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ASTEROIDS AND THE STRATIGRAPHIC SEQUENCE OF THE SOLAR NEBULA. G. J. Consolmagno[1] and D. T. Britt[2], [1]Specola Vaticana (V-00120, Vatican City State; gjc@specola.va), [2]University of Central Florida (Orlando, FL 32816-2385, USA; britt@physics.ucf.edu).

Introduction: A terrestrial geologist can take samples *in situ,* recognizing the stratigraphic relationship between neighboring samples, and then measure their chemical and physical properties in the lab. An analog of a stratigraphic sequence for the solar system can be found in the compositions and orbital locations of small solar system bodies, which represent the relatively unprocessed material from which the major planets were formed. Meteorites represent an invaluable resource of “free” geological material from these small bodies that sample their mineralogy, geochemistry, and small-scale structure. Their physical properties, in particular density and porosity, can be tied to recently determined asteroid physical properties.

Most asteroids are highly fractured, and many of them are rubble piles. By contrasting their densities with the bulk density of their analog meteorites, one can calculate their *macroporosity*, the fraction of large-scale void space in their interiors. Trends in macroporosity can lead us to insights into the structure of the early-forming solar system itself.

Zones in the Nebula: The idea of a chemically zoned solar nebula controlled by proximity to the nascent Sun has been supported by the observation of asteroid spectral classes showing a distinct gradation of material types as a function of distance from the sun.

At about 2 AU, the E class asteroids have meteorite analogs in the enstatite chondrites and achondrites. As yet we have no asteroid densities from this region.

The next major group out is the S class (along with the smaller V, A, R, K, and M classes). The nebular geochemistry in this zone was apparently dominated by olivine and pyroxene chondrules with a strong admixture of Fe-Ni metal, but essentially no water. The typical macroporosity of S class asteroids ranges from 20% to 30%, though exceptions have been observed. The meteoritic/asteroidal materials in this zone also include samples from what is apparently the core (iron meteorites, at least some M-class asteroids), the core-mantle boundary (pallasites), the mantle (brachinite meteorites?; A, S(I), S(II) class asteroids?), and the crust (HED meteorites; V class asteroids) of differentiated bodies. Macroporosities exist for two M class asteroids, but their metallic nature is not certain; if metallic, they would be extremely macroporous (on the order of 70%).

Another small asteroid class in this zone are the K asteroids, which have the CV and CO carbonaceous chondrites for meteorite analogs. They are metamorphosed, anhydrous carbonaceous chondrites low in carbon. We have no densites yet for these asteroids.

Around 3 AU are the dark asteroids of the B, C, F, and G classes whose meteorite analogues are the dark CI or CM carbonaceous chondrites. The spectral differences between these classes are thought to represent varying histories of aqueous alteration or thermal metamorphism; the CI carbonaceous chondrites are rich in water, clay minerals, volatiles, and carbon and represent primitive material that has been mildly heated and altered by water. The macroporosity of asteroids in this class tends to range from 30% to 60%.

The P asteroids peak at about 4 AU, and the D asteroids at 5.2 AU. Water of hydration (which is what is responsible for much of the low density of the CI and CM meteorites) is absent; this material was presumably too cold for any ice to have melted and reacted with the non-ice phases. However, at this solar distance, frozen volatiles (mostly water ice) would compose about one-third of mass with the rest being in the form of loosely packed, low-temperature materials such as carbon compounds, complex organics, fine-grained silicates, and water-ice. Thus their grain densities should be even lower than the 2.4 – 2.8 g/cm^3 of the CI and CM meteorites. The density of the Jupiter Trojan object 617 Patroclus, 0.8 ± 0.2 g/cm^3 is similar to comets. Comparing that density against an inferred 1.5 - 2 g/cm^3 density for its constituents implies a 45% - 60% macroporosity in this region.

The final small body zone is that of the trans-Neptunian objects (TNOs), the source region for the short period Jupiter-family comets. TNOs are the remnants of bodies that formed outward of the accreting gas-giant planets and were likely “pushed” about 8-10 AU farther out from the Sun than where they originally formed. Most comet nuclei densities are around 0.5 g/cm^3; given the “grain densities” of the ices and carbon-rich dust which make up these comets, their low bulk densities mean that they must have macroporosities of approximately 60-80%.

Summary: Macroporosity appears to increase as one travels further from the Sun. Typical S type asteroids range from 20%-30% macroporous; darker C type asteroids can be 40%-60% macroporous; and icy bodies such as comets and small TNOs may be as much as 80% macroporous. Likewise, the meteorites thought to come from the outer part of the asteroid belt, the carbonaceous chondrites, are typically more than twice as porous as the meteorites from the inner belt.

Thus one can envision a solar nebula where distance from the sun not only controls the composition of the material accreting into planets, but the physical nature of that material.