LUNAR DUNITE 72415: NEW INTERPRETATIONS OF OLIVINE TEXTURES AND INCLUSIONS

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Introduction: Lunar dunite 72415 was collected by Apollo 17 astronauts from the Taurus-Littrow valley. It is a brecciated rock, consisting largely of olivine with minor anorthite-rich plagioclase, clinopyroxene, orthopyroxene, Cr-spinel and apatite. Its origin has been the subject of extensive and ongoing debate, with two major groups of interpretations. Some authors (e.g. [1,2,3]) consider that the dunite is a fragment of the lunar mantle, brought to the surface by a major basin-forming impact (most likely the Serenitatis impact). Others reject this hypothesis and have described the sample as being part of the Mg-suite [4,5,6] of mafic cumulates formed in the lunar crust. The electron microprobe investigation by Ryder (1992) [7] appeared to support this latter hypothesis, by showing that the constituent olivine clasts were zoned and therefore consistent only with a relatively shallow igneous origin.

Here we present new electron microprobe images and electron backscatter diffraction (EBSD) data for olivine in a section of 72415. We show that the so-called zoning is a result of analysis of previously unidentified inclusions of clinopyroxene, anorthite and Cr-spinel within the olivine grains. EBSD analysis reveals granular textures indicative of recrystallization, suggesting that olivines have experienced high-pressure (≥60 GPa) shock metamorphism.

Electron microprobe results: Figure 1A shows a Back-Scattered Electron image of an olivine clast in 72415,53. Instead of being pure olivine, it contains numerous tiny inclusions of other minerals, mostly < 10 µm. A false-colour X-Ray map (Figure 1B) confirms that these inclusions largely consist of Cr-spinel, anorthite-rich plagioclase and clinopyroxene, and are often composed of more than one mineral. Many of the Cr-spinel inclusions show vermicular textures, usually with clinopyroxene. Anorthite varies in size and shape. The grains appear as fine (<10 µm) circular blebs (Figure 1) or as elongate channels (>80 µm) (Fig. 2).

These inclusions are found in many olivine clasts in the sample. Their origin is as unclear, but they would clearly contribute to some of the apparent "chemical variation and zoning" in oxides such as FeO and CaO, reported by [7]. In many respects, they appear similar to the numerous previously reported small "Type C" microsymplectites, considered to be formed by impact melting [8]. Similar Cr-spinel-diopside symplectites have been found in olivine grains from a sample of lunar regolith collected by Luna 24 (Khisina et al., 2013) [9]. These authors attributed these symplectites to a process of segregation of Ca and Cr by dehydrogenation and oxidation as a result of decompression. We plan to test this hypothesis by undertaking WDS mapping of olivine clasts in 72415, to determine whether the Cr and Ca were contributed by diffusion from the host olivine.

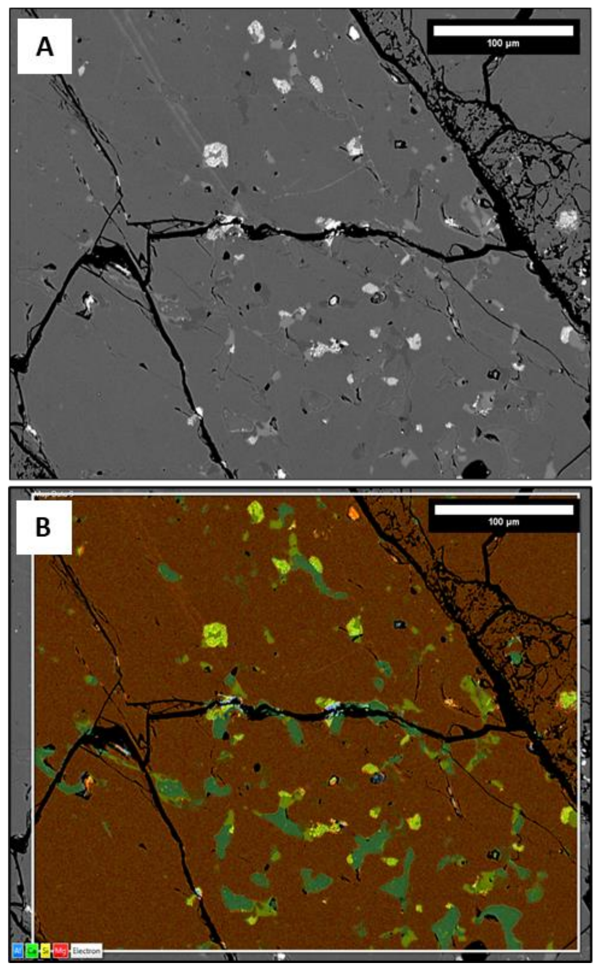

Figure 1. (A) BSE image of an olivine clast in lunar dunite thin-section 72415,53. Scale bar = 100 µm. (B) False-colour X-Ray map of olivine clast shown in A. Yellow = Cr-spinel, teal green = anorthite, bright green = clinopyroxene. Scale bar = 100 µm.

