#1572

Major-Element Geochemistry of Large, Igneous-Textured Inclusions in Ordinary Chondrites

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Abstract

The petrography and major element bulk chemistry of 29 large igneous inclusions from a diverse array of host O chondrites has been examined. These data indicate that (I) none of the inclusions in this study were derived from an igneous-differentiation source; (II) the inclusions can be subdivided into three chemical groups: unfractionated, vapor fractionated, and feldspar enriched; (III) a subgroup of inclusions likely crystallized as free-floating droplets in a space environment, and these were often vapor fractionated; and (IV) some inclusions that probably derive from shock-melted material have a pronounced K enrichment

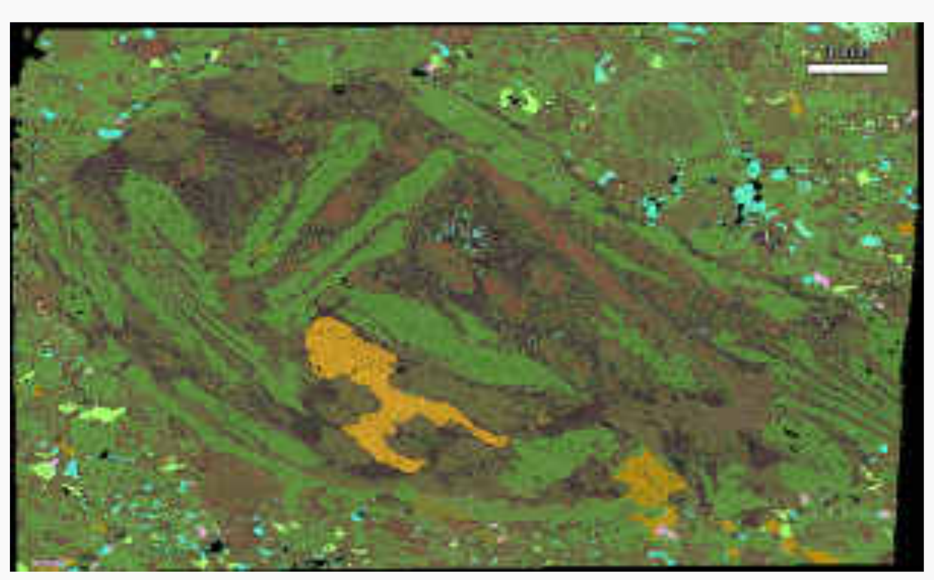
Background

Approximately 4% of O chondrites, which derive from undifferentiated parent bodies, contain large inclusions of material. These inclusions are:

· igneous in texture; they crystallized from a melt
· highly depleted in metal & sulfide relative to host meteorite
· up to an order of magnitude larger than chondrules
· highly variable in texture, mineralogy, and bulk composition
· variable in shape; can be angular, subrounded, or rounded

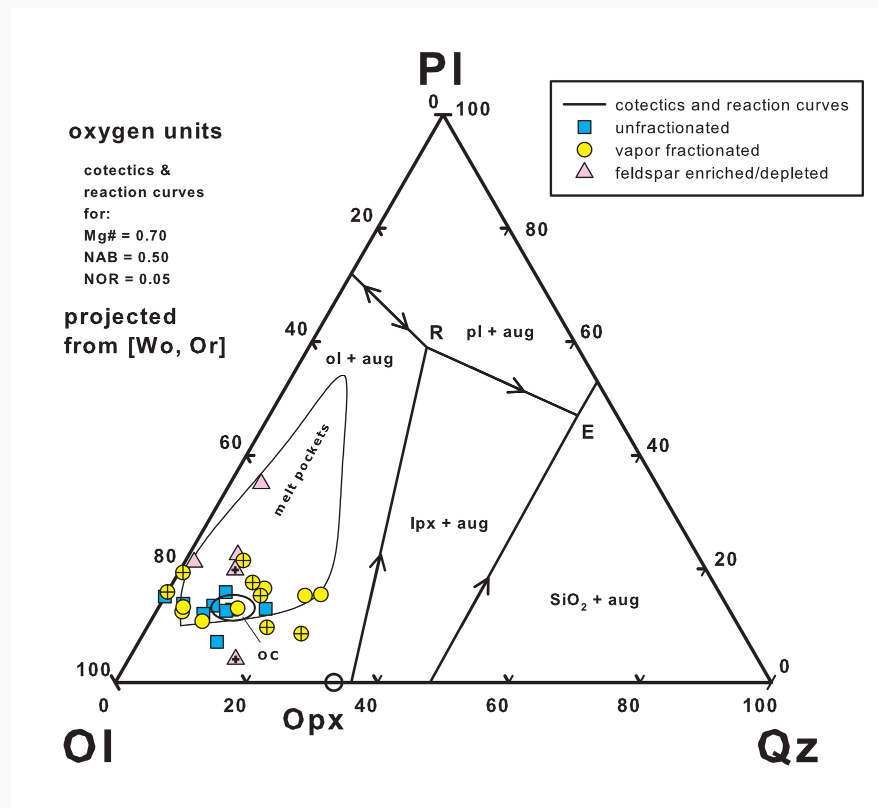
Their relationship to other early solar system material is unclear. They probably have diverse origins. Models proposed for their formation are:

