

SHOCK VEINS IN PAIRED LUNAR METEORITES NORTHWEST AFRICA 3163 AND 4881. R. G. Hopkins and J. G. Spray, Planetary and Space Science Centre, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada (rhopkins@unb.ca).

Introduction: There are currently over 130 confirmed lunar meteorites that have been found on Earth, amounting to a total mass of 281.06 kg [1]. The large majority of these stones are breccias, 98 of which are highly feldspathic and thorium-poor.

These samples provide important supplemental material to the directly acquired material from the Apollo and Luna missions of the 1960s and 70s. This is because the meteorite samples originate from random locations across the lunar surface and provide insight to lunar terranes that have not yet been sampled directly.

Many of the lunar meteorite samples exhibit shock effects, such as shock veins, melt pockets, and shock-induced high-pressure/high-temperature structural states. These shock effects are a result of the extensive bombardment by projectiles that have impacted the Moon and modified its surface since formation.

On Earth, in situ shock veins have, so far, only been identified in the central uplift structures of the Manicouagan impact structure, Canada [2], and the Vredefort impact structure, South Africa [3]. If shock veins only form within the central uplift structures of complex craters then this could provide additional constraints on the source of lunar meteorites containing similar shock features.

Sample Description: This study examines lunar meteorites Northwest Africa (NWA) 3163 and 4881. These are paired stones classified as granulitic breccias, which are breccias that have been thermally metamorphosed at 1000-1100 °C [4].

The hand sample of NWA 3163 (1634 g) is almost entirely coated in a thin, transparent, greenish fusion crust. The interior is pale grey with visible clasts cross-cut by shock veins and fractures, some of which are lined with terrestrial calcite [5]. The hand sample of NWA 4881 (606 g) is an irregular, broken stone that is partially coated with a thin, translucent, greenish fusion crust. The interior is pale grey-brown with visible clasts and fewer visible shock veins and fractures than that of NWA 3163 [5].

In thin section, the textures of both samples range from granoblastic to poikiloblastic, with larger grains of plagioclase enclosing smaller grains of pyroxene and olivine. Both stones possess accessory Ti-chromite, ilmenite, troilite, and iron-nickel. The plagioclase is subhedral, highly calcic (An₉₆₋₉₈), and has been almost entirely converted to maskelynite via shock. Pyroxene and olivine crystals are anhedral.

Pyroxene occurs as orthopyroxene hosts with very fine exsolution lamellae of clinopyroxene. There also exists lithic clasts, most of which comprise maskelynitized plagioclase, with lesser amounts of pyroxene and olivine. Some clasts have edges enclosed by the matrix, inferring clast-matrix interactions. All clasts are more fractured than the matrix.

Shock Effects: The meteorites were subjected to shock pressures of 28-34 GPa (shock stage S3), as inferred through the near entirety of plagioclase being converted to maskelynite [6]. Multiple shock veins ($\leq 100 \mu\text{m}$ wide) and melt pockets ($\leq 400 \mu\text{m}$ wide) are present possessing fluidal-glassy textures lighter than the matrix when observed via electron microscopy (FESEM) in backscattered electron (BSE) mode (Figure 1).

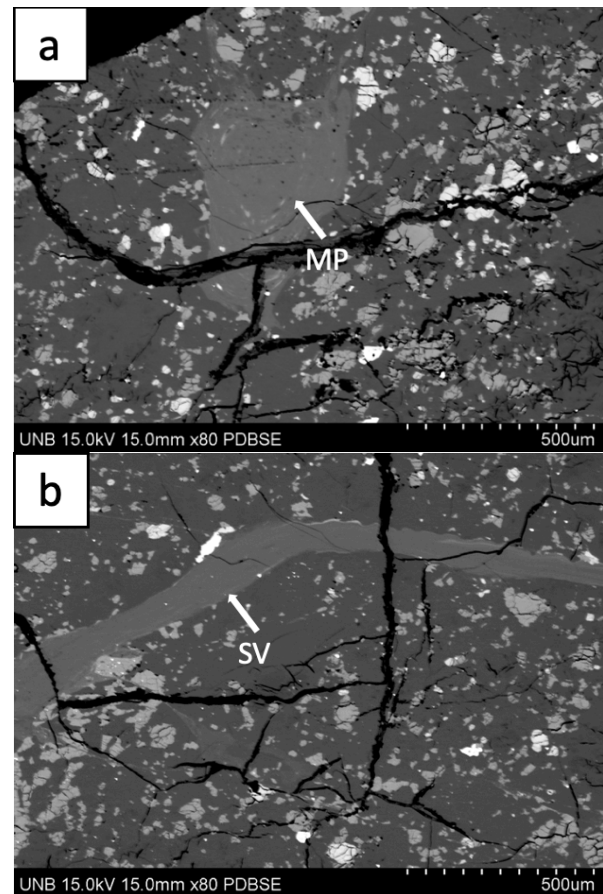


Figure 1: BSE FESEM photos of NWA 3163 displaying granoblastic texture and shock features. (a) melt pocket ($\sim 400 \mu\text{m}$ diameter), labelled MP, and (b) shock vein ($\sim 100 \mu\text{m}$ wide), labelled SV.

