DEPLETION OF LITHOPHILE ELEMENTS IN IRON METEORITES AND THE SEARCH FOR OXIDE PHASES.
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Introduction: Iron meteorites are among the oldest materials in the solar system. Magmatic irons stem from the cores of differentiated planetesimals. It was postulated that these bodies formed shortly after the birth of the solar nebula in close proximity to the Sun and migrated outwards later on. Collisional erosion apparently led to loss of the silicate mantles. However, concentrations of lithophile elements in metal phases should reflect the chemistry of coexisting silicate materials during metal formation (e.g., core formation).

Previous studies have shown that concentrations of lithophile element Si are extremely low in the FeNi metal phases kamacite and taenite in the various groups of iron meteorites [1, 2, 3], and independent whether magmatic or non-magmatic irons were analyzed. Concentrations of Si are typically in the range of 0.02 to 1 ppm in IAB, IIICD, IC, IIA, IIIAB irons. It was also shown earlier that such concentrations of the lithophile element Si are much lower than expected from silicate/metal partition coefficients which predict concentrations to range between 10 and 100 ppm, assuming metal-silicate equilibration at magmatic temperatures [1].

In a more recent study trace concentrations of Si, Mn and Al were analyzed in metal of magmatic IVB irons [2, 3]. IVB irons were chosen for several reasons: (a) their siderophile element abundances can be modeled by fractional crystallization indicating formation over a narrow high temperature range, (b) they have extremely low sulfur contents and (c) they experienced very fast cooling [4, 5]. Si concentrations in these irons are higher than those in other iron groups, yet still below 10 ppm. Concentrations of Al, and Mn in IVB irons are also low [3]. Metal/silicate partition coefficient (D) values indicate that P, Cr and V are compatible with metal over a broad range of fO2 (D ~ 1) while Mn and Si are more incompatible (D < 1) [6]. Compatibility of the elements decreases in the order of P, Cr, V, Mn and Si. CI normalized abundances in IVB irons (figure 1) show depletion patterns that correlate with the compatibility behavior of the respective elements. Therefore, qualitatively, lithophile element abundances are compatible with metal/silicate distribution under oxidizing conditions in IVB irons. However, considering the activity coefficient of Si in metal higher concentrations than those analyzed should be expected. Activity coefficients for other elements, Mn and Al in metal are not well known.

The lack of apparent equilibrium distribution of lithophile elements between metal and silicate in various types of irons was explained either by subsolidus equilibration with a silicate mantle or by locally exsolved lithophile element-bearing tiny phases enclosed in metal.

This observation has prompted a search for oxide phases enriched in lithophile Si and Al enclosed in metal of iron meteorites.

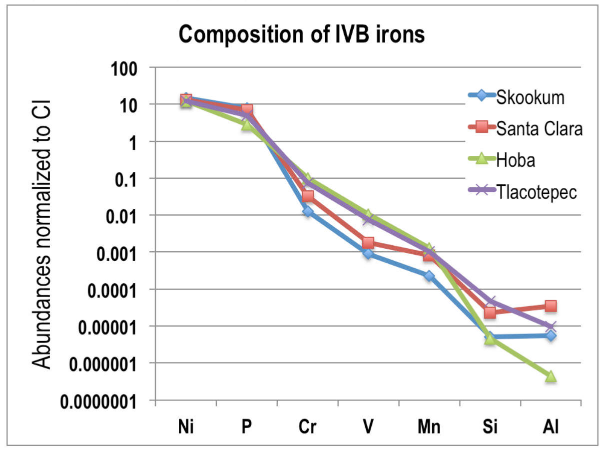

Fig. 1. Results of trace element concentrations in Fe,Ni metal of IVB irons analyzed by ims 1270 in Nancy [3]. Element concentrations are normalized to CI abundances. Qualitatively, the abundance patterns indicate metal/silicate fractionation under oxidizing conditions.

Data: Highly polished sections of IVB irons Skookum, Santa Clara, Hoba and Tlacotepec were systematically scanned by SEM in search for minute grains of Si-rich oxide grains. In addition, slices of each of the above meteorite of several centimeters in size were hand-polished with diamond powder and are currently under investigation by the SEM (e.g., Hoba in figure 2).

