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Part IV

METAL FORMATION AND FRACTIONATION OF SIDEROPHILE ELEMENTS IN THE SOLAR NEBULA

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Chondrites, the oldest and most primitive rocks we can study generally contain abundant metal and have non-volatile siderophile element relative abundances similar to solar matter (1,2). Considering the fact that chondrites are very complex, chaotic, microbreccia-like rocks (e.g. 3,4), the almost unfractionated abundances of the siderophile elements (and also the non-volatile lithophile elements) appear to be miraculous. In reality, this situation places close constraints on the conditions of formation of these rocks early in the solar nebula. In addition, close inspection of the different constituents of chondrites reveals severe fractionations of siderophile elements within each component and yet, the total mixture (= the chondritic rock) appears to be unfractionated. This situation, naturally, indicates an evolution of chondrites within fairly closed systems. On the other hand, the sometimes extreme elemental fractionations and isotopic inhomogeneities observed among some chondritic constituents strongly indicate very different conditions of formation and thus different places within (or sometimes outside) the solar system. Metal in different

constituents of chondrites as well as total siderophile element contents record a variety of formation conditions and processes.

Metal occurs in chondrites (mostly together with sulfides)
(a) within chondrules and lithic fragments either as droplets or as "dusty" inclusions in silicates,
(b) as rims around chondrules and fragments,
(c) as metal-sulfide chondrules,
(d) as aggregates within the chondrite matrix, and
(e) in small amounts in highly fractionated "inclusions" (mainly Ca-rich, Al-rich) (see 5).

Chondrules, now mostly crystalline once molten droplets, are commonly strongly depleted in siderophile elements (e.g. 6,7). Depletion factors between 0.1 and0.3 are very common but they can be as low as 0.005 (8-11). Thus, a fractionation mechanism separating siderophile elements from lithophiles was very effectively operating in the early solar nebula. Four possible mechanisms exist : (a) Sampling, (b) Separation of silicate melts from metal melts, (c) Fractional condensation, and (d) Fractional evaporation. Chondrule bulk data show that most of these processes were operative during chondrule formation. This is documented by a variety of fractionations of the siderophile elements relative to each other. Solid/liquid-vapor fractionations are common and testify for both evaporation and condensation processes. Variable contents of lithophile elements in metal (Si, Cr, P) record reducing conditions. High Ni metals and highly variable Ni/Co ratios indicate oxidizing conditions. Commonly, metal in chondrules records changing redox conditions: metal formed originally under reducing conditions becomes oxidized (formation of phosphates and oxides) or sulfurized (formation of troilite or pyrrhotite, sometimes even pentlandite). On the other hand, siderophile elements (Ni,Co) originally dissolved in silicates under oxidizing conditions exsolved as metal under reducing conditions.

Metal and siderophile element contents of chondrite components thus testify for widely differing redox conditions prevailing in the early solar nebula. They further record complex processing of individual chondrite components and exposure to very different and changing fO_2, fS_2 and T conditions. No systematic sequences for changing conditions can be established now, except for a late stage oxidizing event which appears to be very common and which probably established the final oxidation grade of the ordinary chondrites (H, L and LL groups).

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MINERAL INCLUSIONS IN DIAMONDS FROM THE SLOAN KIMBERLITES, COLORADO

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Mineral inclusions have been recovered from about 40 small (1.5 mm) diamonds from the Sloan 1 and 2 kimberlite pipes in Northern Colorado. Protogenetic and/or syngenetic minerals are olivine, clinopyroxene, sanidine, rutile and possibly native Fe and some phlogopite. Phases interpreted as epigenetic are acmite, richterite, most phlogopite, perovskite, Mn-ilmenite, Cr-spinel, magnetite, clacite, serpentine and possibly been reported in diamond. Epigenetic minerals commonly occur as in-