· shock melting of ordinary chondrites with an associated loss of metal and sulfide
· melting of vapor-fractionated condensate mixtures
· chondrule formation involving a larger melt production volume than typical for chondrules
· igneous differentiation occurring within planetesimals sampled by



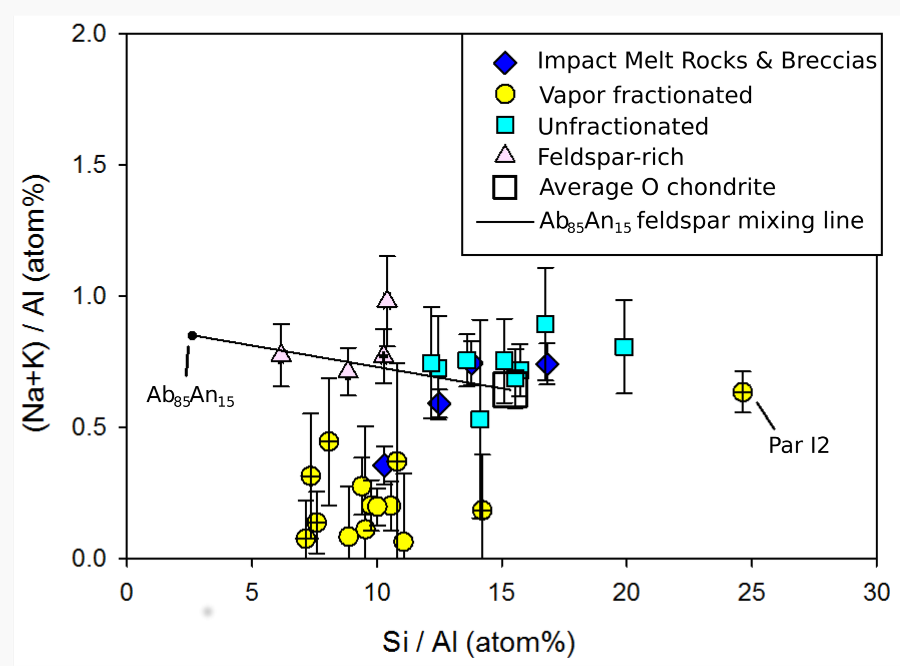
Etr-I1, an example of a large inclusion in the Etter (L6) meteorite. This inclusion is enriched in a feldspathic component (see right), and unique in containing a coarse phosphate grain. Color key same as image below.

