DIFFERENT TYPES OF SPINEL SYMPLECTITES IN LUNAR DUNITE 72415 AND 72417

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1. Introduction:

Spinel symplectites have been reported in Apollo 17 lunar dunite samples 72415 to 72418 [1-6]. We have investigated these samples by electron microprobe and micro-CT.

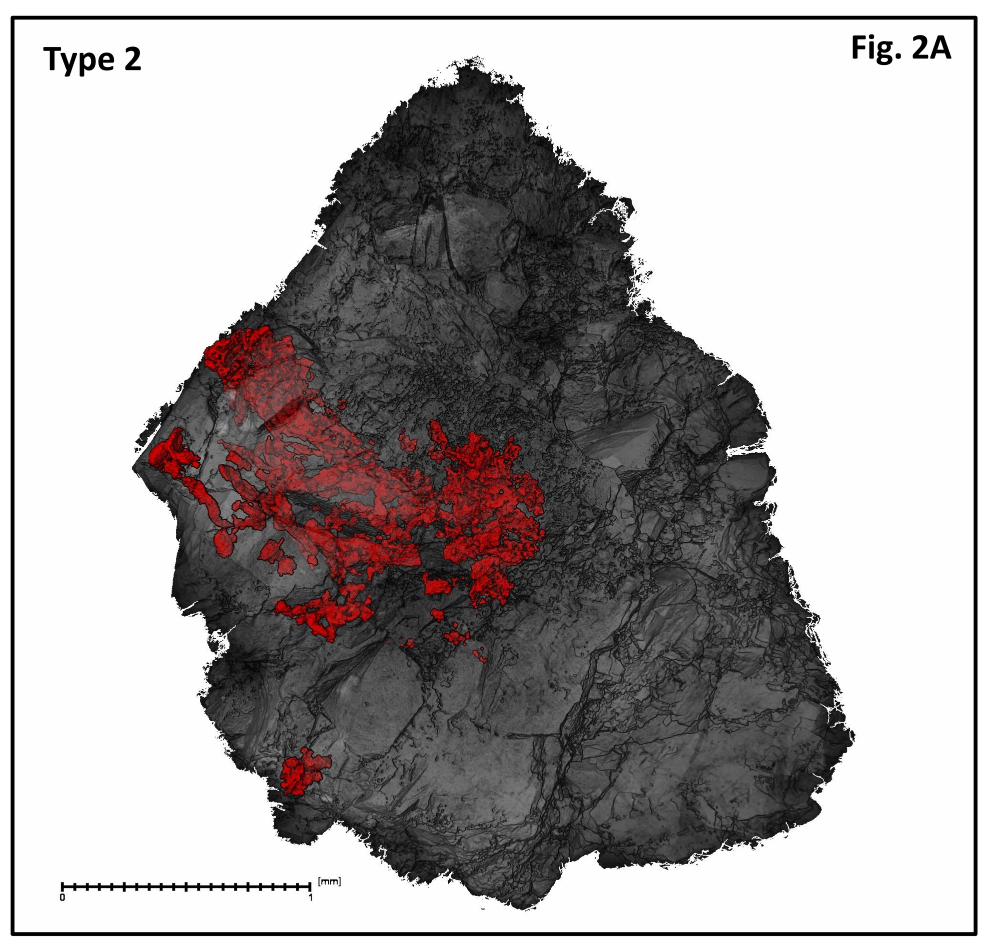
2. Electron microprobe results:

