted because parent ^{187}Re and daughter-product ^{187}Os can "decouple" [1, 2], yielding dates that can be too old or too young. However, EPMA and LA-ICP-MS analyses show that cores and rims have different trace element concentrations (for example, cores are richer in W). We conclude that the range of Re-Os dates on our multi-grain samples reflect mixing of at least two age components.

The discovery of cores and rims in individual molybdenite grains is analogous to multiple age components in U-Pb geochronometers such as zircon, monazite, and titanite. Thus, molybdenite, particularly of *metamorphic* origin, should be carefully examined prior to dating of multi-grain samples to ensure that the requirement of age homogeneity is fulfilled.

[1] Stein *et al.* (2003) *Geochim. Cosmochim. Acta* **67**, 3673-3686. [2] Selby & Creaser (2004) *Geochim. Cosmochim. Acta* **68**, 3897-3908.