Within the larger shock veins and melt pockets small ($\sim 1 \mu\text{m} \times 3 \mu\text{m}$) elongate plagioclase crystals have grown within the glassy matrix (Figure 2a). Larger veins divide into two smaller veins in an anastomosing fashion. Clasts are also common that have been assimilated into the veins as xenoliths. Grains of olivine and pyroxene are commonly melting into the veins with a fluidized texture. With respect to the pyroxene crystals, the lamellae (clinopyroxene) appear to have preferentially melted into the veins (Figure 2b). Pyroxene crystals near, but not within, the shock veins typically display a partially-fluidized rim of clinopyroxene. Thinner ($\leq 10 \mu\text{m}$) shock veins commonly branch off the larger veins and pockets, which may crosscut mineral grains, offsetting them in a fault-like fashion.

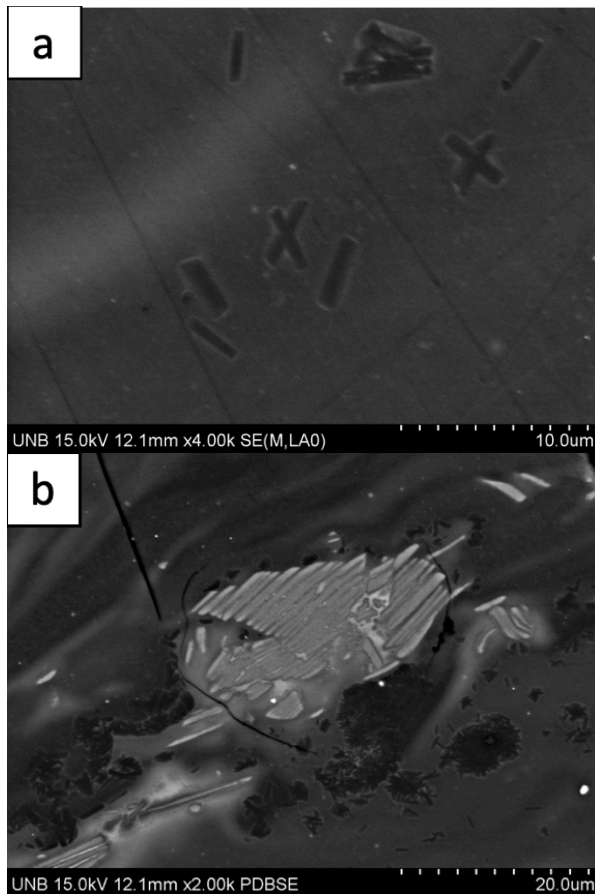


Figure 2: BSE FESEM images of crystals within the larger (50–150 μm wide) shock veins of NWA 3163. (a) displays small elongate plagioclase crystals ($\sim 1 \mu\text{m} \times 3 \mu\text{m}$) that have grown within the once molten matrix. (b) A pyroxene clast within the shock vein with the clinopyroxene lamellae (darker stripes) preferentially melted out.

Analysis of Shock Veins: The shock veins of NWA3163 were analyzed using Raman spectroscopy at the Planetary and Space Science Center at the University of New Brunswick. The results indicate that the shock veins are amorphous, as expected. Interestingly, a small peak at ~ 1000 Raman shift/ cm^{-1} was registering for shock veins $\geq 80 \mu\text{m}$ in width (Figure 3). This response was interpreted as a potential sign of small clinopyroxene crystals that are beginning to crystallize out of the melt of large shock veins. If this is the case it would contribute greatly to constraining the conditions experienced within shock veins during formation.

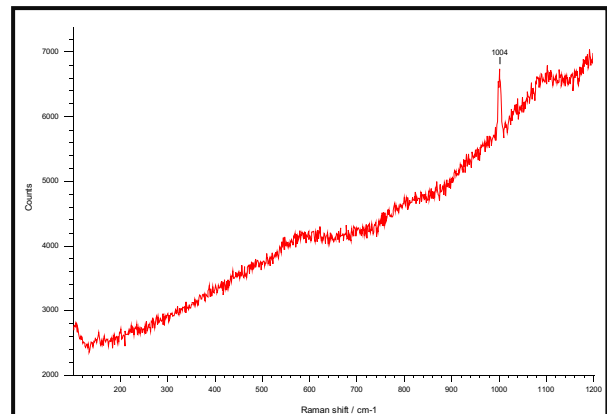


Figure 3: Raman Spectrum of $\sim 90 \mu\text{m}$ wide shock vein within NWA3163. The spectrum displays a generally amorphous structure within the shock vein matrix, with a single peak at 1004, which suggests the development of clinopyroxene crystallites within the melt.

References

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