CR-BEARING MINERALS IN THE GIBEON IVA IRON: INDICATORS OF SULFUR AND OXYGEN FUGACITIES IN THE PARENT BODY Michail I. Petaev, Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138

In the course of the study of vugs and brassy masses [1,2] in the Gibeon Slice V (for description see [1]) I have observed exsolution lamellae of eskolaite (essentially pure Cr_2O_3) in the euhedral chromite grain and daubréelite ($FeCr_2S_4$) lamellae in small brezinaite (Cr_3S_4) inclusions dispersed in the Widmanstätten pattern. This is the first report on eskolaite in meteorites, which has been previously described in some terrestrial occurrences [3,4]. Brezinaite has been previously described and analyzed in the Tucson ataxite [5]. Buchwald [6] suggested the presence of the brezinaite intergrown with daubréelite in many IVA irons, but he did not perform any microprobe analyses. Here I confirm his observations and report microprobe analyses of coexisting brezinaite and daubréelite in the Gibeon meteorite.

The eskolaite forms thin (1-9 µm) lamellae in one corner of the euhedral chromite grain (Fig. 1). In reflected light the eskolaite looks slightly lighter than the host chromite and it shows no anisotropy in the section studied. The host chromite is completely surrounded by metal of the Widmanstätten pattern. In addition to the eskolaite lamellae it also contains small inclusions of tridymite and metal [7]. A small daubréelite bleb occurs at the interface between the chromite and the metal (Fig. 1). The compositions of the escolaite and chromite (Table 1) measured with the 1-µm microprobe beam (15 kV, 20 nA) show only minor variations. Relatively high FeO contents in some eskolaite analyses may be due to contamination with the host chromite. The daubréelite is close to the ideal formula.

Table 1. Compositions of eskolaite and chromite (wt.%)

Mineral	TiO_2	Cr_2O_3	FeO	MgO	Total
Chr	0	72.05	31.58	0.01	103.64
Chr	0	71.76	31.54	0.01	103.31
Chr	0	71.46	31.51	0	102.98
Esk	0	99.38	0.77	0	100.17
Esk	0	101.2	0.36	0	101.59
Esk	0	100.6	1.37	0	101.97
Esk	0	98.62	3.7	0	102.34
Chr	0	71.39	31.5	0.01	102.9

Seven daubréelite-brezinaite inclusions ranging from 37 to 65 µm in the longest dimension were found during the microprobe study of the 2×3 cm polished section. All inclusions occur in the midst of the Widmanstätten pattern. Most of them have droplet-like, rounded shapes (Fig. 2a,b), but one inclusion looks like an euhedral crystal (Fig. 2c). Exsolution patterns of the inclusions vary from wedge-shaped daubréelite masses in the brezinaite host (Fig. 2a) through genuine lamellae (Fig. 2c) to almost complete separation of these phases within the inclusion (Fig. 2b).

Microprobe analyses (1-µm probe; 20 kV, 20 nA) of the coexisting brezinaite and daubréelite are listed in Table 2. The brezinaite analysis (#3-1) with lowest Fe content corresponds to the formula $Fe_{0.087}Cr_{2.910}S_{4.002}$. All daubréelite analyses show substantial Cr excess, with the best analysis (#1-3) corresponding to the formula $Fe_{0.964}Cr_{2.119}S_{3.914}$. However, it is unclear if this is caused by substantial amounts of brezinaite dissolved in the daubréelite, or by contamination of analyses of small daubréelite grains with the host brezinaite.

Table 2. Compositions of brezinaite and daubreelite (wt.%)

#*	Fe	Cr	S	Total
1-1	1.99	54.4	44.45	100.85
1-2	2.07	54.48	44.6	101.18
1-3	18.66	38.17	43.78	100.94
1-4	18.65	38.35	43.78	100.94
1-5	2.12	54.68	44.71	101.6
2-1	18.06	38.89	44.5	101.51
2-2	2.51	54.9	45.91	103.39
2-3	2.6	55.45	46.29	104.42
2-4	15.53	40.89	45.09	101.55
2-5	15.57	41.21	45.52	102.36
3-1	1.77	55.44	47.02	104.27
3-2	1.87	55.34	46.97	104.22
3-3	18.1	39.13	46.26	103.53
4-1	2.48	55.56	46.88	105.01
4-2	10.71	44.77	46.13	101.94
4-3	17.79	39.47	46.12	103.47
5-1	1.97	54.04	46.59	102.64
5-2	2.14	54.35	46.77	103.29
5-3	18.37	38.55	45.86	102.84
6-1	2.54	54.64	46.5	103.77
6-2	18.2	37.46	45.31	101.05
7-1	3.61	53.98	45.8	103.49