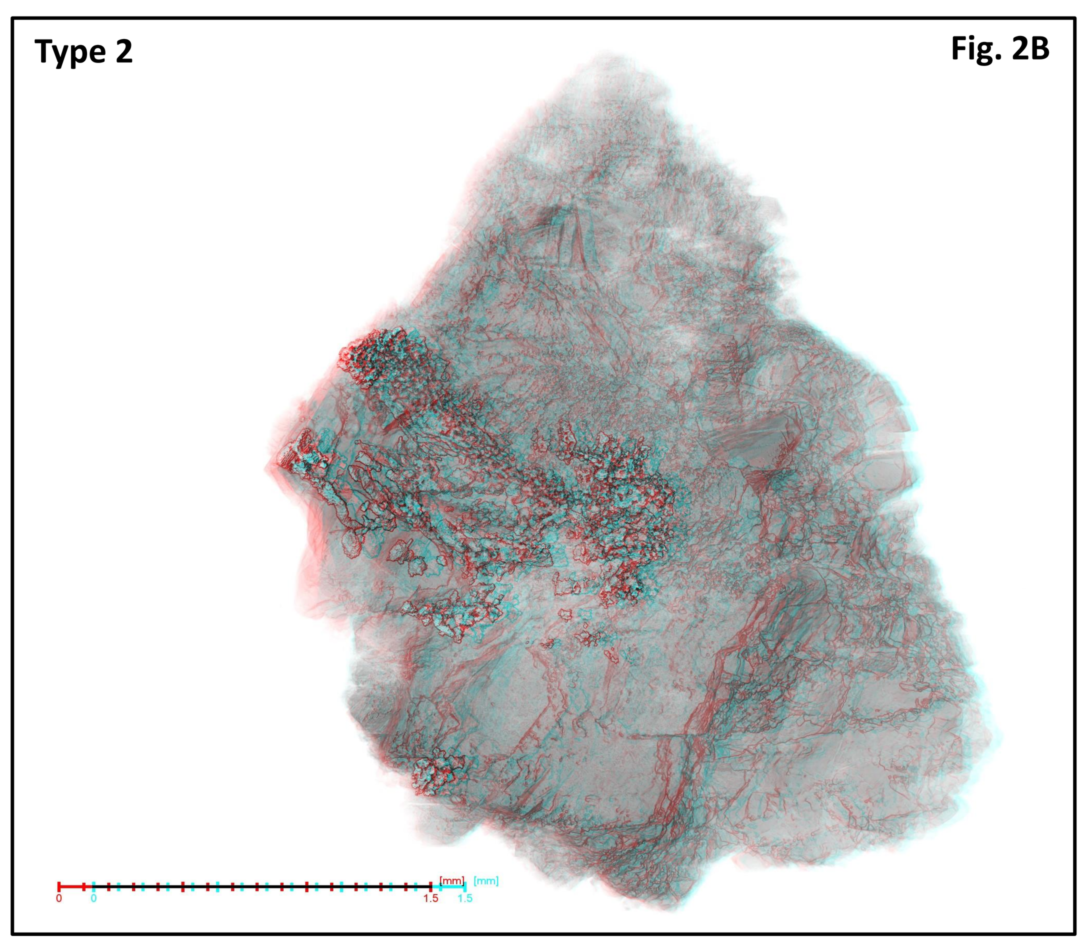
The sample shows a brecciated texture of angular to sub-angular fragments (Fig. 1A) of olivine Fo_{86-89} in a matrix of smaller angular fragments, with rare diopside, anorthite, spinel and Fe-Ni metal. Olivine grains show shock features with undulose extinction, mosaicism and fractures. We have found three types of symplectite with different compositions of spinel. One (spinel Type 1a) is between spinel + diopside ± enstatite (Fig. 1A); Spinel has Mg# = 48 and Cr# = 67. The second symplectite (spinel Type 1b) is between spinel + anorthite and is closely associated with olivine (Fig. 1B); this spinel has Mg# = 60 and Cr# = 49. A third symplectite (spinel type 1c) is much smaller (<30 µm in size), very abundant, only found inside single olivine clasts and is composed of spinel + diopside ± enstatite (Fig. 1C) with an intermediate composition spinel.

