

MELT INCLUSIONS IN PAT91501: EVIDENCE FOR CRYSTALLIZATION FROM AN L CHONDRITE IMPACT MELT. R. P. Harvey, Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996-1410, E. Roedder, Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138.

The recently recovered Antarctic specimen PAT91501 (PAT) was originally classified as an L7 chondrite, based on mineral and oxygen isotope compositions and a macroscopic resemblance to the Shaw L7 chondrite [1]. Unlike Shaw, however, PAT is decidedly igneous in texture, exhibiting both cumulate and poikilitic areas. In cumulate areas an equigranular contact-framework of nearly euhedral olivine grains surrounds interstitial spaces filled by plagioclase, pyroxenes, chrome spinel and several minor phases, while in poikilitic areas large orthopyroxene oikocrysts (rimmed with augite) surround olivine chadacrysts [2,3]. These textures strongly suggest that PAT crystallized from a melt. Further evidence suggests that this melt was of ordinary chondrite composition, and was probably impact-derived. PAT contains large (>1 cm) globular metal/sulfide inclusions, indicating that metal and sulfide liquids have segregated from an immiscible silicate liquid, as is seen in experimental melts of ordinary chondrite starting materials [4, 5]. The modal abundances of major minerals in PAT are similar to those expected during rapid, fractional crystallization from a melt of L-chondrite starting composition [6]. The compositions of spinel grains in PAT are distinct from those found in ordinary chondrites, but are identical to those that would crystallize from an L-chondrite melt [6].

Even given the evidence in favor of an origin for PAT as a crystallized product of an ordinary chondrite impact melt, the cumulate nature in PAT makes it difficult to directly assess the composition of the melt from which it crystallized. Luckily, olivine grains in PAT contain numerous inclusions that can be used to reconstruct the conditions present at the time of crystallization. Preliminary studies on the abundant inclusions in a large olivine grain from PAT (Fig. 1) show that two types are present; inclusions containing only vapor (primary vapor inclusions), and glassy inclusions containing the following major solid phases in varying proportions: high alkali glass; moderate alkali glass of high Si-Al composition; Fe-Ni metal; and Fe sulfide. Glass inclusions also contain small unanalysed solid daughter phases and a vapor bubble comprising 2-10 vol.%. These bubbles result from the combination of two processes on cooling: thermal contraction of the enclosed melt, and volume decrease on crystallization of olivine onto the inclusion walls, and hence are quite different in origin than the primary vapor inclusions. The latter require the existence of a vapor phase at the time of crystallization of the host olivine with a vapor pressure exceeding the sum of pressure from surface tension and depth of burial. The mm- to cm-sized vesicles in PAT were formed by larger volumes of the same vapor phase.

The microscope crushing stage [7] provides an estimate of the gas pressure now present in vapor bubbles within crystals. The vapor bubbles within the glass inclusions now contain a vacuum. We suggest that the vapor phase present at the time of formation, for both the primary vapor inclusions and the bubbles within glass inclusions, consisted of alkali vapors which then condensed to yield a vacuum. We cannot exclude the possibility that other condensable gases such as H₂O were present, or, as an unlikely alternative, a gas such as methane that is highly soluble in the immersion oil used on the crushing stage.

