LUNAR METEORITE DHOFAR 026: A SECOND-GENERATION IMPACT MELT.

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Introduction: The meteorite Dhofar 026 (Dh26) was found in Oman in January, 2000 [1]. It is a clast-poor, anorthositic, crystalline melt breccia with no fusion crust and little terrestrial weathering. Solar wind abundance measurements show that it is unpaired with the lunar regolith breccia Dhofar 025 [2]. The Dh26 oxygen isotopic composition indicates its lunar origin [3], while its major- and trace-element bulk composition [3] shows that a FAN component is a major contributor (bulk An_{98} and Mg#=63), producing a prominent positive Eu anomaly (Sm/Eu = 1.04). We have obtained petrography and EMP analyses to characterize this meteorite. The main mass represents a crystalline impact melt, derived from a mixture of FAN and a component similar to the crystalline lunar spherules (CLS). The spherule-like objects, in turn, are probably impact melts of a mixture containing a highly fractionated, basaltic precursor.

Petrography: The groundmass consists of blebs of olivine up to 10's of µm's in diameter set into multicrystalline plagioclase. "Spherules," made up of acicular plagioclase with interstitial pyroxene and olivine, have well-defined borders with the groundmass. These spherules are usually ~100 µm in diameter and ovoid, but the largest exceed 250 µm in diameter. Spherules make up <0.5% of the meteorite by volume. Blotchy areas seem to be intermediate between the groundmass and spherules. Blotches are composed of olivine and pyroxene with a similar, though degraded, texture as the inside of the spherules. These blotchy areas have no characteristic size and grade into the groundmass with no definite borders. Approximately 50% of Dh26 by volume has this blotchy texture, though this is difficult to estimate because of the indefinite borders. Minor chromite, ilmenite, troilite, and apatite occur as small (<20 µm), isolated blebs within the poikilitic groundmass.

Mineralogy: *Poikilitic groundmass*. Olivines are unzoned and vary little among blebs within the narrow range Fo_{61-64} (Fig. 2b). Groundmass feldspar is An_{95-99}; embedded single-crystal clasts of feldspar are slightly more calcic at An_{96-99} (Fig. 2c). Ilmenites have extremely low Mg# (6-8). Spinels plot along the chromite-ulvöspinel join though they are too small to determine possible chemical zonation. Troilite is common and often associated with FeNi metal. The largest metal nuggets are Ni-rich (15-27 wt% Ni; 1.0-1.3 wt% Co). Minute high-Ni metal blebs are often included in troilite and olivine grains but are too small for analyses. Apatite is chlorine-rich.

Spherules. Spherules are composed of acicular plagioclase with a lower An content (An_{93-95}) than their surroundings (Fig. 3). Olivines (Fo_{52-81}; Fig 2) in the spherules vary in composition within a single spherule and show a bimodal distribution. Pyroxenes within a single spherule can range from augite to very iron-rich compositions (Fig. 2). Spherules are surrounded by a thin rim of "clean" plagioclase, separating them from blotchy areas. Most spherules have tiny void spaces but some have much larger spaces as well (Fig. 1b shows both small and large spaces). Void space is usually filled with Si. It is unclear at this point whether these Si-filled spaces are artifacts of preparation.

Blotchy areas. The plagioclase (An_{95-98}) in these areas is indistinguishable from the poikilitic groundmass (Fig 3). The composition and distribution of olivines (Fo_{70-80}) and pyroxenes, on the other hand, is indistinguishable from the spherules (Fig. 2)

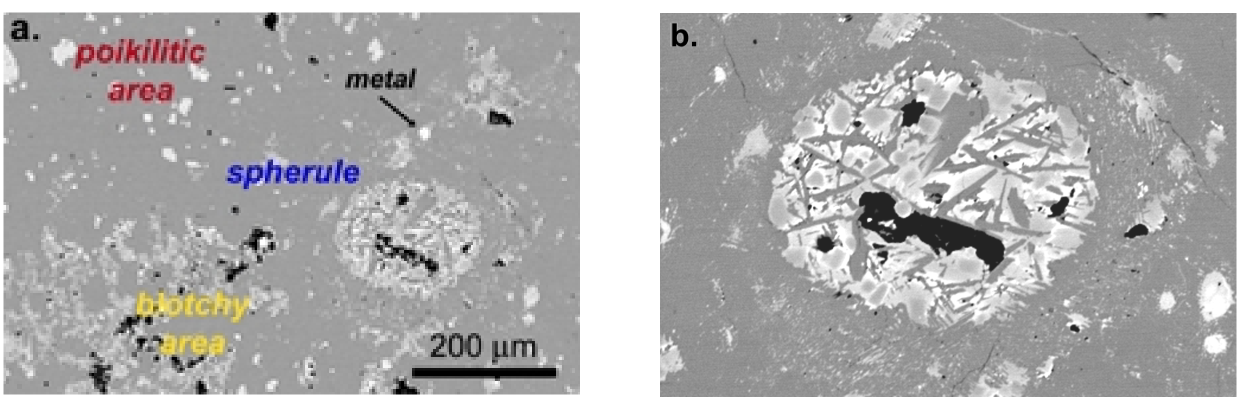

Figure 1: BSE images of Dh26: a) typical poikilitic and blotchy areas; b) spherule enlarged to show its texture.

