Regolith Compaction Processes Recorded in Chondrites

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Chondrites experienced and recorded a very wide range of chemical and physical processing in both nebular and asteroidal settings. Among the features arising from asteroidal processes are the following: (1) most of these meteorites are breccias; (2) some CV3s and CMs contain flattened chondrules and exhibit foliation; (3) veins are found in some CIs, CMs, CV3 dark inclusions; (4) CR2s, all CIs, some CR2s and CMs display weak alignment of matrix phyllosilicates, and (5) shearing (mylonitization) around lithic fragments. While these features have generally been assumed to have involved impact deformation in asteroidal regoliths, a process sometimes referred to as regolith or impact gardening, we suggest here that all these particular features could have arisen naturally from cycles of wet-dry and freeze-thaw environmental conditions in asteroid regoliths.

All of the extensively (e.g. Y82042, ALH 83100, Cold Bokkeveld, Y-791198, EET 90047) and completely (ALH 88045, EET 83334, Kaidun CM1 lithology) altered CMs contain rounded to elliptical aggregates of phyllosilicates, carbonates, spinels (chromite and magnetite), Fe-Ni sulfides, and embayed olivines and pyroxenes, which are relict chondrules [1]; these sometimes define a definite foliation direction generally ascribed to impact shock of low degree [2-5]. However, most chondrites only minor signs of shock effects, and we therefore suggest that static burial pressure was the principal agent responsible for chondrule flattening in many cases, and believe that the processes involved in burial compaction deserve more attention than they have hitherto received in the asteroid literature. It is probable that even in the wettest regions of an asteroid dry periods were experienced during the periodic breaching of an icy surficial rind [6], which could have occurred during impacts or "volcanic" venting of gas and heat from the interior (this assumes internal heating), or perihelion passages near the sun. Thus, there should have been multiple wet-dry cycles involved in the genesis of these materials.

It is well-known to soil scientists that conditions of radically alternating humidity can have important morphologic and petrologic consequences. Grains and lithic clasts can become rotated, crushed and drawn out into linear features (shearing). Porosity (including contraction and shearing cracks) and other bulk physical properties will vary in dramatic manner. These effects would be most pronounced for the CI and CR chondrites, as well as the Kaidun CM1 lithology, where the swelling clay saponite is found in abundance. Easily altered materials will be dissolved while more resistant, and brittle materials will be pulverized and mixed into matrix [7]. Another important process to be considered is periodic growth and melting of ice crystals in the regolith [8]. The positive molal volume change during crystallization of water will induce oriented microfabrics to develop in the regolith, normal to the direction of ice crystal growth. Thus, platy grains (such as phyllosilicates) will develop a pronounced compaction and preferred alignment. Since the orientation of the growing ice mass will vary for each succeeding generation of growth, the eventual result will be to impart a particular, invasive, regolith fabric consisting of anastomosing strings of phyllosilicates with roughly aligned basal directions for each string (see Figure 1). Such textures are common in the wettest chondrites: CIs and CMs. Growth and collapse of these asteroidal icicles will also impart cyclical changes in bulk regolith porosity, induce rotation and movement of crystals and lithic fragments through frost heaving, and consequent shearing. This process could also account, to some degree, for the flattened chondrules. We therefore suggest that cyclical, indigenous environmental processes, rather than processes generally considered as impact gardening, could be responsible for many of the late stage petrologic characteristics of wet carbonaceous chondrites. Bulk petrographic features of chondrites should be investigated more systematically in order to test this suggestion. Such cyclical heating and freezing would naturally arise from elliptical orbits about the sun, as has been most recently advocated by T. Nakamura and co-workers.

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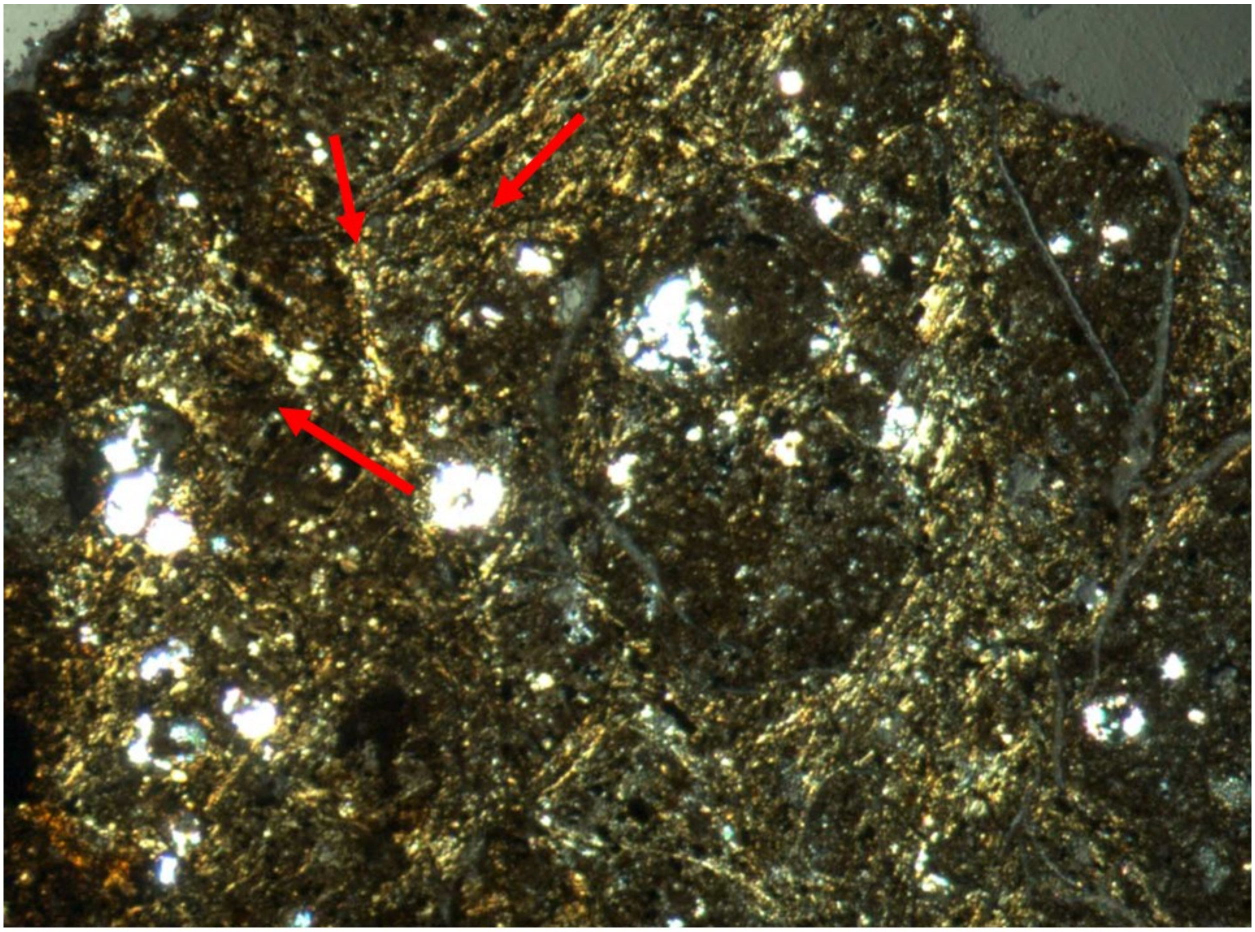

Figure 1. Arrows indicate three directions of aligned phyllosilicates in a cross-polars optical image of a thin section of the Orgueil CI chondrite. View measures 9 mm across.