ON THE CHONDRITE-ACHONDRITE TRANSITION.

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What are primitive achondrites? They are not meteorites with chondritic composition that lack chondrules – some acapulcoites, winonaites and Type 7 ordinary chondrites contain relict chondrules. A classification based on lack on chondrules is inappropriate because olivine is barely consumed by initial melting, and where the duration of peak metamorphism was brief there was demonstrably insufficient time for complete recrystallisation. Primitive achondrites are meteorites with highly equilibrated metamorphic textures – but many Type 6 ordinary chondrites contain numerous 120º triple junctions and moderately coarse grain sizes. Ideally, there should be a petrological definition, a metamorphic isograd, that marks the chondrite-achondrite transition. Most would consider that the onset of equilibrium-based silicate partial melting (i.e., not instantaeous shock melting) marks this transition, and it is one of only a few metamorphic isograds available to meteoriticists. However, it is difficult to recognise the textures associated with silicate partial melting, although these were recently more clearly defined by us [1]. In this study I have examined over 35 primitive achondrites of different types, and over 30 Type 6 ordinary and CK condrites, to clarify the textural, mineralogical and geochemical changes associated with the chondrite-achondrite transition.

One subtle textural change across the chondrite to achondrite transition is in the distribution of plagioclase. Plagioclase grains in Type 6 chondrites are enlarged (up to 250 µm common, over 500 µm rare) and have many 120º triple junctions with olivine and pyroxene, and although sub-skeletal grains that are interconnected over small scales are common within remnant chondrules, there are many isolated grains. In clearly melted primitive achondrites (e.g., lodranites), plagioclase forms large (sometimes multiple mm), skeletal grains that form a matrix between olivine and pyroxene grains; 3D x-ray tomography indicates large scale interconnectivity. In meteorites that may have undergone only minor melting (<5%), which represent the transition to achondrites, plagioclase starts to show wetting textures and convex contacts with olivine and pyroxene; these are associated with the co-existence of plagioclase-rich silicate melt and residual silicates. But this texture can be subtle, and so the transition is difficult to recognise via this criteria.

Another apparently consistent change is the appearance of low-Ca pyroxene exsolutions in clinopyroxene. In lodranites, these exsolutions are coarse and abundant, reflecting extensive enstatite-ferrosilite substitution into the augite structure at high temperatures. In nearly all low-shock acapulcoites, winonaites and Type 7 ordinary chondrites examined, these exsolutions are very narrow, but still discernable with an optical microscope (easily detectable with an SEM). In all low-shock Type 6 ordinary chondrites and some chondrule-bearing acapulcoites, the clinopyroxene is free of low-Ca pyroxene exsolutions. Thus it is suggested that these exsolutions represent an isograd marking the chondrite-achondrite transition. These mineral isograds can be used to determine a chondrule density factor (chondrules per cm^2), and geochemical data to establish a clear set of criteria for the chondrite-achondrite transition. Furthermore, some chondrule-bearing acapulcoites should be categorised as Type 6.

References: [1] Tait A.W., Tomkins A.G., Godel B.M., Wilson S.A. and Hasalova P. 2014. *Geochimica et Cosmochimica Acta* 134:175–196.