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Interpretations: The meteorite groundmass is a crystalline impact melt consisting of poikilitic olivine in multicrystalline, nearly granulitic, plagioclase. This interpretation is further supported by the existence of accessory minerals solely within the groundmass.

Whereas the difference in plagioclase An contents between the spherules and the groundmass is small, it is statistically significant, arguing that the spherules are foreign to the groundmass. The intact spherules appear to be stable within the groundmass; they are rimmed by "clean" feldspar produced by equilibration of Mg and Fe between the groundmass and the spherules. The blotches seem to be derived from spherule-like precursor materials that are being resorbed into the melt, losing their borders, and equilibrating their plagioclase content in the process.

The MAGFOX program was used to predict the equilibrium crystallization of a melt with the bulk Dh26 composition. Plagioclase (An_{98}), olivine (Fo_{89}), and pleonastic spinel are the first phases to crystallize. Pyroxene does not appear until 97% fractional crystallization, further strengthening the foreign nature of the spherules and blotchy areas. The model-derived Mg# of the olivine does not match the rock, probably because the whole-rock Mg is split between the xenocrysts and the melt. In fact, the whole-rock Mg# (0.63) corresponds well with the Mg# of the poikilitic olivines. Normative and native feldspar compositions also coincide very well.

The spherules themselves are probably an earlier generation of impact melt. The characteristic textures and mineral assemblages in Apollo 14 CLS's [4] indicate their origin as impact melt splashes. Spherical objects are also found in the highlands lunar meteorite QUE94281 [5]. The spherules in Dh26 appear to have a similar origin, though they contain little to no true glass. The pyroxene in these spherules is clearly derived from a highly fractionated source; the low Mg# and high An# are comparable to Luna 24 VLT and Apollo 11 and 17 low-K basalts [6]. The spherules may be impact melt fragments derived from or incorporating such a target, perhaps from the east limb of the Moon. Alternatively, these characteristics could result from mixing a FAN component with mare or cryptomare material, perhaps on the lunar far side.

The low mafic phase Mg# in both the spherules and groundmass precludes a substantial contribution from Mg-suite rocks (Fig. 4). There is no mineralogical evidence for the presence of a KREEP constituent. The metal in Dh26 has a cosmic Ni/Co ratio (~20).

Though the Dh25 and Dh26 meteorites are different in texture and mineral chemistry, they were found very near each other and may have been ejected from the Moon in a single impact event. In this scenario, Dh26 may represent a basement lithology, whereas Dh25 can represent an upper layer of the target.

References: [1] Nazarov, M. (2000) *Meteoritical Bulletin 84*. [2] Shukolyukov, Yu. A. (2001) *this volume*. [3] Taylor, L. A., et al. (2001) *this volume*. [4] Ruzicka, A., et al. (1998) *MAPS 35*, 173-192. [5] Arai, T. and Warren, P. H. (1999) *MAPS 34*, 209-234. [6] Papike, J. J., et al. (1991) in *Lunar Sourcebook*, 121-181.

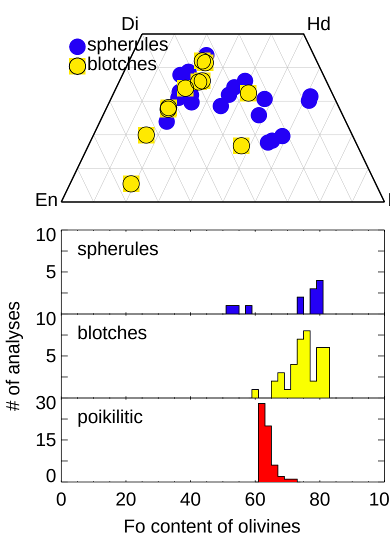

Figure 2: Pyroxene and olivine compositions in Dh26.

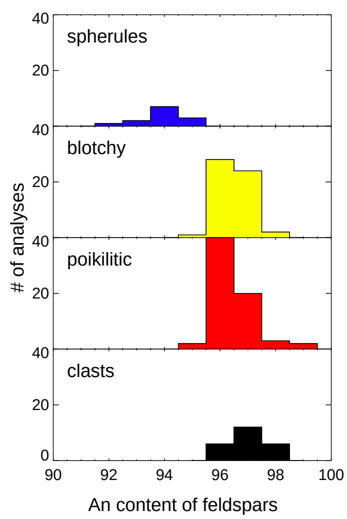

Figure 3: An content in Dh26 feldspars.

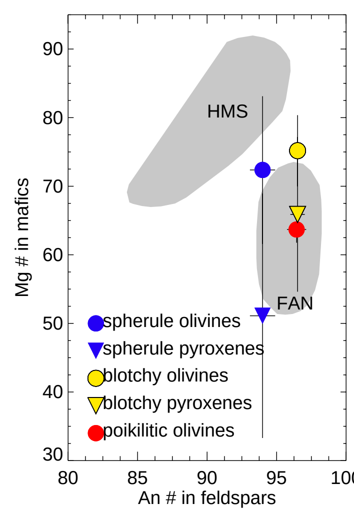

Figure 4: Mg# vs. An# for mafic minerals and feldspars in Dh26.