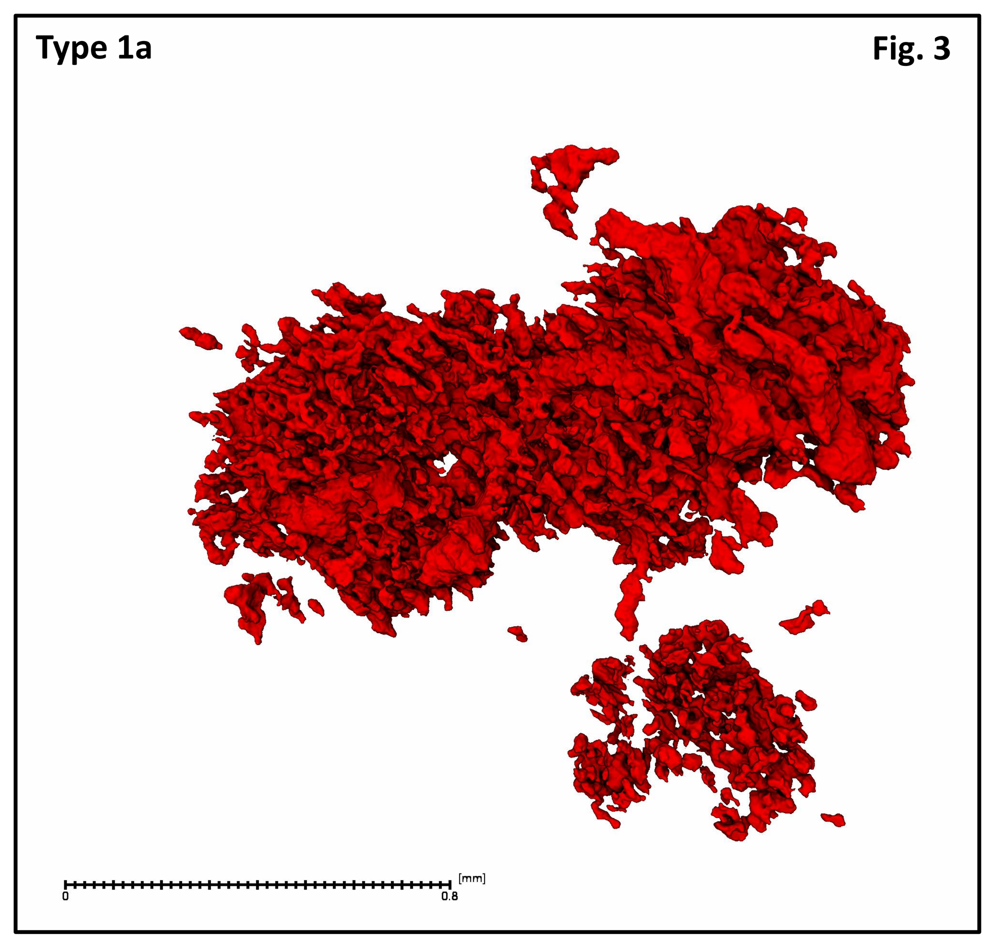
Figure 1A. (i) BSE and (ii) false colour image of a spinel (purple) + clinopyroxene (green) + orthopyroxene (light brown) symplectite (Type 1a) clast from TS 72415,53. Scalebar = 25 µm. ***Figure 1B.*** (i) BSE and (ii) false colour image of a spinel (pink) + anorthite (dark green) + olivine (brown) symplectite (Type 1b) clast in TS 72415,53. Scalebar = 50 µm. **Figure 1C.** (i) BSE and (ii) false colour image of a symplectite (spinel type 1c) only found inside single olivine clasts, composed of spinel (purple) + diopside (green) ± enstatite (light brown). Scalebar = 10 µm.

