

A NEW ANGRITE OXYBAROMETER: OLIVINE-MELT VANADIUM DISTRIBUTION IN D'ORBIGNY

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Introduction: Angrites are enigmatic differentiated achondrites comprised of both plutonic and volcanic members [*e. g.* 1]. Volcanic angrites, in particular, are significant because they record the earliest-known volcanic processes of a differentiated parent body at ~4 Ma after CAI formation, providing critical geochronological constraints on ages of planetary differentiation [2]. They are also unique in that they contain unusual mineral phases and quench textures, can contain glasses that are representative of bulk composition, and can contain vesicles [1-4]. D'Orbigny is the most thoroughly examined volcanic angrite, but there is no consensus as to the exact mechanism of its formation [*e. g.* 1, 4]. [4] suggested that volcanic angrites may have formed from the mixing of a more evolved magma with a primitive magma on the angrite parent body prior to quenching, explaining textural features such as reverse zoning in olivine and diopside. In order to understand the complex petrogenesis of angrites, numerous studies have measured oxygen fugacity, the effective concentration of oxygen, of the angrite parent magma [5-8]. Understanding this component of angrite petrogenesis is critical, as oxygen fugacity (fO_2) determines the oxidation states and partitioning behaviors of transition elements (*e. g.*, Fe and V) during crystallization. [8] performed crystallization experiments with angritic melts and found that Eu/Gd ratios in pyroxene and plagioclase varied systematically as a function of fO_2 , which suggested that angrites crystallized at an fO_2 of approximately one log unit above the iron-wüstite oxidation buffer (IW+1). These results were consistent with thermodynamic calculations in [6], but more recent work presented by [7] has shown variability (IW - 2 to IW + 3.7) among different mineral phases in D'Orbigny. Further work is needed to determine the oxidation history of this primitive yet complex material.

Methods: This study employs a new oxybarometer previously used for terrestrial komatiites [9-10] that calculates fO_2 according to the partitioning behavior of V between olivine and melt/glass ($D_V^{Ol/Liq}$). Due to the multiple valence states of V, as fO_2 increases, $D_V^{Ol/Liq}$ decreases systematically [9]. Trace element concentrations were collected using the ThermoFinnigan Element 2 Inductively Coupled Plasma Mass Spectrometer (ICP-MS), coupled to a New Wave UP213 ultraviolet laser ablation system at the University of Maryland Plasma Mass Spectrometry Laboratory. We have calculated oxygen fugacity by measuring V in olivine and using the V content in glass spheres (GS), which [3] found were representative of D'Orbigny bulk composition.

To assess the accuracy of this method for D'Orbigny, we have also collected trace element data for pyroxene and plagioclase. The cores of these minerals should be derived from the angrite parent magma, and ratios of Eu/Gd in pyroxene and plagioclase can be used to interpret fO_2 of the precursor melt [8]. Major oxide concentrations used to calibrate trace element data were collected using the ThermoFisher energy dispersive x-ray collector coupled to a FEI Nova NanoSEM 600 at the Smithsonian Institution's Mineral Sciences Department at the National Museum of Natural History.

Preliminary Results: fO_2 values calculated from olivine-GS distribution coefficients correlate strongly with the Ca content of olivine. Mg-Fe olivines appear to have crystallized between $\log(fO_2) = IW - 0.5$ and $\sim IW + 0.25$, which is consistent with the calculated fO_2 of pyroxene cores in [7]. Additionally, measured Eu/Gd ratios in pyroxene and plagioclase show a similar oxygen fugacity approaching $\sim IW - 0.75$.

Ca-Fe olivines, however, yielded fO_2 of $\sim IW + 6$, which is far more oxidizing than any calculated fO_2 values for meteorites in previous studies, apart from some CK chondrites [11].

Discussion: While the $D_V^{Ol/Liq}$ oxybarometer may prove useful in calculating fO_2 for olivines within the fayalite-forsterite series, the high Ca content in many angrite olivines may change the behavior of V distribution, rendering the method ineffective for this meteorite group. If D'Orbigny is comprised of a mixture of two magmas [4], then it could be that the Ca-Fe olivine measured was not derived from the same parent magma as Mg-Fe olivine, which would also render the oxybarometer ineffective.

Future Work: By the time of this presentation we will determine bulk V content for D'Orbigny using dissolution methods following [9-10] for comparison to oxygen fugacities calculated from glass compositions. The oxybarometer will be further evaluated by calculating fO_2 from olivine-spinel geothermometry [12], following methods in [13].

References:

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