PLANETARY COMPOSITIONS - CLUES FROM SMALL BODIES AND THE SUN. Edward R.D. Scott and Horton E. Newsom. Institute of Meteoritics, Dept. of Geology, University of New Mexico, Albuquerque, NM 87131.

A number of beliefs about compositional trends in the solar system appear to be based on weak evidence or discredited models: 1) concentrations of common rock-forming elements in planetesimals varied simply with distance from the sun; 2) these concentrations were largely controlled by ambient nebular temperatures; 3) the concentration of oxidized iron increased monotonically with increasing heliocentric distance; 4) outside the formation location of CI chondrites, all planetesimals had the same relative abundances of rock-forming elements as CI chondrites; 5) the diversity of chondrite compositions requires that asteroids formed over a wide range of heliocentric distances, 0.3-5 AU; 6) planets with compositions that do not fit simple chemical trends must have experienced giant impacts; 7) chondrites with elemental abundances outside those of the nine chondrite groups (e.g., ALH 85085) must have been chemically altered by impacts or asteroidal heating. We argue that all of these statement are incorrect, and that chemical heterogeneities and irregularities in the nebula were much larger than commonly believed.

Chondrites and asteroids. Chondrites are composed of diverse mixtures of components (chondrules, matrix, refractory inclusions, metallic Fe,Ni and sulfides) with uncorrelated abundances. Thus, even though the bulk concentration of oxidized iron may increase with increasing heliocentric distance for some planets (Mercury, Earth, Mars), and for the E, O and C chondrites, it is unlikely that bulk FeO varies monotonically with distance from the Sun. Most chondrites have FeO-rich matrices, and the abundance of matrix increases through the E-O-C chondrite sequence, but some ungrouped chondrites, such as Kakangari, have properties that violate these trends [1]. Thus the bulk FeO concentration depends on three factors each of which probably did not vary monotonically with heliocentric distance: the FeO concentrations of chondrules and matrix and their relative proportions.

In general, concentrations of rock-forming elements and concentrations normalized to Si do not show simple trends among the nine chondrite groups. Only elements that are concentrated in a single chondritic component (e.g. siderophile or refractory elements) may show simple trends [2]. Even then, differences between the compositions of a specific component in the nine chondrite groups may produce uncorrelated variations among siderophile or refractory abundances. Only in very limited parts of the asteroid belt (e.g. the ordinary chondrite formation region) were there simple correlations between composition and distance from the Sun. Asteroids with similar abundances of volatiles, refractories or oxidized iron, may have formed at diverse heliocentric distances. We should not, therefore, expect to find simple chemical trends among the concentrations of rock-forming elements in solar system bodies.

The petrographic and chemical properties of the nine chondrite groups, the ungrouped chondrites, inferred compositions for the precursors of differentiated meteorites, and the mismatch between meteorite and asteroid properties all suggest that meteorites provide a highly biased sample of asteroidal materials. We infer that chondrites are much more diverse chemically than suggested by the nine groups.

Outer solar system. The apparently identical composition of CI chondrites and the non-volatile part of the solar photosphere might imply that planetesimals that formed outside of the CI chondrite formation zone (>3 AU?) must have had CI proportions of non-volatile elements. However, there are significant differences between solar and CI chondrite abundances of Fe, Mn, Ge and Pb: solar Fe/Si is 1.4 x CI [3]. Mean elemental abundances of interplanetary dust particles [4] and dust from Comet Halley [5] both show significant departures from CI abundances for some elements. For example, Fe/Si in Halley is 30% of CI and mean IDP values for Fe/Si are 65-80% of CI. Thus solar photospheric abundances may not be identical to primordial solar nebula abundances [6], and to some extent, the resemblance between the compositions of CI chondrites and the non-volatile part of the solar photosphere may be fortuitous. Concentrations of rock-forming elements in primitive dust beyond 2 AU could have varied monotonically [6]. In that case, irregularities in the compositions of bodies may not extend beyond the region of chondrule formation.

Origins of chemical heterogeneities in the solar nebula. Lewis' equilibrium condensation theory [7] may be useful in understanding broad chemical differences between the inner and outer planets, but it fails to explain the chemical differences between chondrites. Each chondrite did not equilibrate with the nebula at a specific temperature, nor are chondrites composed of components that equilibrated with the nebula at diverse temperatures. To some extent the compositions of the components are controlled by their thermal processing in brief high temperature events in the nebula (e.g., loss of volatiles from chondrules, formation of refractory inclusions by evaporation and condensation). But all components also retain chemical memories of their fine-grained precursor materials, both presolar and solar. Even though these precursor materials are fine-grained (submicron or micron in size) they do not aggregate into chemically or isotopically homogeneous lumps. Chondrules, matrix lumps and interplanetary dust particles may have four-fold variations in elemental ratios, which result from the tendency of individual minerals and phases to aggregate preferentially. The solar nebula was not the simple quiescent object pictured by current models, and chemical heterogeneities among grain aggregates were enhanced by the episodic large deviations from local equilibrium that must have formed chondrules [8].

Planets. Evidence from chondrites and asteroids suggests that 100-km chondritic planetesimals with highly diverse compositions formed inside the asteroid belt. Jupiter can be blamed for the failure of asteroids to make a planet, but not for their chemical diversity. Planets may have accreted from locally derived planetesimals, which had as much chemical diversity as the chondrites in the asteroid belt [9, 10]. Even if planets formed by chaotic movements across overlapping accretion zones [11], rather than orderly accretion from narrow zones, it is unlikely that the record of chemical heterogeneity of their planetesimals could be completely erased. Thus chemical differences between planets that depart from any overall monotonic variation of chemistry with heliocentric distance may be a normal result of the accretion process.

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