TEXTURAL AND STRUCTURAL EVIDENCE OF REGOLITHIC AND NON-REGOLITHIC PROCESSES IN CHONDrites

J. Stewart Nagle, Lunar Curatorial Laboratory, Northrop Services, Inc., P.O. Box 34416, Houston, Texas 77034

Companion studies (5) conclude that compacted lunar polymict breccias and polymict achondrites represent relatively mature regolith that was lithified by subcrater processes. A relatively small proportion of polymict breccias are not compacted, and appear to be thermally altered. In this study, thin sections of all the Antarctic carbonaceous chondrites, type 3 and 4 ordinary chondrites, and some type 5 and 6 chondrites in the JSC collection were examined texturally for comparison to polymict lunar and meteorite breccias. In contrast to the lunar breccias and achondrites, many of the chondrites showed little evidence of regolithic processes. Accumulation in a gravity field and limited exposure to regolith-forming conditions best account for the textural properties of chondrites.

All of the carbonaceous chondrites in the JSC collection have multiply-rimmed, i.e. pisolitic-appearing inclusions; fragmented particles are uncommon. Multiply-rimmed particles probably formed by accretionary, rather than regolithic processes (2).

Some of the carbonaceous chondrites, and some type 3 ordinary chondrites, including ALHA 76004, ALHA 78084, and ALHA 77034 are essentially assemblages of well-sorted chondrules. They contain very few of the fragmented and internally shattered grains which would be indicative of impact processes. Diverse chondrule compositions (8) and diverse droplet textures suggest varied sources and cooling histories (1), (4), but bell-shaped size distributions and extremely good sorting of grains are more characteristic of gravitational sorting than assemblage by regolithic processes. Further evidence of gravitational sorting processes is seen in the comparative grain size distribution of stony chondrules and metallic droplets in ALHA 76004, ALHA 77003, and ALHA 78084; the sorting coefficient of metallic and stony components is identical, although the stony chondrules have a much larger median grain size. If electromagnetic processes were responsible for sorting of particles, there would be sorting by composition, not by grain size.

A Stokes law settling processes is the most likely mechanism of accumulation because stratification and current-related structures were not observed in any of the above meteorites -- or in any of the other type 3 meteorites in the JSC collection. The only evidence of bedding of any kind is a possible size gradation in ALHA 77004, where one size of the slide is fine-grained, and adjacent to the fine zone is a coarse zone which grades into a medium-grained zone. Although the median grain size of each zone is different, the sorting is nearly the same throughout the slide; hence the slide could be a section through a graded bed. In terrestrial sediments, graded bedding results from differential settling of various sorted particles (6). Although ALHA 77011.23 has relatively few fragmented chondrules and may have been only minimally affected by bombardment processes, sorting of metal particles differs from that of the stony chondrules, suggesting some difference between processes of accumulation, compared to the well-sorted chondrites.

Many other type 3 chondrites, including ALHA 79003, 79167, 77160, 77215, 77216, and 77217 are breccias which show clasts in hand specimen, and which contain angular fragments of chondrules, mineral grains which appear glassy or which have undulose extinction, and internal fracturing. Such features are attributable to impact-related shock (7). The chondritic breccias consist principally of coarse fragments, with very few fragmented fines; as such they are comparable to immature soils, as are the monomict achondrites (5).

Further evidence that chondrite breccias represent only lithified immature soils is the rarity of type 1 and 2 unequilibrated chondrites. A frag-
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mentation process such as regolith maturation would be required to produce unequilibrated rocks that were poor in chondrules.

Most of the type 4 chondrites show relatively loose packing, and radially arcuate lapillar structures that consist of clumps of chondrules outlined by irregular metallic patches. Such structures are common in ballistic sediments such as ejecta (5). Grain margins and matrices of such chondrites are annealed, making these rocks comparable to Apollo breccias 10045 or 10060, and suggesting that they were formed from hot ejecta. However, all type 4 annealed chondrites examined were texturally immature, and comparable in grain size distribution to type 3 chondrites.

It has been suggested that chondrites are not differentiated because they were formed on relatively small planetesimals (1). The interpretation here, that chondrite breccias represent only immature soils, is consistent with such a view. Mature regolith and associated breccias would not form on small asteroids that periodically shed their regolith after moderate-sized collisions (3).

There is a continuous negative correlation between abundance of rimmed chondrules and fragmented chondrules (Fig. 1). Carbonaceous chondrites, which have accretional inclusions, also have the highest percentage of rimmed chondrules, whereas fragmented chondrites have very few rimmed chondrules or pieces of rimmed chondrules. Furthermore, rimmed chondrules are of intermediate abundance in the sorted, but unfragmented chondrites. (These sorted and unfragmented chondrites appear to coincide with primitive chondrites (7), but I prefer to call the meteorites sorted, because sorting and fragmentation can be readily calculated.) The fragmented chondrites show evidence of accumulation under regolithic conditions, but the well-sorted chondrites, with unfragmented rimmed chondrules show much less evidence of regolith-type processes. More work is needed to clearly define the non-regolithic processes responsible for the formation and evolution of the well-sorted chondrites.

Fig. 1. Relationship of rimmed to fragmented chondrules, in chondrites from the JSC Antarctic meteorite collection.

References