FLUID INCLUSIONS

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FLUID INCLUSIONS IN STONY METEORITES -- A CAUTIONARY NOTE

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Warner et al.[1] reported the presence of fluid inclusions in thin sections of diogenite ALHA 77256, and Bjurbole, Faith, Holbrook and Jilin chondrites. Subsequent investigation of fluid inclusions in meteorites and lunar rocks have demonstrated the existence of fluid inclusions in shergotitte EETA 79001, ALHA 81005 (lunar meteorite), Apollo 16 sample 61538, and many Bjurbole chondrules*. Measurements performed on these new inclusions call into question the extraterrestrial origin of many of the fluid inclusions reported by Warner et al. and illustrate the need for caution in interpreting any fluid inclusions observed in thin sections of extraterrestrial material.

EETA 79001. A glass fragment from EETA 79001, a shergottite collected in Antarctica, contains a single fluid inclusion within a spherical vesicle. The vesicle is 6 µm wide and occurs along a fracture in the center of the thin section. This inclusion exhibits a peculiar freezing behavior: upon cooling, the bubble grows larger and moves to the side of the inclusion where it remains at all lower temperatures. Around -40°C a second phase appears to grow adjacent to the bubble, causing the bubble to deform. Below -80°C the refraction index of the "fluid" increases to match that of the enclosing glass, making the outer rim of the inclusion invisible. As the inclusion is warmed from low temperatures, the outer rim fades in at -80°C; the second phase shrinks and disappears around -20°C. Finally, the bubble begins moving around -9°C, indicating that no solid exists at higher temperatures. This behavior is quite similar to that observed in fluid inclusions in ALHA 77256 (1, p. 732-733), except for the observed change in refraction index. This difference may be due to the enclosing medium. In EETA 79001 the inclusions are within glass, in ALHA 77256 the inclusions are within orthopyroxene (which has a much higher refractive index) so that any change in refractive index of the fluid may go unnoticed.

ALHA 81005 (lunar meteorite). Numerous fluid inclusions were observed in two thin sections of ALHA 81005. In both section,fluids occur within vesicles in the clear glass fusion crust, within vesicles in the brown, swirly impact melt glass and within feldspar and pyroxene crystals of breccia fragments. The fluid inclusions vary from <1 µm to over 10 µm, and are found at all levels of the thin section; there is no tendency for fluid inclusions to be concentrated on the bottom of the thin section or along visible fractures. The fluid filling the vesicle has an index of refraction close to that of the glass. Freezing behavior of these fluids are not known because the samples could not be frozen.

Lunar Glasses. Thin section 61538,7 is a brown, vesicular impact melt glass which forms a coating on a polymict breccia. This thin section contains over 50 fluid inclusions that occur within spherical vesicles. More than half of these fluid inclusions occur very near the bottom of the thin section; the remainder occur at higher levels. There is no apparent association of the filled vesicles with any visible fractures. The fluid inclusions vary from <1 µm to over 12 µm, and, like the fluids in ALHA 81005, have a refractive index similar to that of the enclosing glass. The freezing behavior of these inclusions is identical to that described above for the EETA 79001 inclusions.

No fluid inclusions have previously been observed in lunar samples, despite extensive searching by several investigators (cf., 2), so the possibility that these inclusions are artifacts of thin section preparation was investigated. A 19 µg sample of untreated 61538 glass was observed under an optical microscope in air. Although hundreds of vesicles were observed in this

*The term "fluid inclusion" used here will refer to inclusions which contain a visible moving vapor bubble which is readily observed under high power (1250x).

manner, no filled vesicles were seen. It is therefore concluded that all the fluid inclusions observed in lunar glass 61538 are artifacts created during thin sectioning. Most likely, a fluid phase was drawn along submicroscopic fractures, via vacuum (vesicles in lunar glasses can be at vacuum, E. Roedder, pers. comm.) and/or capillary action, into vesicles as the samples were sawn. Several fluids are used in lunar thin section preparation at JSC. Of these, the saw coolant exhibits the most similar freezing behavior to the fluid artifacts: upon cooling, the saw oil crystallizes, producing very fine crystals. At very low temperatures (below -80^{o}C) a second phase appears to exsolve, or a coarser set of crystals grow; it is difficult to determine which is occurring. Upon warming, this second phase (coarser set of crystals) disappears around -20^{o}C and the fine crystals finally melt around -11^{o}C. In addition to this distinctive freezing behavior, the saw oil fluoresces a blue color when exposed to ultraviolet radiation (P. Radomski, pers. comm.) as do other hydrocarbons (3). A fluid inclusion in ALHA 77256 also fluoresces blue (S.C. Bergman, pers. comm.).

Bjurbole Chondrules. Several thin sections of Bjurbole chondrules contain fluid inclusions; one chondrule in particular has over 30 documented fluid inclusions, ranging in size from 1 μm to 8 μm. The inclusions occur at all levels of the thin section and are generally not associated with visible fractures. Both 2- and 3-phase inclusions occur within this chondrule. The 3-phase inclusions are similar to those described by Warner et al. Because of their small size, freezing behavior is difficult to document in these fluid inclusions, however, a 6 μm long inclusion appeared to freeze (as seen by a sudden movement of the vapor bubble) around -20^{o}C. In order to evaluate the possibility of these inclusions being artifacts of thin section preparation, several thin sections of Bjurbole chondrules were impregnated with dark blue epoxy and sawn in alcohol. No fluid inclusions were observed in these specially-prepared samples, even in chondrules texturally identical to those previously observed to contain over 30 fluid inclusions. In addition, several apparent "holes" within minerals were observed to be rimmed with blue epoxy -- similar to the "glass" phase reported by Warner et al. (p. 734) in their 3-phase inclusions.

In light of the above observations of fluid inclusions in a variety of extraterrestrial samples, the origin of fluid inclusions in stony meteorites described by Warner et al. is in question. The lunar fluid inclusions described above are unquestionably the products of thin section preparation and their similar properties to fluid inclusions in other extraterrestrial samples places heavy doubt on the origin of these inclusions. In conclusion, any fluid inclusions observed in *thin sections* of extraterrestrial samples must be treated with caution; fluid inclusions observed in unprepared samples however (e.g., 4) may indeed be candidates for true extraterrestrial fluids.

References: (1) Warner, J.L. et al. (1983) in: Proc. 13th Lunar and Planet. Sci. Conf., Part 2, JGR 88, sup., A731-A735. (2) Roedder, E. (1981) in: Fluid Inclusions: Applications to Petrology, MAC Short Course Handbook 6, 101. (3) Burruss, R.C. (1981) in: Fluid Inclusions: Applications to Petrology, MAC Short Course Hankbook 6, 138. (4) Fieni, C., et al. (1978) Meteoritics, 13, 460.

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