Figure 2 shows a false-colour X-ray map of a large channel structure, >140 µm in length, formed of anorthite associated with clinopyroxene and Cr-spinel blebs. A 2D slice image of a Computed Tomography

(CT) scan of a fragment of 72417 reveals a similar shaped low-density phase inside a large olivine clast. These channels do not bisect the entire clast but are always confined to the olivine clasts and are present in varying volumes. They are thought to be composed largely of anorthite.

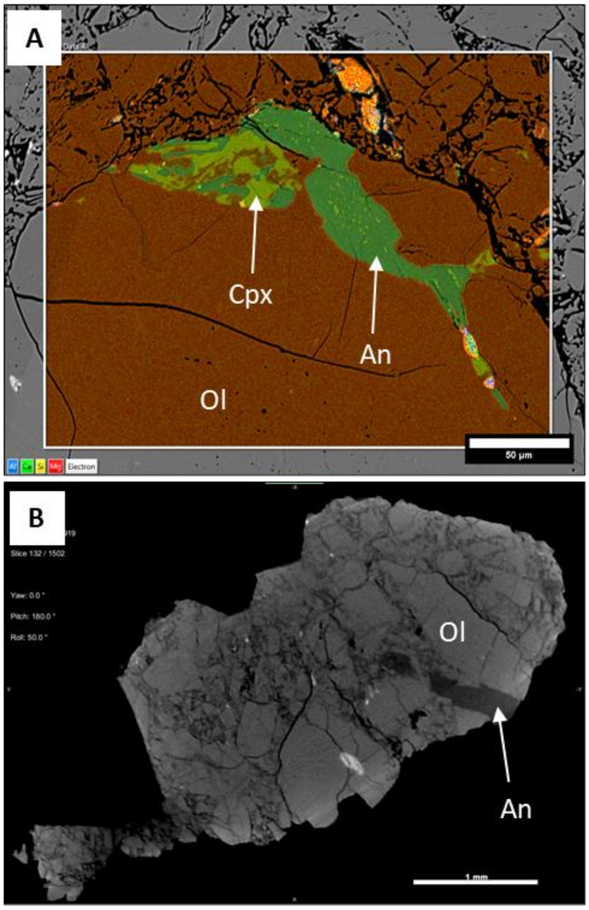

Figure 2. (A) False-colour X-Ray map of olivine clast in 72415, showing a large anorthite channel. Yellow = Cr-spinel, teal green = anorthite, bright green = clinopyroxene. Scale bar = 50 µm. (B) 2D slice image of a CT scan through a fragment of 72417, highlighting a low-density phase in an olivine clast is interpretated as anorthite. Scale bar = 1 mm.

EBSD data: Electron backscatter diffraction investigations of the olivine clasts in thin-section 72415,53 were conducted using a Zeiss Crossbeam 550 SEM with an Oxford Instruments Symmetry 2 EBSD detector at The Open University. These analyses revealed a variety of textures within the sample, with some grains showing partial or total recrystallization, while other grains demonstrate little to no shock deformation (Figure 3). Such diversity is expected in a

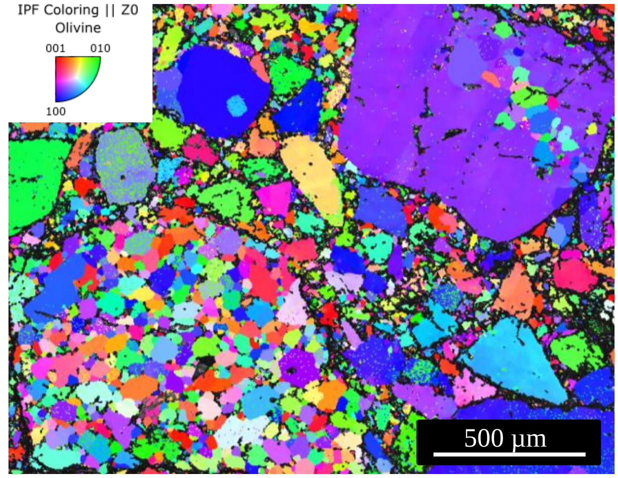

Figure 3. Inverse Pole Figure map of large area of thin-section 72415,53, demonstrating the variable textures within olivine clasts, including partial recrystallization (top-right), total recrystallization (bottom-left) and those with little to no deformation.

brecciated sample. However, a previous study of this sample [7] report minimal deformation, with only thin melt veins crosscutting the sample. Based on the apparent low shock deformation of the sample, it was suggested that large-scale deep crustal-excavating impacts had not occurred, and the sample had experienced minimal impact processing. This argued against a deep mantle origin for the sample. The presence of olivine with textures indicative of total recrystallization and partial recrystallization, however, can be inferred as a result of shock pressures of ≥ 60 GPa [10]. These pressures suggest that at least some grains have experienced large-scale and possibly deep impacts that excavated into the lunar mantle.

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