PATOS DE MINAS: A COMPOSITIONAL STUDY OF SULFIDES, SCHREIBERSITE AND COHENITE.

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Introduction: Patos de Minas (from hereon Patos) is a normal hexahedrite with 5.36 wt% Ni hosting round nodules of troilite with daubreelite exsolution lamellae [1-2]. The polished sections of Patos (from the MHN, Rio de Janeiro, Brazil) contain sulfide globules that consist of two phases: Cr-bearing troilite and daubreelite each occupying half of it with bars of troilite in daubreelite. These sulfide globules have ~ 5 mm in diameter with round small troilite/daubreelite globules (300 – 500 µm) attached to them (Fig 1a). Some globules are thinly rimmed (totally or partially) by schreibersite and cohenite. In one globule we found the first silicate phase observed in this meteorite [3]. It consists of a perfectly round silicate inclusion (400 µm in diameter) within an almost perfectly round sulfide inclusion. The REE pattern, with the HREEs depleted with respect to the LREEs showing a weak Tm+ and a strong Eu+ anomaly, is reminiscent of the group II CAI REE abundance pattern. The very high Nb content indicates that the precursor of the silicate could have been a sulfide [3]. In addition to sulfide globules, a subhedral chromite crystal with eight cavities filled with kamacite or sulfides or a combination of both phases was also observed. The chromite is partly enveloped by troilite and daubreelite. The latter is rimmed by schreibersite (Fig. 1b). Major, minor and trace element analyses were made on the various phases in order to understand metal partitioning and origin of the meteorite.

Results and Discussion: The chemical compositions of the different phases present in Patos and measured by EMPA are given in Table 1. No significant chemical variation was detected between those sulfides forming globules and those filling the cavities in or rim of the chromite inclusion. An exception is a slight increment in the chromium content in the daubreelite that fills the cavities in chromite (Fig. 1b).

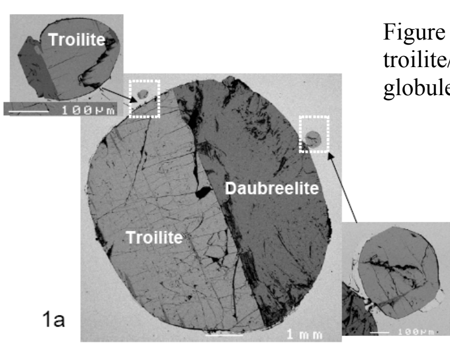


Figure 1a: troilite/daubreelite globules from Patos.

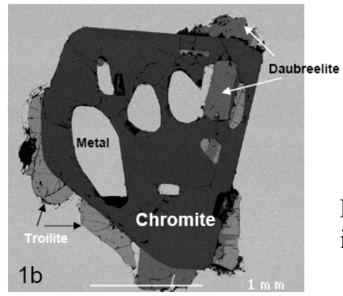


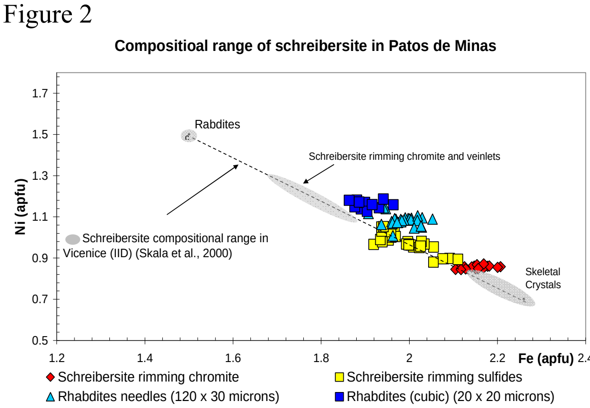
Figure 1b, chromite inclusion in Patos.

		Sulfide Globule				Chromite Inclusion	
	Metal	Daubreelite	Troilite	Schreibersit	Cohenite	Troilite	Daubreelite
N	25	20	15	25	15	8	8
Fe	91.8	18.6	58.3	53.4	89.9	61.5	19.7
Co	0.59	0.04	0.15	0.19	0.23		
Ni	5.19	0.07	0.03	30.7	1.54		
Cr		30.7	0.80			0.83	34.4
Mn		0.56					0.12
Si							
P	0.11			15.0			
S		48.3	39.7	0.05		36.4	45.3
Total	97.7	98.3	99.0	99.3	91.7	98.7	99.4

Table 1: Chemical composition of major and minor elements in sulfides, schreibersite and cohenite from Patos (wt%).

Schreibersite occurs as thin rims coating troilite, daubreelite and chromite. Some globules are rimmed by cohenite. Euhedral crystals of schreibersite (rhabdites) are present forming elongate needles (~120 x 30 µm) or squares (~20 x 20 µm). The plot in Figure 2 correlates the chemical composition of various morphological schreibersite types (the chemical variations in the Vicenice (IID) octahedrite [4] are shown for comparison). Larger grains are characterized by the lowest nickel content.

Figure 2



LA-ICP-MS analyses were performed with a Thermo-Scientific Element-XR ICPMS and a 193 nm GeoLas ArF excimer laser at the Memorial University of Newfoundland using the iron meteorites Hoba (IVB, ataxite) as a calibration standard and Filomena (IIA, hexahedrite) as a secondary reference material. Some of the analysed phases have trace element contents that are below the detection limit, which are as follow (in ppm), Os: 0.003; Ru: 0.026; Pt: 0.002; Rh: 0.008; Pd: 0.02; As: 0.03; Au: 0.002. The siderophile trace element abundances in kamacite, troilite, daubreelite, schreibersite and cohenite in a rounded sulfide globule are given in Table 2.

