INVESTIGATING METHANE INFILTRATION AS A DRIVER FOR SMELTING IN UREILITES

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Introduction: Ureilites contain regions of smelting, which is generally accepted to occur along olivine grain boundaries by reaction with graphite [1], for example:

$$2C^0 + 2(Fe,Mg)_2SiO_4 = Mg_2SiO_4 + 2SiO_2 + 2Fe^0 + 2CO$$

Smelted regions appear as Fe-depleted silicate domains within olivine, with imbedded FeNi metal. This metamorphic process accounts for the large range in Mg#, but would need to be a brief process and involve rapid melt migration [2] to account for the small extent of observed reaction. In all planetesimals that are internally heated by ^{26}Al and ^{60}Fe, temperature increases with depth. The associated increase in pressure inhibits smelting reactions unless the temperature gradient is steeper than the pressure gradient [1]. Small bodies can have such gradients, but would require that occurs at lower temperatures than the olivine-graphite smelting reaction [3]

Observations: We have studied the textural setting of smelting in ureilites. In several samples, smelting was observed in halos around fine internal fractures within olivine grains. This observation implies that a transported volatile phase was responsible for driving smelting along these fractures.

In addition, the smelting-related texture at olivine-graphite contacts is discontinuous. If ureilites have achieved temperatures sufficient for smelting between these minerals, we would expect all olivine-graphite contacts to display smelting textures, given the longevity of radiogenic metamorphism.

Discussion: Both fracture-hosted smelting in grain cores, and discontinuous smelting at grain boundaries require a driving mechanism different to those previously described. Smelting of olivine by methane would occur at lower temperatures than olivine-graphite smelting (because C in CH_4 is C^{4-} and thus a more powerful reductant than graphite), and allows for migration of the reducing agent through microfractures within grains. Methanogenic smelting could occur through:

$$CH_4 + 4(Fe,Mg)_2SiO_4 = 4Fe + CO_2 + 2H_2O + 4MgSiO_3 \text{ or}$$

$$CH_4 + 2(Fe,Mg)_2SiO_4 = 2Fe + C + 2H_2O + 2MgSiO_3$$

Ureilites also contain significant abundances of diamond grains amongst mostly amorphous graphite. Current theories regarding the origin of these diamonds suggest that they are pre-solar, solar nebular material or shock-related grains [4]. However, the first two options require that the ureilite parent body contained far more primordial diamonds than even primitive chondrites, which then survived protracted low P metamorphism at T>1070°C [5]; an unlikely proposition. Shock formation of diamonds is also an unsatisfactory explanation as they occur both in shocked and unshocked samples [6]. Our mechanism for smelting could promote diamond formation through vapor deposition. This process is well established in the growth of industrial diamonds, and is the accepted explanation for diamond formation in a nebula setting. Volatile infiltration and methogenic smelting also explains the high noble gas abundance of the graphite/diamond matrix.

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