*First digit is the inclusion #, the second - point #

The occurrence of the brezinaite, daubreelite and metal equilibrated with one another is inconsistent with the phase diagram of the Fe-Cr-S system at 700 and 600°C [8]. However, later studies [9,10] have found a wide stablity field of $FeCr_2S_4$-Cr_3S_4 solid solutions in equilibrium with metal at 550°C and below. According to these phase diagrams, daubréelite-brezinaite inclusions initially crystallized as a single solid solution of $FeCr_2S_4$ in Cr_3S_4, which exsolved upon further cooling.

Coexistence of the chromite in direct contact with the daubréelite and metal, and the intergrowths of the daubréelite and brezinaite, strongly suggest that at some point during cooling of the IVA parent body these minerals were equilibrated with one another. This provides an opportunity to estimate sulfur and oxygen fugacities of this process. The reaction:

$$FeCr_2O_4 + 2\ S_2 = FeCr_2S_4 + 2\ O_2 \quad (1)$$

depends upon f_{O2}, f_{S2} and temperature. If one of these parameters is known or can be estimated independently, then the relationship between the temperature and another intensive parameter (f_{S2} or f_{O2}) may be expressed in a simple, conventional form. It is customary for the iron meteorites to consider f_{S2} buffered by the metal-troilite equilibrium:

$$Fe + 0.5\ S_2 = FeS \qquad (2).$$

In the case of Gibeon it is also worthwhile to take into account other buffer reactions:

$$3\ Cr + 2S_2 = Cr_3S_4 \qquad (3)$$

$$3\ Fe + 2\ Cr_3S_4 + 2\ S_2 = 3\ FeCr_2S_4 \qquad (4)$$

$$Fe + 2\ Cr + 2S_2 = FeCr_2S_4 \qquad (5).$$

The values of the intensive parameters of the reactions 1-5 were calculated based on the consistent set of thermodynamic data for relevant minerals [11]. The calculations result in the somewhat surprising conclusion that the presence of daubréelite and brezinaite in the metal requires f_{S2}'s lower than that of the metal-troilite buffer. This is consistent with lack of exsolved daubréelite-troilite nodules in the Gibeon sections studied while such nodules are typical of iron meteorites of other groups. Coexsistence of the daubréelite and chromite also indicates that the f_{O2} should not be higher than IW-2 at high temperatures and must be much lower as temperature decreases.

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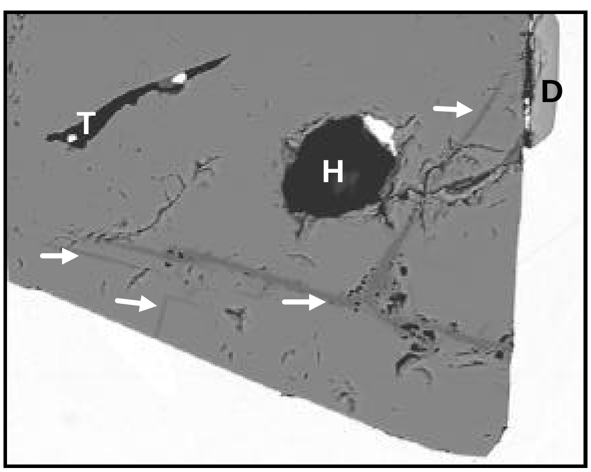

Fig. 1. Eskolaite lamellae (dark gray; arrows) within the chromite host (gray). BSE image. The daubréelite (D) is light gray. White = metal. Black = tridymite (T) and hole (H). (Width of view 285 μm.)

Fig. 2. The daubréelite-brezinaite inclusions. BSE images. White = metal; darker gray = brezinaite host; lighter gray = exsolved daubréelite; black = holes or shadow due to high contrast of images. Thin black strait lines are scratches. **a**. Daubréelite wedges in brezinaite. (Width of view 70 μm.) **b**. Almost complete separation of the daubréelite (bottom) from the brezinaite. (Width 55 μm.) **c**. Daubréelite lamellae (shown by arrows) in the brezinaite host. (Width 55 μm.)