UREILITE PARENT BODY SIZE(S): SMELTING EXPERIMENTS

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Experimental determination of smelting equilibria relevant to ureilite petrogenesis shows that the range of ureilite compositions are consistent with parent body sizes of at least ~100 km radius.

Progressive smelting produces compositional variation among ureilites. Both Goodrich et al. (1) and Takeda (2) summarize evidence for this although the details of their petrogenetic scenarios are quite different. Berkley and Jones (3) interpreted the large graphite crystals found in some ureilites as primary magmatic features with the implication that graphite + gas equilibria control the redox state of ureilites. We adopt this view. In the presence of graphite, a certain pressure must be maintained for the silicates to retain a particular complement of ferrous iron. Progressive reduction observed in ureilites is consistent with depressurization and partial smelting during ascent and emplacement of ureilite magmas on their parent object(s). The question is: what pressures are necessary in the presence of graphite to explain the most Fe-rich ureilites, and what pressure drop is consistent with the extent of smelting observed? These questions were answered by Goodrich et al. (1) on the basis of calculated equilibria using solution models for gas, silicate liquid, solid, and metallic liquid. We were curious to investigate the extent to which the uncertainties in those solution models might introduce elasticity into the estimated minimum size for the ureilite parent body. The interest in doing so is supplied by the studies of Prinz et al.(4) and Clayton and Mayeda (5) indicating the possibility that the ureilites come from multiple parent bodies. It would be surprising if all these objects must be derived from *different, large* bodies, considering the paucity of identified candidates.

10-20 mg chunks of lunar samples 12002 and 60315 (+15% An) (=6A315) were encapsulated in small graphite crucibles with ventilated tops. The crucibles and silicate were inserted within an open Pt tube. The tube and contents were run in a rapid quench, externally heated, 1/4" I.D. TZM vessel pressurized with CO at 1210-1219°C for 12-24 hr. Reaction between the graphite and CO establishes a gas composition (CO/CO2, pO_2) appropriate to the temperature and total pressure set experimentally. The silicate equilibrates with the graphite and gas. Following quenching and depressurization, charges were extracted and prepared for optical and electron probe analysis. Changes in the silicate assemblage and composition are a function of total pressure and are shown in Figure 1.

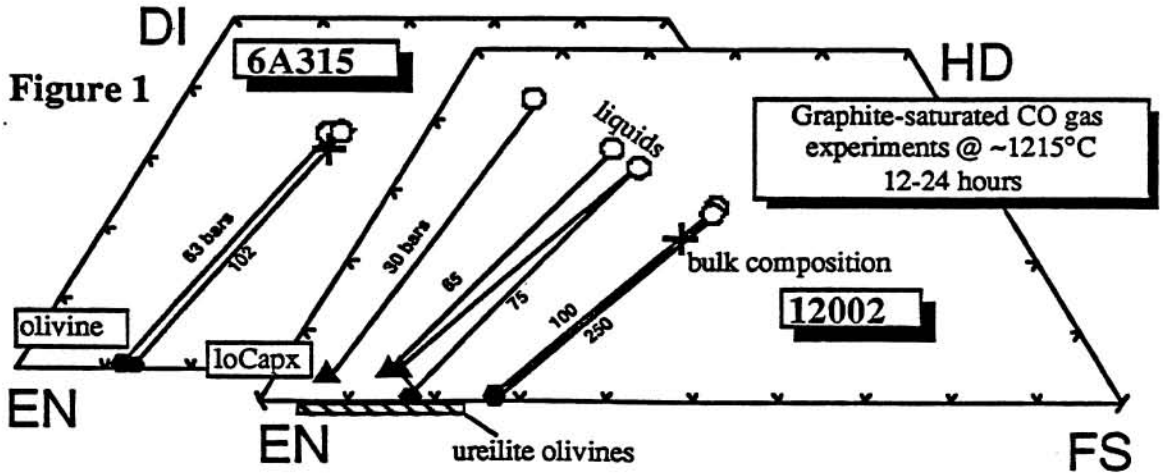
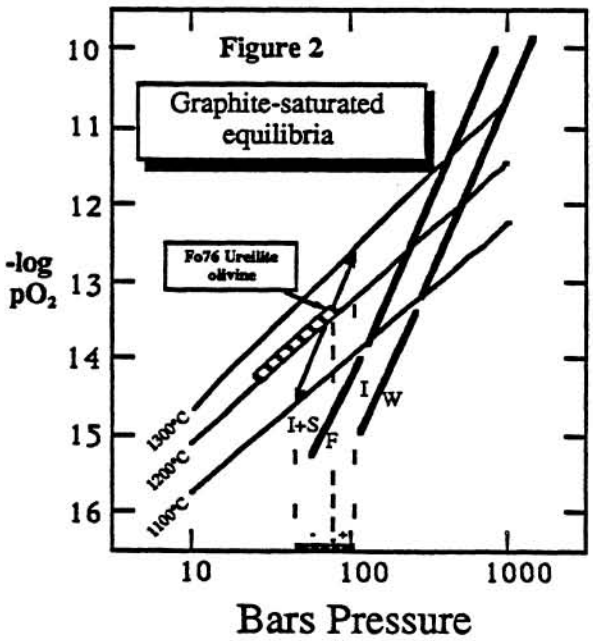