Igneous Differentiation



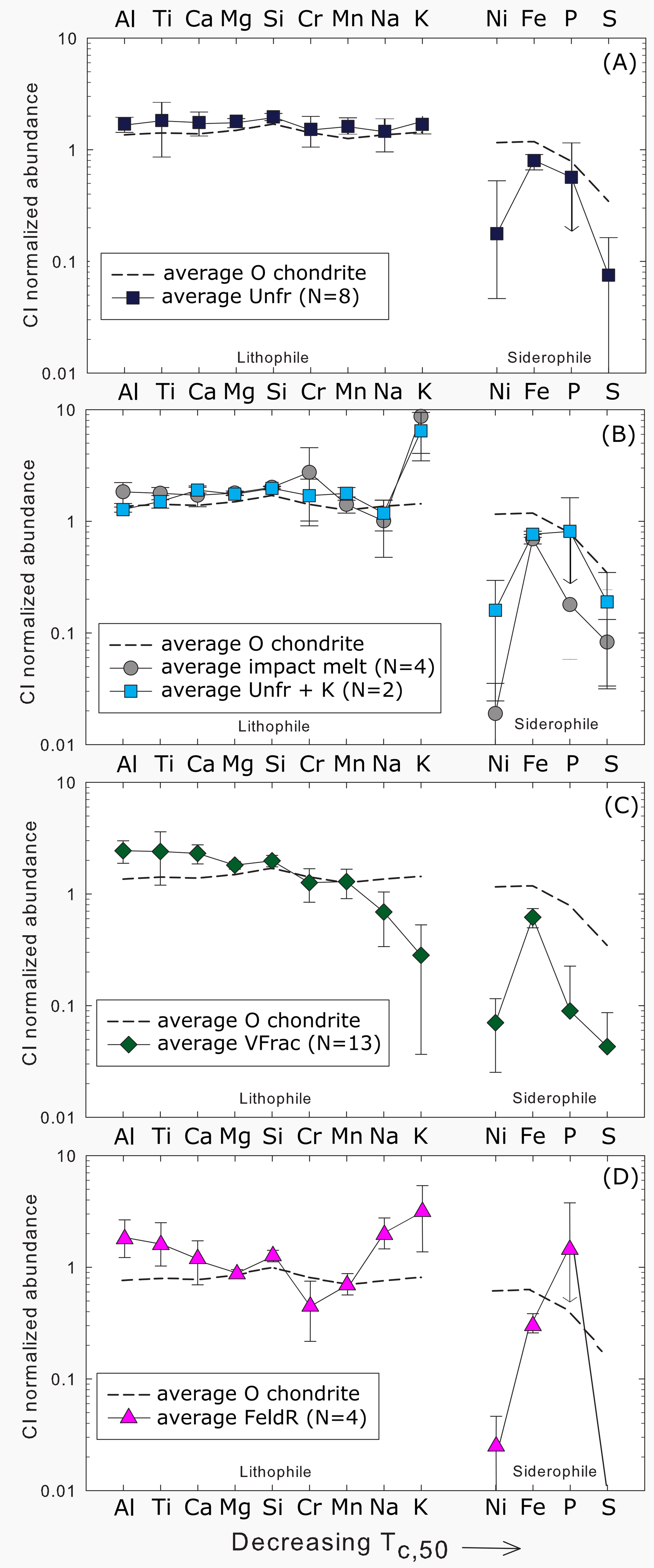
Normative olivine-quartz-plag composition for all inclusions clusters around average O chondrite composition. None of the inclusions plot on or near any cotectics or reaction curves, which would be expected for a melt that was igneously processed. It is thus unlikely that any of the inclusions in this study originated from a differentiated source. Crossed symbols are droplet-formed inclusions. Errors smaller than symbol size.

