

**ESTABLISHING THE LIQUID PHASE EQUILIBRIUM OF ANGRITES TO CONSTRAIN THEIR PETROGENESIS.** F. L. H. Tissot<sup>1</sup>, M. Collinet<sup>1</sup>, N. Dauphas<sup>2</sup> and T. L. Grove<sup>1</sup>, <sup>1</sup>Dept. of the Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA, USA ([tissot@mit.edu](mailto:tissot@mit.edu)), <sup>2</sup>Origins Lab, Dept of the Geophysical Sciences and Enrico Fermi Institute, The University of Chicago, Chicago, IL.

**Introduction:** Angrites are a series of differentiated meteorites, extremely silica undersaturated and with unusually high Ca and Al contents [1]. They are thought to originate from a small planetesimal parent body of ~ 100-200 km in radius ([2-3]), can be either plutonic (*i.e.*, cumulates) or volcanic (often referred to as quenched) in origin, and their old formation ages (4 to 11 Myr after CAIs) have made them prime anchors to tie the relative chronologies inferred from short-lived radionuclides (*e.g.*, Al-Mg, Mn-Cr, Hf-W) to the absolute Pb-Pb clock [4]. They are also the most volatile element-depleted meteorites available, displaying a K-depletion of a factor of 110 relative to CIs.

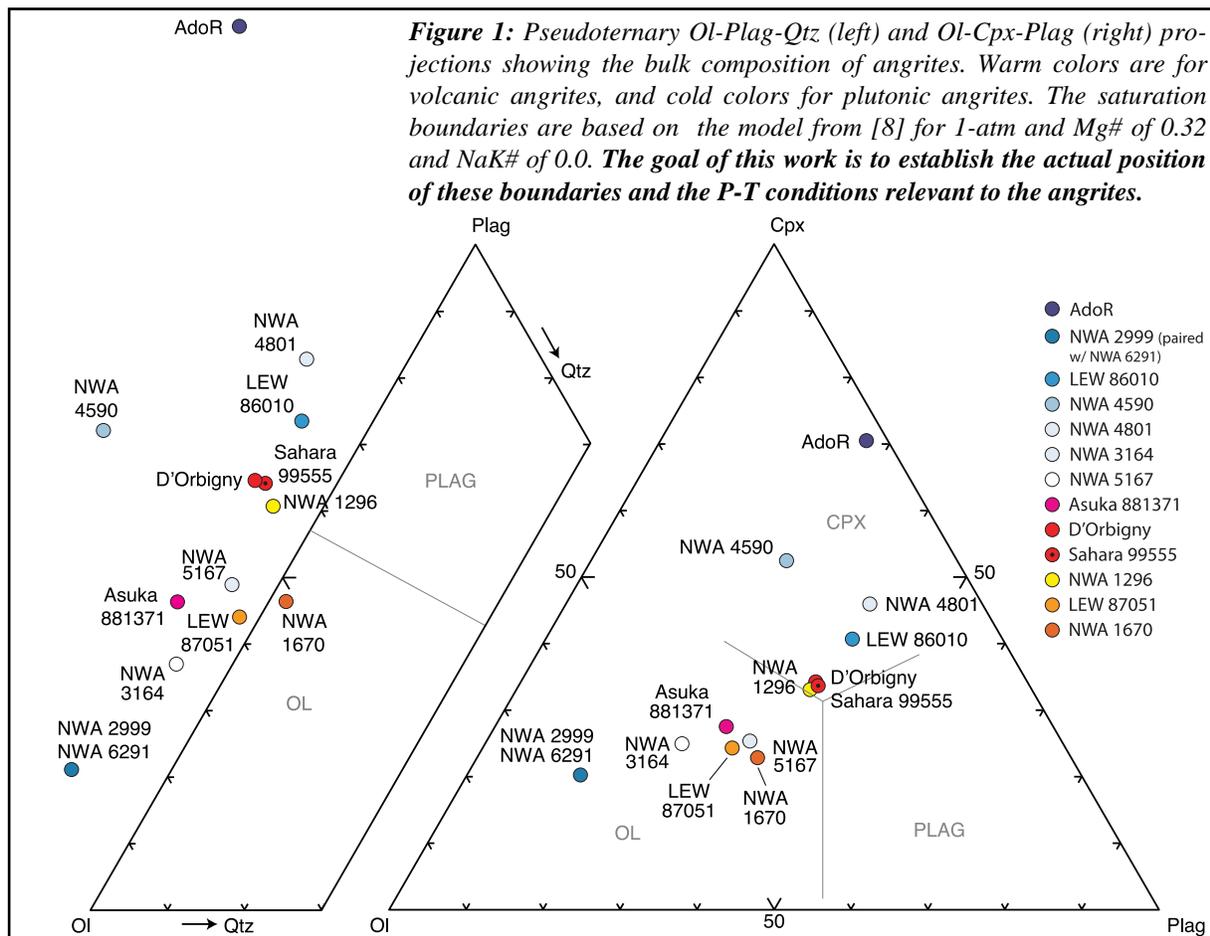
The limited number of angrite specimens available and their unusual chemical compositions have long hindered our understanding of their petrogenesis. The seminal angrite petrogenetic study of Longhi [5] had to rely on the only 4 specimens available at that time,

which included two very similar quenched angrites (Asuka 881371, Lewis Cliff 87051, hereafter LEW 87051), one plutonic angrite (Lewis Cliff 86010, hereafter LEW 86010) and the very atypical plutonic angrite Angra dos Reis (hereafter, AdoR), a 98% pyroxene cumulate.