In addition, polished sections of IC iron Bendego, IIIAB iron Turtle River, and IVA-an Steinbach were mapped by WDS with a JEOL superprobe.

So far only in the section of Bendego Si-rich oxides were found (figure 4). All other scanned material has not yet revealed any such phases.

Furthermore signals of $^{28}Si/^{56}Fe$ were carefully monitored during measurement cycles to spot for excursions of the signal potentially indicative for Si-rich inclusions. Only in rare analyses there is evidence for potential inclusions.

Conclusions: The IC iron meteorite Bendego is so far the only iron meteorite where Si-rich inclusions were found enclosed in metal. Bendego metal has Si concentrations on a level comparable to all other irons analyzed yet. This observation is in accordance with the proposed exsolution model of lithophile elements from metal at subsolidus conditions [1]. On the other hand, given the lack of Si-spikes in signals during ims analyses in IVB irons and the absence of Si-rich inclusions in metal of other iron meteorites investigated by SEM and electron microprobe question this model unless effective diffusion could mobilize these elements over large distances. This seems possible for iron meteorites with low cooling rates but may be less likely for IVB irons with high cooling rates.

Fig. 2. One of the hand-polished slices of collection material from the Hoba meteorite. Slices were carefully studied with optical microscopy and are currently under investigation with the SEM.

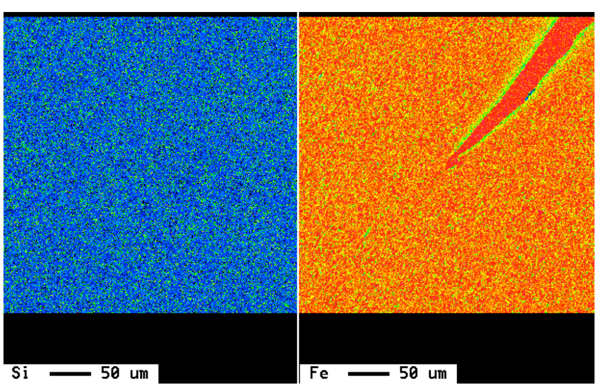

Fig. 3. EMP map of Si and Fe in a polished mount of IVB iron Hoba. Clearly visible is a relatively broad kamacite spindle in taenite. On this scale, no Si-rich inclusions were spotted.

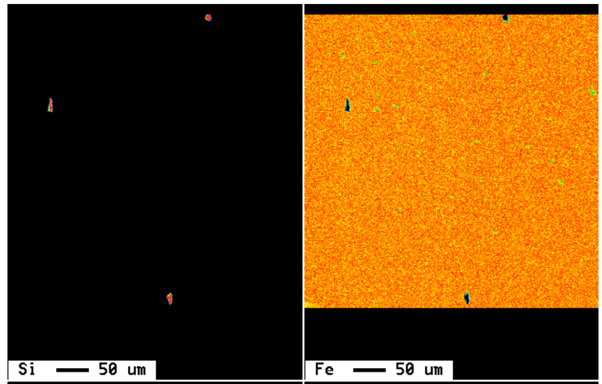

Fig.4. EMP map of Si and Fe in a polished mount of IC iron Bendego. Clearly visible are three larger Si-rich inclusions in Fe,Ni metal.

References: [1] Pack A. et al. (2011) *Meteoritics & Planet. Sci.*, 46,1470-1483. [2] Zipfel J. et al. (2011) *Meteoritics & Planet. Sci.*, 46, A262. [3] Zipfel J. et al. (2013) *Meteoritics & Planet. Sci.*, 48, A5226. [4] Campbell A. J. and Humayun M. (2005) *GCA*, 69, 4733-4744. [5] Yang J. et al. (2010) *GCA*, 74, 4493-4506. [6] Walter M. et al. (2000) *In* Origin of the Earth and moon (eds. R.M. Canup and K. Righter), pp. 265-289. *University of Arizona Press.*