Chemical Groups

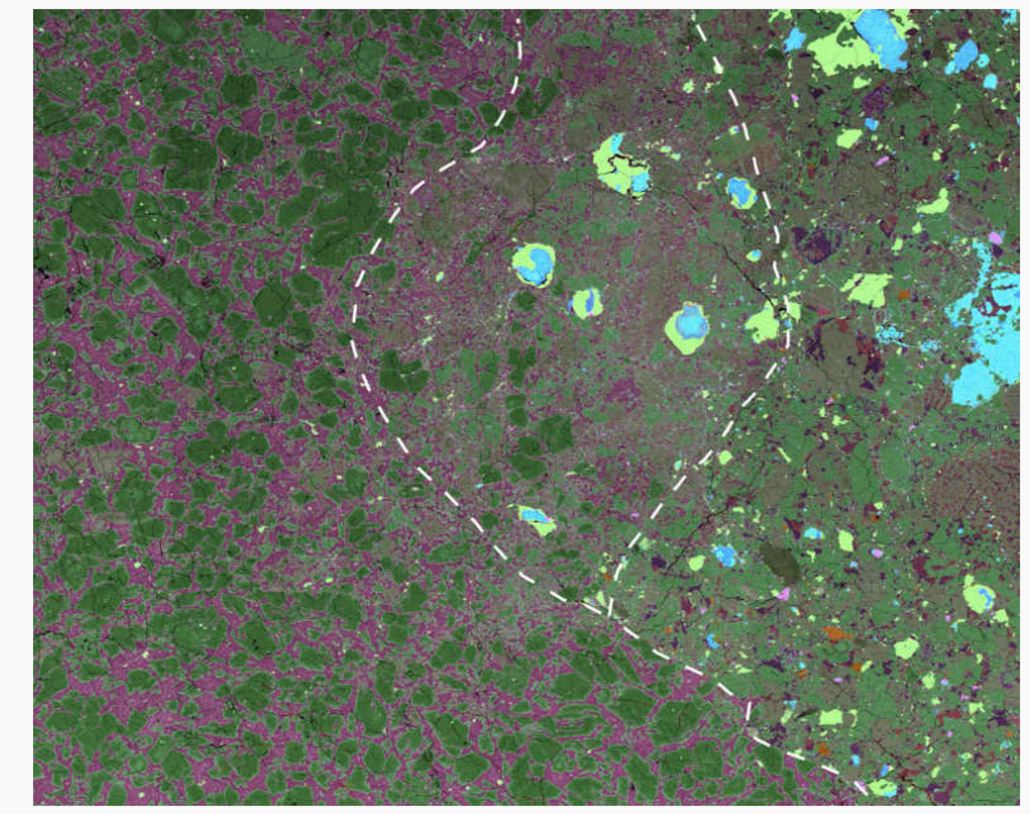


Al-normalized Na+K vs Si for all inclusions. The vapor fractionated inclusions tend to have a distinctly lower (Na+K)/Al ratio than the unfractionated inclusions, as a result of losing the more volatile Na and K. The lone exception, Par-I2, an inclusion from Parnallee, also lost Al, possibly though fractional condensation. The feldspar enriched inclusions are enriched in both the alkalis and Al. A mixing line of Ab85An15 and average O chondrite is shown; the feldspar-enriched inclusions are in good agreement with this line. Crossed symbols are droplets.

Results and Discussion

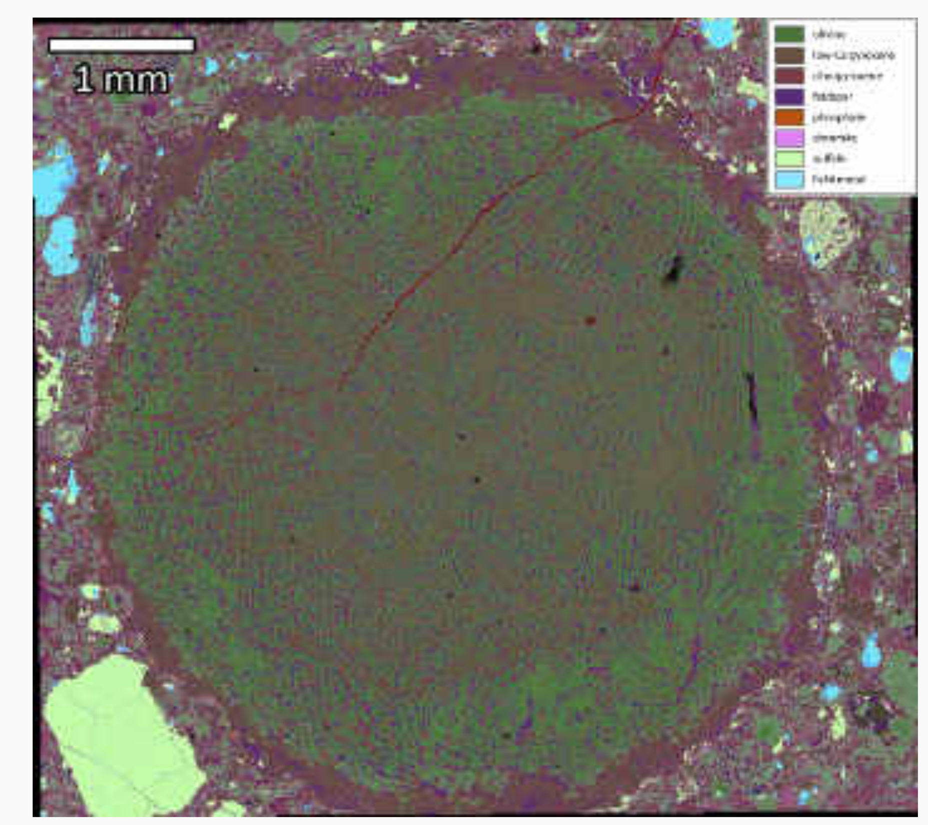


Shock Melt



Several of the inclusions in this study are probably shock melts. 869-I1, shown here, appears to have intruded into and partially melted the host. Two inclusions, including 869-I1, have essentially chondritic bulk chemistries but are enriched in K, in some cases to a striking degree (see left). Analyses of other samples known to be shock-melt have also shown an excess of K, suggesting that Kenrichment may be an indicator of shock.