Figure 1

Bulk compositions are given by crosses. Charges run at 100 bars or more had no Fe liquid metal present; all Fe available is oxidized into the silicates. Charges run at lower pressure developed a liquid metal phase, with the silicates showing complementary depletion in oxidized Fe. Olivines from fully oxidized charges at ~100 bars are quite different in 12002 and 6A315 as a consequence of the different Mg# of the bulk compositions. If excess Fe metal had been included with the charges, such a difference would not be expected. At ~65 bars, both compositions have sustained reduction to the point of generating a free liquid metal phase and gross differences between the Mg# in the silicates of the two compositions are reduced. However, 12002 has lost enough FeO from the silicate to precipitate loCapx instead of olivine. If olivine were present in 12002 at ~65 bars, it would be Fo84. In contrast, Fo88 is observed in the more feldspathic composition, 6A315, at this pressure. This olivine compositional difference indicates the redox equilibria *are* sensitive to the solution properties of the silicate liquid.

Using the 12002 results for pressure versus Mg# at graphite saturation, the range of ureilite olivines [Fo76-Fo95] corresponds to pressures from 90-25 bars. Figure 2 is based on Sato's (6) graphite-saturation surface. Isotherms trace the relation between pO_2 and total P for graphite + gas equilibria. The ISF and IW curves are the trace of the intersection of these weakly pressure-dependent buffers with the graphite saturation surface. [Note the apparently paradoxical listing of the reduced assemblage (e.g. I or I+S) on the high pO_2 sides of these curves. As pO_2 is raised from the IW curve at constant P (but still following the Gr+CO surface), the reduced assemblage is encountered because the Gr+CO curve increases pO_2 more slowly with temperature than the buffer curve.] These buffer curves are ~parallel to isopleths of Mg# in the silicates. Error bounds upon the pressure implied for the most FeO-rich ureilites can be evaluated as a function of uncertainties in petrogenesis temperature. Changing the temperature from 1100-1300°C along an Mg# isopleth changes the estimate of pressure from 50-105 bars for Fo76. This estimate of maximum ureilite petrogenesis pressure may be compared to the 200 bars calculated by Goodrich et al.(1) from the best estimates then available. Direct experimental determination lowers the minimum parent body size estimate by a factor of ~2-4, but the conclusion that the ureilite parent object(s) are substantial [at least ~100 km radius] still stands.



References: (1) Goodrich CA et al.(1987) **GCA 51**, 2255-2273 (2) Takeda H (1987) **EPSL 81**, 358-370 (3) Berkley JL and Jones J (1982) **PLPSC 13, JGR 87**, A353-364 (4) Prinz M et al. (1987) **Meteoritics 22**, 482-483 (5) Clayton RN and Mayeda TK (1988) **LPSXIX**, 197-198 (6) Sato M. (1979) **PLPSC 10**, 311-325.