# Shock veins in paired lunar meteorites Northwest Africa 3163 and 4881

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Many lunar meteorite samples exhibit shock effects, such as shock veins, melt pockets, and associated high-pressure/ high-temperature polymorphs. However, the mechanism of formation of shock veins and melt pockets is not well understood. 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 (Canada), and Vredefort (South Africa) impact structures.

This study examines the paired lunar meteorites Northwest Africa (NWA) 3163 and 4881. They are classified as granulitic breccias (breccias that have been thermally metamorphosed at 1000–1100 °C). 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. Pyroxene occurs as orthopyroxene hosts containing very fine exsolution lamellae of clinopyroxene.

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. Multiple shock veins (≤100 µm wide) and melt pockets (≤400 µm wide) are present, possessing fluidal-glassy textures lighter than the matrix when observed via electron microscopy (FESEM) in backscattered electron (BSE) mode. Within the larger shock veins and melt pockets, small (~1 x 3 µm) elongate plagioclase crystals have grown within the glassy matrix. Clasts that have been assimilated into the veins as xenoliths are also common. Grains of olivine and pyroxene have commonly melted into the veins with fluid (melting) margins. With respect to the pyroxene crystals, the lamellae (clinopyroxene) appear to have preferentially melted into the veins. Thinner (≤10 µm) shock veins commonly branch off the larger veins and pockets, which may crosscut mineral grains and offset them in a fault-like fashion.

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 ≥80 µm in width. This is interpreted as 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.

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