At this writing, the angrite collection contains 16 different types of angrites and includes 5 plutonic angrites, 9 volcanic angrites, 1 dunitic angrite (Norhtwest Africa 8535, hereafter NWA 8535 [6]) and 1 angrite that might represent an intermediate stage between volcanic and plutonic angrites (Norhtwest Africa 10463, hereafter NWA 10463, [7]). This increased sample set provides us with an opportunity to refine our understanding of the angrite petrogenesis.

### Two groups of quenched angrites:

When projected in pseudoquaternary Ol-Cpx-Plag-



Qtz diagrams, two compositional groups appear amongst quenched angrites (Fig. 1). Group 1 contains angrites Asuka 881371, LEW 87051 and Norhtwest Africa 1670 (hereafter, NWA 1670), while Group 2 includes angrites D'Orbigny, Sahara 99555 and Norhtwest Africa 1296 (hereafter, NWA 1296). Group 2 plot very near the Ol-Plag-Cpx-melt 1 atm saturation boundary as predicted by [8] for a liquid with Mg # = 0.32 and NaK # = 0.0 of these angrites. Group 1, on the other hand, is in the olivine primary phase space and calculations of fractional crystallization of olivine from these liquids converges on the composition of the Group 2 [4], at the expected Ol-Plag-Cpx saturation boundary [8]. This relationship between the two quenched angrite groups has been proposed by previous studies on the basis of major and minor element trends in Ol, Cpx and Plag minerals and cooling rates experiments (*e.g.*, [9-11]).

As a first step in deciphering the conditions of magmatic processing experienced by the angrites, the goal of our study is to investigate the phase equilibrium of a natural angrite from Group 2 to determine the actual location of the saturation boundary and the P-T conditions relevant to the composition and  $fO_2$  of the angrites.

#### Previous experiments:

To date, no experimental studies have been performed on natural angrites to constrain the phase equilibria relevant to the angrite petrogenesis. Previous experimental studies have tried either (i) to produce angritic melt by partial melting of chondrites (*e.g.*, Allende and Murchison, [12-13]) or devolatilized chondrites ([14]), or (ii) to constrain the cooling rates of the quenched angrites by performing crystallization experiments [9, 15]. The only attempt at constraining the phase equilibria of angrites was done by [5], using liquid boundaries and solid solution parameterizations in the CMAS+Fe system (from [16]).

#### This work:

We have undertaken a series of 1 atm equilibrium experiments on a representative composition of the quenched Group 2 (D'Orbigny) angrites. Starting composition is an oxide mix. The mix was conditioned 3 days in a gas mixing furnace at 1050°C to react the oxides to more stable minerals. Experiments are performed in iron capsules placed in evacuated silica tubes, imposing an oxygen fugacity close to the Quartz-Fayalite-Iron buffer ( $fO_2 \sim IW-1$ , [17-18]), relevant to the angrite samples, whose  $fO_2$  is thought to be between IW and IW+1 ([19-20]). Our initial results show that on the D'Orbigny composition chosen, the experimental charge is saturated with Olivine (Fo 51),

Anorthite (An 100) and hercynite-spinel (65-35) at near liquidus conditions (1143°C). The experiment contains 13 % olivine, 16 % plagioclase, 71 % liquid and trace amount of spinel. Based on the composition of equilibrium olivine cores and the glass, we calculate equilibrium exchange coefficient between Fe and Mg,  $Kd_{Ol-Liq}^{Fe-Mg}$ , of 0.284, in agreement with the range of values for basaltic low-Ti, low alkali melts.

#### Discussion:

The D'Orbigny angrite is saturated with Ol (Fo 63), Anorthite (An 99.9-100), and Al-Ti bearing diopside-hedenbergite (fassaite). Our experimental charge at 1143°C is saturated with Ol (Fo 51) and Anorthite (An 100), but a fassaite pyroxene has not yet appeared, presumably because the pressure of our experiment is too low and that the actual crystallization pressure must be greater than 1 atm.

Experiments at lower temperatures and higher pressure are underway to determine the conditions of multiple saturation with olivine + anorthite + clinopyroxene for this angrite group. The pressure of angrite multiple saturation could provide new constraints on the minimum size of the angrite parent body. We will report the results of these new experiments at the meeting.

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