

THE STABILITY OF HIBONITE IN SILICATE MELTS: IMPLICATIONS FOR THE ORIGIN OF HIBONITE-BEARING INCLUSIONS FROM CARBONACEOUS CHONDRITES.

J.R. Beckett and E. Stolper. Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125

Introduction. Hibonite (Hib) is commonly found in Ca-, Al-rich inclusions (CAIs) from carbonaceous chondrites (1-4) and is predicted to be a high-temperature condensate in a cooling gas of solar composition (5). Based on textural arguments, some Hib-bearing CAIs appear to have crystallized from melts (3,6) while others are interpreted to be vapor-to-solid condensates (2). We report results of equilibrium crystallization experiments on bulk compositions in the Hib stability field for the system CaO-MgO-Al₂O₃-SiO₂ (CMAS) and on partitioning of TiO₂ between Hib and coexisting melt. Given a melt composition, our results constrain whether or not Hib can crystallize from a particular bulk composition and, if so, at what temperatures, and thus provide constraints on the origin of Hib-bearing CAIs.

Starting Compositions. Glass (G1), G1+Hib or G1+corundum (Cor) starting materials were used. Ten bulk compositions for which Hib is on or near the liquidus were selected to map out the Hib saturation surface in CMAS. In some cases glasses were made of equivalent bulk compositions spiked with 1-2 wt% TiO₂. Experiments were conducted in air in a Del Tech DT-31 vertical quench furnace. Samples were suspended in the hot spot using Pt-wire loops for 24-265 hrs and quenched into H₂O.

Experimental Results. Hib, spinel (Sp), anorthite (An), CaAl₄O₇ (CA2), melilite (Mel) and Cor were produced in various experiments. Compositions of An, Cor and CA2 are essentially those of pure end-members. Mel is gehlenitic (<~Ak3). Synthetic Hib is CaAl₁₀Mg(Si,Ti)_{0.19}-CaAl₁₂O₁₉ (CA6) with wt% SiO₂ <(1.2). Wt% TiO₂ (Hib/glass), D_{Ti}^{Hib} , is 0.9-1.2 for 1-3.5 wt% TiO₂ (glass). The effective D_{Ti}^{Hib} in CAIs melted under reducing conditions will be even lower because there is very little trivalent Ti in meteoritic Hib (7).

In Figure 1, hibonite saturated melt compositions in CMAS are projected from CA6 onto the plane Gehlenite (Ge)-An-Sp and contoured in wt% CA6. Multiply saturated melt compositions used to construct Fig. 1 (8-12) are indicated. TiO₂ stabilizes Hib relative to other phases and lowers wt% CA6 on the saturation surface. Figure 2 shows isotherms on the Hib-saturated liquidus in CMAS. Figure 3 is an Sp projection of the Sp-saturated liquidus onto the plane Ge-An-Forsterite (Fo) after (13) with Hib- and Cor-saturated phase boundaries from this work.

Discussion. Bulk compositions (3) of Sp-Hib-bearing (SH) inclusions from Murchison plot near the Sp apex in Figure 1 below the Hib-saturation surface. The crystallization sequence is Sp+Sp+Hib. According to Figure 1, CA2 should be the third phase to crystallize. However, the low temperature crystallization sequence of SH-inclusions is uncertain due to high their bulk TiO₂ (3-6 wt%) and low SiO₂ (0.1-2 wt%). Paque and Stolper (14) determined the crystallization sequence of a Hib-bearing inclusion (ES) described by (4). Based on Figure 3, Cor and Hib are expected to crystallize from ES although neither phase was observed by (14). This implies nucleation problems for Cor and Hib as suggested by (14). The crystallization of metastable Cor in place of Hib in this study is also consistent with nucleation difficulties for Hib. Paque (15) has described a CA2-containing patchy area in a type A inclusion. The expected crystallization sequence of this area [wt % CMAS+TiO₂= 29.0, 6.37, 47.9, 15.4, 1.04 (16)] is Sp+Mel+CA2+Hib, consistent with the observed phase assemblage.

