FLUID INCLUSIONS IN DIOGENITE ALHA-77256

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Two distinct classes of fluid inclusions have been discovered in the achondritic meteorite ALHA-77256, a diogenite collected in Antarctica. Both classes are contained in orthopyroxene En

These new data improve the characterization of fluid inclusions in ALHA-77256, and suggest that our temperature of the experiment (generally

We reject the possibility that fluid inclusions in ALHA-77256 are artifacts. The locations of fluid inclusions were mapped to ensure that they are not artifacts in the mounting medium or were otherwise introduced during sample preparation (3). Inclusions occur at all levels in the thin sections and are not confined to the top or bottom or the rock chip where epytox is used to bond the sample to the glass slide. Fluid inclusions are present in samples that were vacuum impregnated and in samples not impregnated. Fluid inclusions we observe are artifacts introduced during thin section preparation or due to impact on Antarctic ice, inclusions should be present in other Antarctic meteorites prepared in a similar manner which is not the case.

Two Phase Inclusions - The most common class of fluid inclusions in ALHA-77256, abundant in the ten selected sections examined, are irregular in shape and contain vapor bubbles with widely ranging relative volumes. The vapor bubbles do not generally move spontaneously at room temperature, or rapidly upon heating, suggesting that the included fluid may have a high viscosity. Because the vapor bubble moves somewhat when the inclusion is heated (Fig. 1), and the liquid and vapor homogenize when the temperature is raised, we infer that they are liquid-vapor inclusions and not gas-vapor inclusions. These inclusions range in size from 1 to 100 µm across and have shapes that are lenticular, lobate, branching, and amoeboidal (Fig. 2). Some of these inclusions are irregular in two dimensions, thin in the third dimension, and occur in planar groups. Others are irregular in three dimensions; the irregularities occasionally appearing in thin section as false phase boundaries. An inclusion with such a false boundary is shown in Figure 3: one view shows the vapor bubble to the left of the false boundary, the second view shows the inclusion with the liquid and vapor homogenized, and the third view shows the vapor bubble to the right. The vapor bubble ranges from 1 to >90 volume % of these inclusions, and inclusions occur that have no vapor bubble. The vapor bubble displays a continuous decrease in size as inclusions are heated from -180° C to homogenization of liquid-vapor to liquid. A discrete solid phase is formed on freezing, and melting is observed on heating but is not accompanied by a drastic change in relative vapor bubble size. Observed final melting ranges from -9°C to -8°C. As homogenization is approached the vapor bubble decreases in size and exhibits movement. In some cases bubbles display rapid motion within a few degrees of homogenization. Homogenization temperatures range from about 30°C to >300°C with no preferred temperature (Fig. 5). Not shown on Figure 5 are 15 inclusions that did not homogenize at the maximum temperature of the experiment (generally 225°C). Freezing is observed in some of these inclusions, although we have cooled many as low as -185°C without seeing freezing. When freezing is observed, a solid phase appears below about -20°C, and the vapor bubble reforms below about -60°C. Preliminary Raman spectroscopy work (method described in (5)) using the MOLE microprobe (CREGU-Nancy, France) has verified that the inclusions are aqueous; symmetric and antisymmetric stretch bands characteristic of H₂O (3200-3600 cm⁻¹) were found. Raman vibration bands characteristic of CO₂, CH₄, H₂O, and other hydrocarbons were not found, suggesting that these species are not present in appreciable concentrations (>1 mole %).

There are several possible compositions for the included fluid in the two phase inclusions of ALHA-77256 that are compatible with our observations: (1) it is an aqueous fluid that contains a large quantity of dissolved components (salts). Such a solution must be complex (i.e., more than a ternary mixture) to account for the observed melting phenomena, and in addition will be viscous. However, daughter salt crystals might be expected in such a solution, but they are not observed; (2) it is an aqueous fluid that precipitates an unknown solid phase at very low temperature. At higher temperature, the unknown solid goes through a solid-solid transformation to water ice. Water ice will then melt somewhat below 0°C. If the unknown solid has a smaller molar volume than ice, a decrease in vapor bubble size with increasing temperature may be explained. However, this case cannot account for the apparent viscous nature of the fluid. We are continuing our experiments and intend to open the inclusions and analyze the fluid by gas chromatography and mass spectroscopy (6) and the daughter salts by SEM.


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Three Phase Inclusions - This class of inclusion consists of a spherical liquid-vapor droplet encased in an irregular inclusion of a phase that has low relief relative to the orthopyroxene host (Fig. 4). These inclusions are irregularly distributed in ALHA-77256: about 20 occur in section 52, one occurs in section 59.2, and none were observed in the other sections we examined. The inclusions range in size up to 40 μm across, and the liquid-vapor droplets attain diameters up to 5 μm. The low relief phase is a colorless isotropic solid that appears to be glass. Attempts to analyze this glass have been unsuccessful because we have not located a spot where the glass cuts the section surface so it is accessible to the electron microprobe. The liquid-vapor droplets are distinct from the liquid-vapor viscous inclusions. The vapor bubble moves spontaneously at room temperature and consistently occupies about 1 volume % of the droplet. It is exceedingly difficult to obtain microthermometric data for the liquid-vapor droplets due to their small size which is commonly below the optical resolution of our microthermometric apparatus. Homogenization from liquid plus vapor to liquid occurs in the range 80-100°C. Freezing has not been observed, mostly due to the small size of the liquid-vapor droplets. This liquid may be aqueous.

The origin of these fluid inclusions is unknown, and the physical and chemical characteristics of the included fluid are poorly constrained. We are continuing our characterization of these fluid inclusions. We do not yet understand the significance of the extraterrestrial fluid trapped in these inclusions, although we are sure they carry an important message.

REFERENCES