Table 2

	Kamacite	Daubreelite	Troilite	Schreibersite	Cohenite
N	*6*	*5*	*5*	*4*	*6*
Re	**4.91**	**0.006**	**0.015**	**0.212**	**2.252**
Os	**66.1**	**0.022**	**0.025**	**0.862**	**2.103**
W	**3.75**	**0.102**	**0.108**	**0.911**	**3.816**
Ir	**47.9**	**0.080**	**0.123**	**0.300**	**0.332**
Mo	**5.86**	**2.502**	**2.251**	**11.3**	**24.0**
Pt	**36.3**	**0.071**	**0.115**	**0.053**	**0.057**
Ni	**53.6**	**0.14**	**0.570**	**142.2**	**13.9**
Co	**4.55**	**27.1**	**40.6**	**788.9**	**714.1**
As	**2.93**	**0.100**	**0.081**	**0.365**	**0.973**
Au	**0.77**	**0.057**	**0.166**	**0.038**	**0.050**
Ga	**73.4**	**33.4**	**0.722**	**29.3**	**1.500**

There is no significant variation in the abundance of the siderophile trace element as shown by the analyses performed on both sides of the sulfide globule. Exceptions are: Mo and Ga (Fig. 3). The content of Mo in kamacite gradually decreases (symmetrically on both sides) towards the globule. Both phases forming the edge (schreibersite and cohenite) have high Mo contents (Table 2).

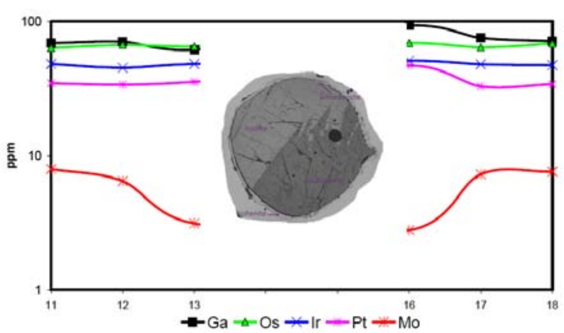


Figure 3, Analyses in kamacite performed on both sides of the sulfide globule.

However, the Ga content in kamacite gradually increases in those analyses performed close to daubreelite. Although the abundances of the siderophile trace elements in troilite and daubreelite are similar, they differ in their Ga contents (Table 2, Fig. 4).

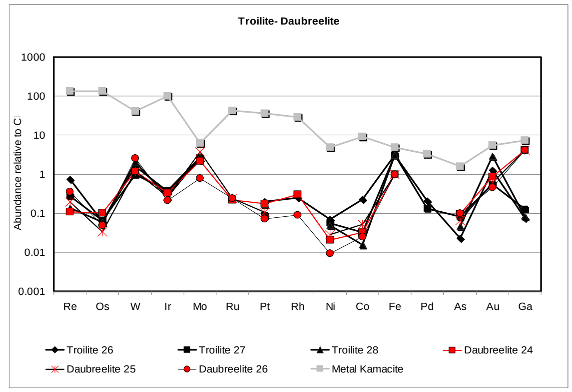


Figure 4, Normalized abundances of siderophile elements in troilite, daubreelite and kamacite.

Variations in the Ga contents are also observed in the schreibersites. The schreibersites that coat daubreelite have the highest Ga contents (~ 56 ppm) while those rimming troilite or included in cohenite have Ga abundances similar to those measured in troilite (~ 3 ppm) (Fig. 5).

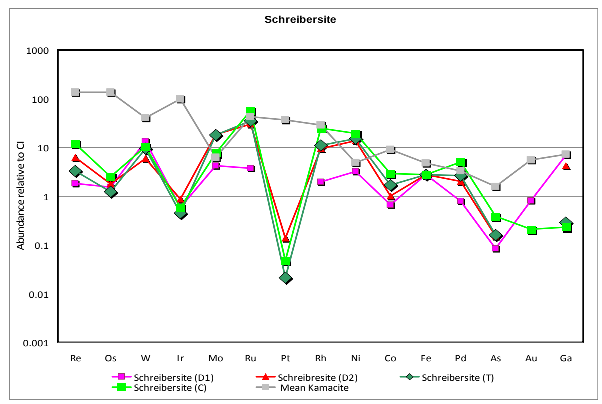


Figure 5, Normalized abundances of siderophile elements in schreibersite.

Our results allow us to propose mineral partition coefficients (Kd) for Ga in Patos (and possibly for other IIAB irons), as follows: for daubreelite/schreibersite: Kd daub/schr: 0.6-0.97; for troilite/schreibersite: Kd troil/schr: 0.25.

References: [1] Buchwald V.F. 1975. Handbook of Iron Meteorites, Univ. of California, p.965; [2] Kracher et al., (1980) GCA, **44**, 773-787; [3] Varela M.E. et al. 2009. MAPS #5092; [4] Skála, R. et al (2000) *J. Czech Geol. Soc.* **45**, 175-192 ; [5] Wasson J. et al. 2007. GCA **71**, 760-781.