METAL AND SULPHIDE PHASES IN INTERSTITIAL VEINS IN 'DIMICT' UREILITES – INSIGHTS INTO THE HISTORY AND PETROGENESIS OF THE UREILITE PARENT BODY.

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Introduction: Ureilites are ultramafic carbon-bearing meteorites whose petrogenetic history remains controversial. On the basis of their mineralogical and petrographic characteristics, they appear to be residues from partial melting/smelting on the ureilite parent body (UPB) or more rarely an interaction of such residues with melt [e.g. 1-3]. Most ureilites have a 'typical monomict' mineralogy and petrography: coarse-grained ol ± pyx (pig ± opx ± aug) with interstitial carbon-rich material. Approximately 10-15% of ureilites are polymict breccias composed of lithic and mineral clasts thought to have formed through impact gardening, after the UPB had been completely disrupted by a major impact [4-7]. They contain a wide variety of clasts of typical ureilite material, as well as rare material derived from chondritic meteorites, ureilitic melt clasts and mineral clasts derived from previously unknown meteorite types [7]. A rare sub-class of polymict ureilites contain clasts of two typical, monomict lithologies with different mineral assemblages and compositions. Three paired samples from Frontier Mountain, Antarctica (FRO 90168, 90228 and 93008) display this 'dimict' texture [7-9].

Dimict ureilites contain veins that intrude along the boundaries of the different lithologies and also intrude into the adjacent clasts. These veins are largely composed of rounded silicate minerals derived from the adjacent lithologies in a matrix of highly magnesian olivine and low-Ca pyroxene. They also contain exotic mineral clasts, including albitic feldspars and ferroan olivines [7,8]. Significantly we observe that the veins are much richer in metal and sulphide phases compared with adjacent lithologies and also contain significant amounts of carbon (Figs. 1 and 2). The nature of the veins in dimict ureilites has been little studied and thus their origin remains poorly understood; however, they clearly provide important evidence about the origin of dimict ureilites and the presence of impact-derived melts within the UPB. A better understanding of the history of the dimict ureilites and how they differ from the more common polymict ureilites will offer significant insight into the complex history of the UPB. We have therefore carried out a preliminary investigation into the nature of the vein material in FRO 90168, 90228 and 93008, concentrating on the unusual metal and sulphide phases therein.

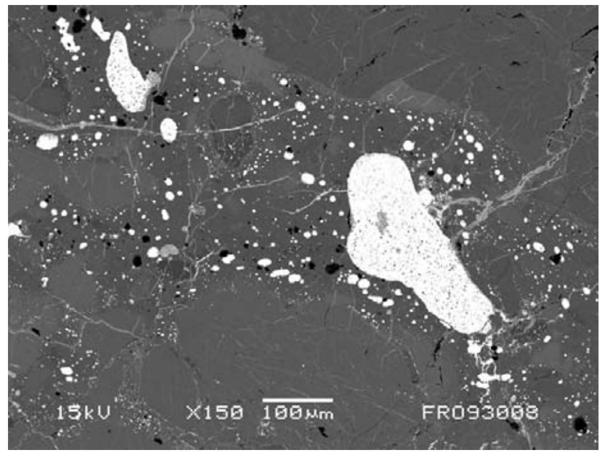

Fig. 1. Vein material in FRO 93008 composed of rounded blebs of Fe-FeS-FeO, C-rich phases and rounded 'ghost' silicates.

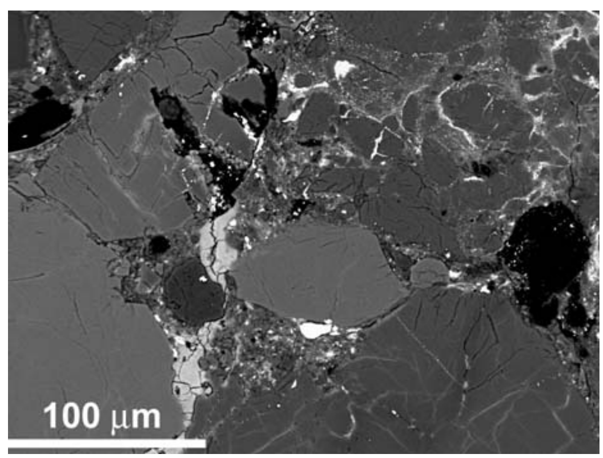

Fig. 2. Vein material in FRO 90228 composed of angular and rounded silicates, C-rich phases and metallic and FeS phases. Bright grain, lower centre, is possible hapkeite.

Methods and Results: The mineralogy and petrography of vein material were surveyed using analytical SEMs at the Natural History Museum and EPMA at NASA Johnson Space Center. The sections investigated (FRO 90168, 90228 and two sections of FRO 93008) all contain vein material, although it is most abundant in FRO 90168 and 93008.