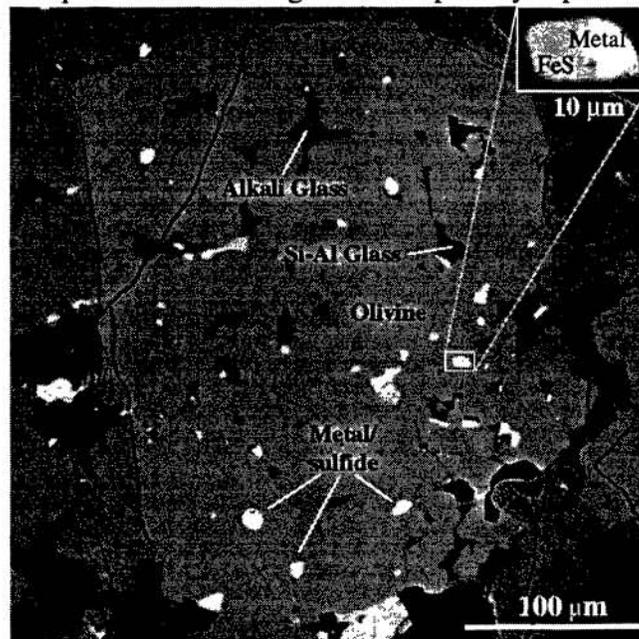


Figure 1. Backscattered electron photomicrograph of a PAT91501 olivine grain with abundant inclusions.

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We assume that some mixture of olivine (which plated out on the walls of the inclusion) and the four major inclusion phases (alkali-rich glass, Si-rich glass, metal and sulfide) will represent a parental magma for PAT. The minor phases, which combined account for <1% of the surface area of the grain studied, were not used in the model. Mass-balance calculations, following the methods of [8, 9], were used to calculate the parental magma composition. A system of mass-balance equations was constructed, including both exact and inexact constraints such as partition coefficients of major elements between olivine and coexisting liquid. These equations were weighted to give a high relative importance to the mass balance of the system and a low relative importance to the starting conditions (the modal abundances of the inclusion phases and the amount of admixed olivine).

Inclusion phase compositions and the results of the mass balance calculations are shown in Table 1. In general, the calculated parental magma compositions are very similar in bulk composition to an L chondrite, with a few distinctions. The PAT parental melt is slightly richer in FeO, SiO₂, Al₂O₃ and the alkalis (combined Na₂O and K₂O) than the bulk L chondrite composition, as might be expected for a magma generated by a high degree of partial melting. In addition, the PAT parental melt appears deficient in CaO, suggesting either that the minor inclusion phase apatite may have been under-represented in the model, or that crystallization of some Ca-rich phase preceded trapping. The phase relationships between the two presumably coexisting, compositionally distinct Si-rich melts (as well as the pre-existing Si-poor chondritic melt) are unknown at this time.

The melt trapped during crystallization of the PAT olivine grain studied here supports the other evidence which suggests that this meteorite, and some related meteorite lithologies, are derived from a high degree of partial melting or total melting of ordinary chondrite material, presumably by impact processes [6]. The existence of lithologies like PAT suggest that phase segregation and differentiation may be relatively widespread at the surface of larger meteorite parent bodies, and can be invoked to explain the observed enhanced presence of olivine suggested by some asteroid reflectance spectra [6, 10].

Table 1. Composition of PAT91501 inclusion phases and calculated parental melt. Average L chondrite composition from [8].

Vol. % Incl.	Major inclusion phases				Metal	Calculated PAT91501 melt	Avg. L chondrite from [11]
	Host olivine	Alk.-rich glass	Si-rich glass	FeS			
	63.2%	14.6%	8.9%	7.1%	6.2%	--	--
SiO ₂	37.86	64.79	75.54	0.00	0.00	40.06	39.72
Al ₂ O ₃	0.01	21.48	18.50	0.00	0.00	4.78	2.25
MgO	37.88	0.05	0.04	0.00	0.00	23.95	24.73
CaO	0.04	2.45	0.18	0.00	0.00	0.54	1.85
FeO	23.69	0.72	0.76	0.00	0.00	15.14	14.46
Na ₂ O	0.02	9.76	3.47	0.00	0.00	1.90*	1.06*
K ₂ O	0.00	0.63	0.74	0.00	0.00		
Fe	0.00	0.00	0.00	62.91	88.38	5.54	7.03
Ni	0.00	0.00	0.00	0.03	10.14	0.64	1.24
S	0.00	0.00	0.00	36.94	1.43	7.13	5.76
Total	99.50	99.88	99.23	99.88	99.95	99.68	98.10
Comp.	Fa _{26.3}	Or ₄ Ab ₈₅				*Combined Na ₂ O, K ₂ O	

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