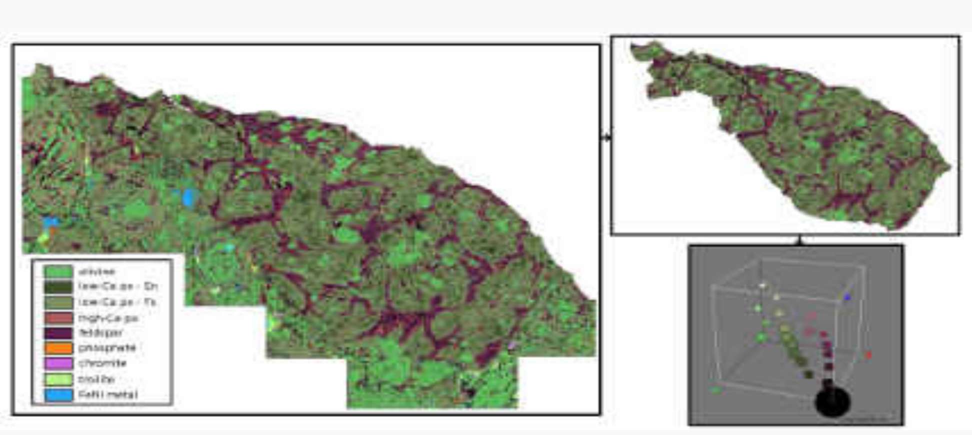
Drop-formed Inclusions



Eight inclusions are round in shape, have textures commonly seen in chondrules, concentric textures, radial variations in texture and/or chemistry, have distinct rims, and appear to have interacted with their surroundings. They probably, like chondrules, crystallized as free-floating droplets in space. Interestingly, all of these inclusions may have been affected by a volatility fractionation process (left).

Methods and Samples

Polished thin sections of 29 inclusions have been examined with optical light microscopy (OLM) and scanning electron microscopy (SEM). False-color phase maps were collected to determine modal abundance (via pixel counting, see below), and phase compositions were determined with a silicon-drift energy dispersive X-ray (EDX) detector integrated with an Oxford Instruments AZtec X-ray analytical system. Bulk chemistry was then calculated via modal reconstruction.



Meteorite	Inclusion	Host type	eq.?	bulk trend	independent?
NWA 8231	8231-I1	H4-6	yes	unfrac	no
Tamdakht	Tdk-I1	H5	no	feldspar depleted	yes, droplet
	Tdk-I2	H5	no	vapor frac	no
NWA 7873	7873-I1	H5-6	no	unfrac	no
Gunlock	Glk-I1	L3.6	no	unfrac	no
Khohar	Khr-I1	L3.6	no	vapor frac	no
NWA 7869	7869-I1	L3.7	no	vapor frac	yes, droplet
	7869-I2	L3.7	no	vapor frac	no
NWA 7872	7872-I1	L3.7	no	vapor frac	yes, droplet
NWA 869	869-I1	L3-6	no	unfrac	no
NWA 8141	8141-I1	L3-6	yes	unfrac	yes
Cynthiana	Cyn-I1	L4	no	vapor frac	no
Kramer Creek	KrC-I1	L4	no	vapor frac	yes, droplet
McKinney	McK-I1	L4	no	vapor frac	no
	Mck-I2	L4	no	vapor frac	no
NWA 7870	7870-I1	L4	yes	feldspar enriched	yes, droplet
NWA 7871	7871-I1	L6	yes	unfrac	no
Etter	Etter	L6	yes	feldspar enriched	no
Palo Verde Mine	PVM-I1	L6	yes	unfrac	no
Ragland	Rgl-I1	LL3.4	no	feldspar enriched	no
Parnallee	Par-I1	LL3.6	no	vapor frac	yes
	Par-I2	LL3.6	no	vapor frac	yes, droplet
	Par-I3	LL3.6	yes	unfrac	yes, droplet
Lut 005	Lut-I1	LL3.7	no	vapor frac	yes, droplet
Richf eld	Rfd-I1	LL3.7	no	vapor frac	yes, droplet
NWA 4859	4859-I4	LL5	yes	feldspar enriched	yes
	4859-I18	LL5	yes	unfrac	yes
NWA 8232	8232-I1	LL5	yes	unfrac	yes
Oberlin	Obl-I1	LL5	yes	unfrac	no

Future Work

The work presented here is a subset of a larger project that aims to better understand the origins of these inclusions. Additional samples will be examined with the techniques described here and added to the survey. Trace element composition will be determined for all samples with SIMS, certain samples will be analyzed for O isotopes, and some samples will be dated with either I-Xe or Hf-W methods.

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