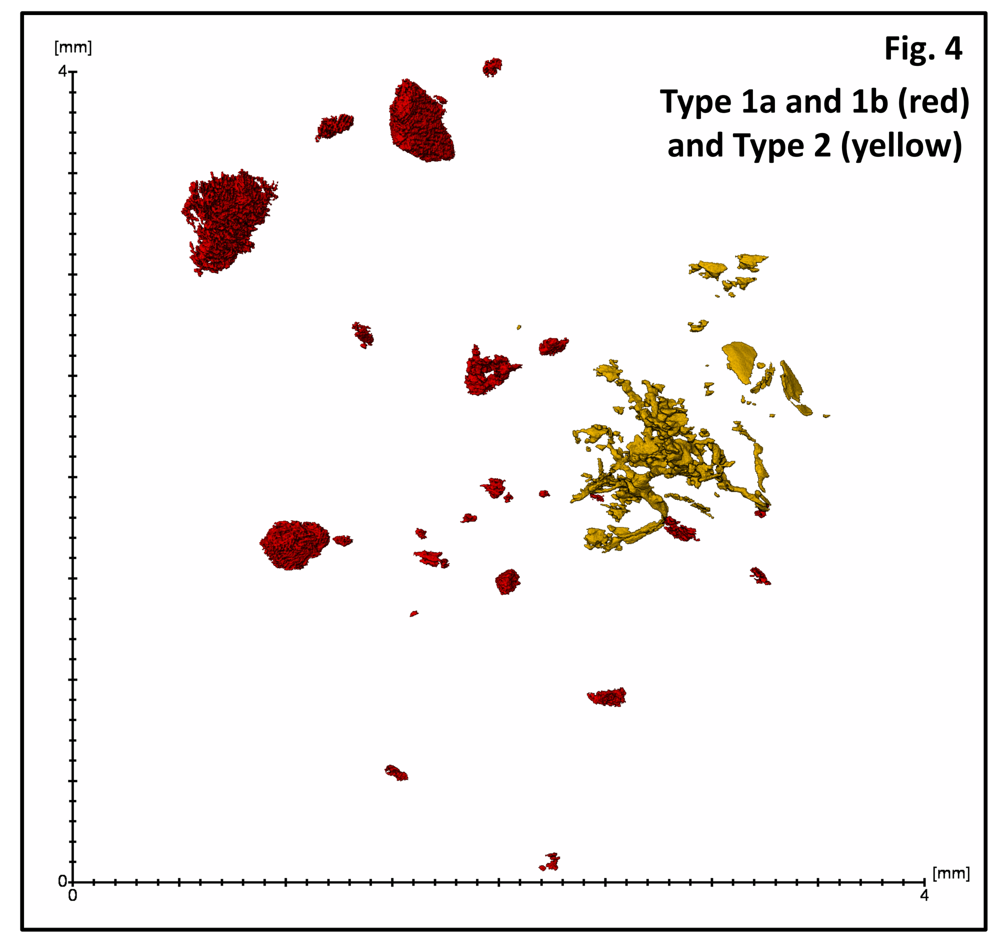
3. Micro-CT results:

Micro-CT analysis confirms that spinel forms complex structures of varying size, shape and texture (Fig. 2, 3, 4 and 5). Spinel type-1a forms randomly orientated elliptical (<0.6 mm) structures with a highly vermicular texture; spinel is wholly contained within a single grain and forms a single crystal. Some individual spinel structures have angular edges indicating fracturing. Spinel type-1b forms smaller elongate interstitial structures. Spinel type-1c cannot be imaged because of its small size. A completely new large unfractured high density structure with many individual elongate branches forms linear channel-like features (Fig. 4 and 5) often terminating at plate-like structures. Such structures have only be seen in the CT scans. We interpret this as a melt texture (Type 2) that may be composed of spinel or perhaps troilite and requires further investigation.