Textural evidence [e.g., inclusion of Hib in cores of melilite, lack of Hib near crystal edges (2), axiolytic growth textures at outer edges of inclusions (6)] suggests that Hib is an early forming phase in Allende type A's. However, primary bulk compositions of type A's (17,18) plot 40-60 wt% below the Hib saturation surface. Hib will not be a near-liquidus phase for these inclusions. Moreover, Hib in Allende type A's can have several wt% TiO₂ (2,4). Based on our experiments, similar concentrations in Hib crystallized from a molten type A composition are only expected under near-solidus conditions. If type A's were melted, then Hib in the interiors of inclusions must, in most cases, be relict. Those Hib grains axiolytically intergrown at the outer edges of type A's (6) may have crystallized from a Ca-, Al-rich boundary layer caused by volatilization of the molten droplet.

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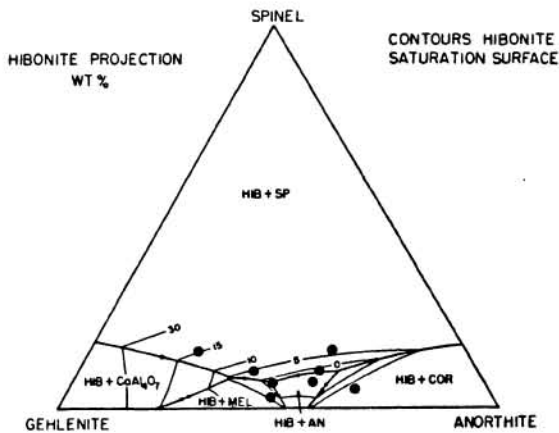


Figure 1

Fig. 1. Hib-saturated liquidus projected from CA6 onto the plane Ge-An-Sp contoured in wt % CA6. Circles indicate projections of bulk compositions examined in this study. Only eight are shown because some bulk compositions differed only in the amount of CA6.
 Fig. 2. Isotherms (°C) on Hib-saturated liquidus projected from CA6 onto the plane Ge-An-Sp. Circles indicate projected compositions of Hib-saturated melts used to construct the diagram.
 Fig. 3 Projection of Sp-saturated liquidus onto the plane Ge-An-Fo after (13) with Hib-saturated curves modified using data from this study.

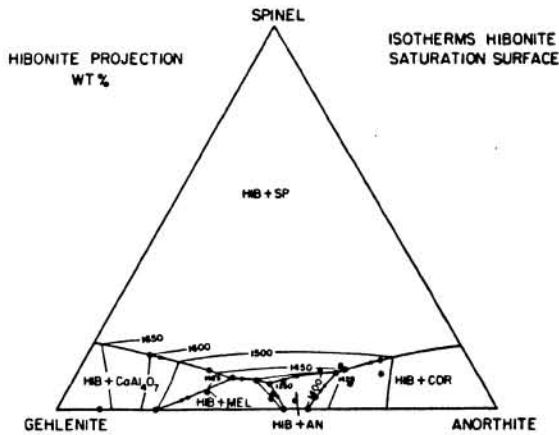


Figure 2

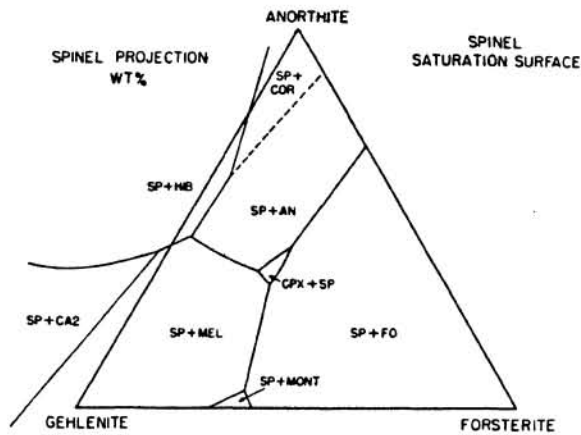


Figure 3