Metal and sulphide grains: Perhaps most importantly a single grain of a mineral very similar in composition to hapkeite (Fe_2Si) [11] was found in FRO 90228 (Figs. 2,3; Table 1). If the FRO 90228 grain is indeed hapkeite, it is only the second known occurrence of this mineral and the **first** from an asteroidal meteorite. A grain of possible hapkeite has also been found in polymict ureilite EET 87720 (H. Downes, unpub. data).

	Hapkeite (Dhofar 280)		'Hapkeite' (FRO 90228)	
	wt% el.	at% el.	wt% el.	at% el.
Fe	75.3	63.4	75.98	64.55
Si	18.4	30.3	18.09	30.56
Co	0.12	0.009	bd	bd
Ni	3.14	2.51	4.49	3.63
P	1.85	2.82	0.30	0.46
Cr	0.37	0.33	0.87	0.79
Total	99.2	100	99.7	100

Table 1. Weight % and atomic % element data for FRO 90228 'hapkeite' (this study) and Dhofar 280 hapkeite [11].

Suessite $(Fe,Ni)_3Si$ was found in vein material in FRO 90168 and 93008. Suessite is common in polymict ureilites [10,12,13] but has not previously been reported from dimict samples. Troilite is abundant in all vein material, and Cr-rich troilite (~ 6-11 wt% Cr) is also observed in FRO 90168. Kamacite is also present in vein material in all samples and a single grain of taenite (~17 wt% Ni) also occurs in FRO 90228. In both FRO 90168 and 93008 we found grains of 'kamacite' with high Si contents (4.2-5.4 wt % Si) (Fig. 3). Finally, we observed several grains of an iron phosphide mineral (~ 82 wt% Fe, 15 wt% P, 3 wt% Ni), which appears to be schreibersite.

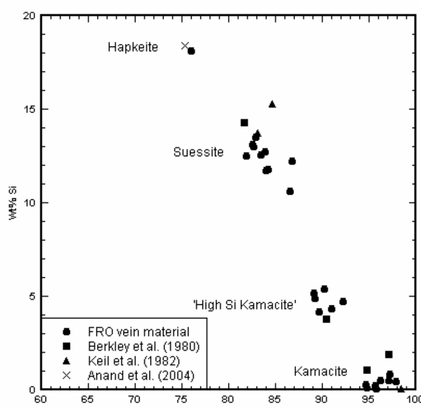

Fig. 3. Fe (Wt%) vs Si (Wt%) for FRO ureilite vein material and literature data.

'Blebs and globules': We have observed abundant rounded metal-sulphide globules with very fine-grained symplectitic 'quench' textures (Fig. 4), especially prevalent in FRO 93008. The globules are composed mainly of Fe metal, Fe oxide and Fe sulphide; 'dark' globules are richer in Fe oxide and sulphide and 'light' globules are richer in Fe metal and slightly depleted in sulphide. Both contain carbon phases and are slightly enriched in phosphorus.

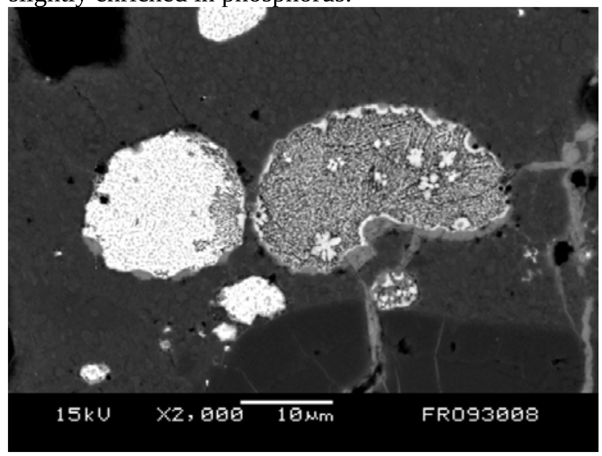

Fig. 4. Two globules in FRO 93008 vein material, 'dark globule' on right, 'light globule' on left, embedded in a high-Mg silicate matrix.

Conclusions: The veins in FRO dimict ureilites appear to have formed from an impact melt that invaded between the ureilitic clasts. The melt was derived from the UPB (deduced from the presence of abundant carbon) under very low oxygen fugacity conditions (inferred from the presence of Fe-silicides and phosphides). Metal/sulphide-silicate immiscibility occurred during cooling of the vein, forming the globules. The high-Si kamacite may have formed in a very high pressure environment. The metal and sulphide phases observed in the FRO vein material are similar to those reported for clasts in polymict ureilites by Herrin et al. [10]. Such material may have been formed by gardening of impact veins such as those studied here.

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