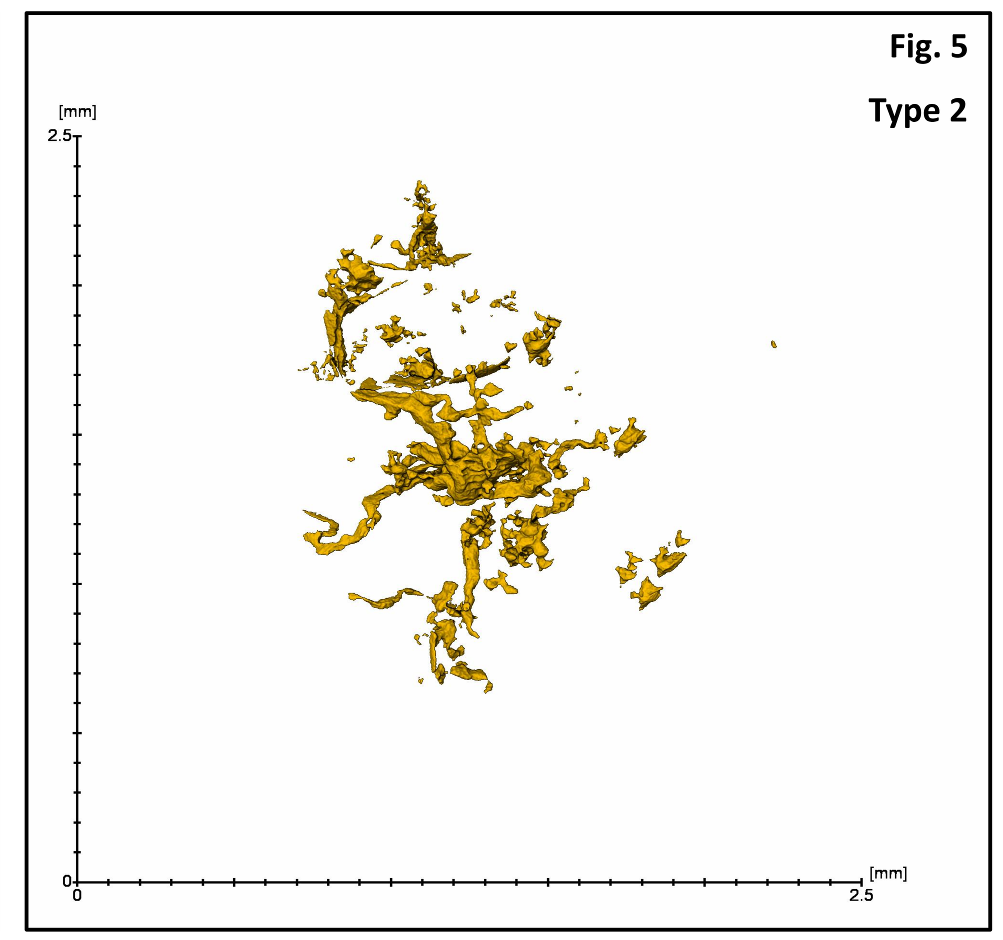


Figure 2A. 3D rendered micro-CT image from lunar dunite 72415,4 showing type 2 texture. Scalebar = 1 mm. ***Figure 2B.*** 3D anaglyph of lunar dunite 72415,4 showing type 2 texture. Scalebar = 1.5 mm. ***Figure 3.*** 3D rendered image of image from lunar dunite 72415,4 spinel type 1a texture. Spinel forms an ellipsoidal highly complex vermicular structure over 0.2 mm in length. Spinel is fully contained in an individual grain and individual branches form a single grain. Scalebar = 0.8 mm. ***Figure 4.*** 3D rendered micro-CT image from lunar dunite 72417,9003 showing two contrasting textures: spinel type 1a and 1b (red) and type 2 (yellow). Scalebar = 4 mm. ***Figure 5.*** 3D rendered micro-CT image from lunar dunite 72417,9003 showing type 2 (yellow) isolated. Scalebar = 2.5 mm.

4. Discussion:

Many studies discussed the origin of symplectites in lunar dunites. Interpretations fall into two categories: shallow formation (crust) and deep formation (mantle). As the symplectites commonly occur along ol-an grain boundaries (our Type 1b), [2] suggested that the stability pressure for ol + an + spinel had not been exceeded, so crystallization was shallow. They proposed that the dunites are ol + sp cumulates and that later adcumulus ol growth was associated with crystallization of opx, cpx, an and Cr-sp as vermicular intergrowths. [5] proposed that variations in texture and phase assemblages reflect local variations in the trapped melt composition. In contrast, [1] reported zones of sp symplectites (our Type 1a, 1b) and tiny ovoid inclusions in olivine (our Type 1c). The intergrowths were interpreted as existing prior to excavation and that the lunar dunite represents a very early differentiate derived from the upper mantle, i.e. a cumulate formed during early lunar differentiation and associated gravitational settling. [3] also reported eutectoid intergrowths of sp + pyx and occasional plagioclase (our Type 1a and 1b) and considered that the lunar dunite formed under high pressures and temperatures, and originally contained garnet because the microsymplectites (our Type 1c) have an idealized bulk composition of a garnet. [4] proposed that these symplectites formed by garnet breakdown. [7] suggested that decomposition of a high-pressure Cr-rich garnet in deep mantle cumulates occurred during mantle overturn.

Based on texture and mineral chemistry, we propose that spinel Type 1a, b and c have different origins. The large sp + cpx symplectites (spinel Type 1a) formed from decompression of garnet brought up from ~420 km depth by convective overturn. Type 1b are shallower origin with interaction of ol and decompression melts forming ol + an + sp symplectites. Type 1c have an exsolution origin, possibly from melt inclusions. Type 2 textures are younger than all Type 1 textures and are most likely related to shock melting.

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