DO THE OLIVINE-PLAGIOCLASE OBSERVATIONS AT BASINS IMPLY LUNAR MANTLE OVERTURN?

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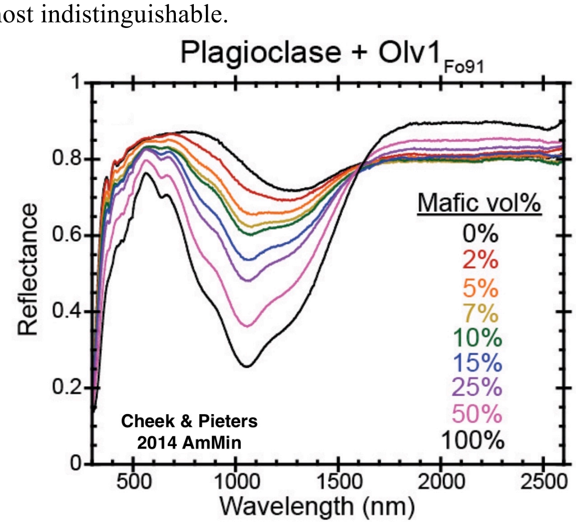
Introduction: The role of olivine in lunar crustal evolution has been debated for decades. Remote characterization of olivine-dominated lithologies began with the first detection in the central peaks of Copernicus using earth-based telescopes [1] and continued to assessment of the global distribution of olivine exposures often associated with basins that are now possible using orbital sensors [2, 3]. Origin hypotheses for the olivine typically include excavation from a lunar mantle source or a layered pluton of Mg-suite crustal materials. However, different sources are likely for different geologic environments and perhaps even multiple source at a single location [4].

Existence of layered (Mg-suite) plutons is consistent with observation of material excavated by a few medium size craters that exhibit multiple lithologies (olivine-rich, pyroxene-rich, anorthositic) in close proximity along their rim or interior (e.g. Proclus [5]). Nevertheless, a large fraction of olivine detections obtained remotely (especially at basins) occur alone in association with extensive plagioclase or feldspathic terrain. This strongly suggests that the origin and evoluton of olivine from a deep-seated source must be intimately tied to association with extensive plagioclase.

Detectibility of olivine. As illustrated below, the diagnostic features of olivine can be readily detected when olivine is even 10% of a mixture with plagioclase. On the other hand, it is quite difficult to estimate the abundance of plagioclase in a mixture with olivine based on the shape of the multicomponent feature. For example, dunite and a 50/50 plag/olivine troctolite are almost indistinguishable.



Laboratory spectra of crystalline plagioclase mixed with various amounts of volume % olivine [6]

Data constraints. The entire inner ring of Orientale (Inner Rook) has been shown to be dominated by massive amounts of plagioclase, including the pure crystalline anorthosite phase, PAN [7]. This not only supports the magma ocean prediction of extensive cumulate plagioclase forming the lunar crust, but (equally important) it also indicates that part of the basin-forming process can bring to the surface relatively coherent subsurface lithologies without extensive mixing, specifically for the inner ring [8, 9, 10].

The spatial context of olivine at basins evaluated with M3 data, such as at Crisium and Moscoviense [e.g. 11], indicates the olivine-rich areas are not found as a massive unit, but instead as a localized block of olivine-rich material (maximum a few km in size) embedded in a sea of plagioclase. Schrödinger may be an intermediate case [12] that also tapped a pluton. Although dunite cannot be ruled out for these areas, as discussed above the olivine occurs most likely as troctolite.

Inferences and questions. Clearly, a massive anorthositic crust formed early in lunar evolution. At basins, the observed olivine that is associated with this feldspathic crust (without other neighboring mafic minerals) argues against its origin as a Mg-suite layered pluton. The small localized occurrences of olivine also argue against it being derived directly from a olivine bearing mantle. Instead, the data suggest the olivine and plagioclase coexist in the lower crust, with olivine/troctolite being a common but not dominant component.

A question that merits discussion from multiple perspectives is the origin of this olivine/troctolite in the lower crust and whether this olivine-plagioclase association could be the result of mantle overturn early in crustal evolution.

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