THE ORIGIN OF GROUP IIF IRON METEORITES - CLUES FROM METALLOGRAPHIC COOLING RATES;
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Abstract With only five members, group IIF is one of the smallest groups of iron meteorites. Their high Ni concentrations give them an ataxitic texture which inhibits determination of their metallographic cooling rates using traditional techniques. Cooling rates based on α-bandwidths show a wide range [1] suggesting that these irons did not cool in a common core. We find that the previously determined α-bandwidth cooling rates [1] are in error due to the presence of massive schreibersite blebs in the α-spindles on which the cooling rates are based. We have therefore re-determined the metallographic cooling rates of the five group IIF iron meteorites based on α-bandwidths of α-lamellae devoid of schreibersite. We have determined metallographic cooling rates based on three sets of observations: 1) Ni profiles in the taenite rims surrounding α-lamellae, 2) Ni profiles in the outer edge of α-lamellae, and 3) bandwidths of α-lamellae. We find cooling rates of approximately 10 K/My for all five members of group IIF. Low overall Ni concentrations observed in the α-lamellae may, however, indicate a lower cooling rate at low temperatures. The metallographic cooling rates suggest that the IIF iron meteorites cooled slowly in a central core.

α-bandwidth cooling rates Previous estimates of the cooling rates of group IIF iron meteorites [1] have been based on measurements of the α-bandwidths [2]. Due to the high Ni concentrations of the IIF iron meteorites the α-spindles are widely separated and the growth of the α-phase is therefore controlled entirely by the cooling rate, and not influenced by impingement of γ-lamellae. The α-bandwidth cooling rate method may therefore be used to obtain metallographic cooling rates for these meteorites. The previously determined α-bandwidth cooling rates show a large variation from ~1K/My for the two high-Ni members Repeev Khutor and Corowa to 40-150 K/My for the low-Ni members Del Rio, Dorofeevka and Monahans [1]. The slow cooling rates inferred for the two high Ni members are based on a number of very wide α-spindles observed in these two meteorites. According to [2] and our observations these wide spindles contain massive schreibersite blebs in their cores. The growth of the α-spindles in the host γ-phase ceases when the excess Ni from the growing α-phase can no longer diffuse into the γ-phase. In the presence of schreibersite the Ni can continue to diffuse into the schreibersite which allows the α-spindles to grow further. α-spindles grown this way in the two P-rich high-Ni members can therefore not be used to calculate cooling rates without taking schreibersite into account. α-lamellae without schreibersite can, however, still be used to derive α-bandwidth cooling rates. These lamellae have most likely nucleated later than the schreibersite-bearing lamellae. Since undercooling results in more narrow lamellae, the α-bandwidth cooling rates represent upper limits on the high-temperature cooling rates. We find that the α-bandwidth method yields an upper limit on the high-temperature cooling rate of ca. 2000 K/My.

Taenite profile cooling rates The α-lamellae are surrounded by rims of taenite through which the Ni concentration decreases to the bulk value in the surrounding plessite. The width and shape of the Ni profiles across these taenite rims are measures of the cooling rate. Measurements of the widths of the γ-phase at three different Ni levels provide information of the cooling rate at three different temperatures: a) The widths of the γ-phase at 15-20 wt% Ni is narrow (~10-20μm) suggesting that the cooling rates at high temperatures were either high or that the α-lamellae experienced significant undercooling. b) The width of the taenite rim at intermediate Ni concentrations suggest a slow cooling rate ~10 K/My at intermediate temperatures. c) The narrow width of the taenite profile at high Ni concentrations (above 35 wt%) suggests that the cooling rate at low temperatures was more than ~ 1 K/My. The simplest interpretation of these data is that the cooling rate was ~ 10 K/My

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throughout the temperature range where the Widmanstätten pattern formed. This requires significant undercooling (~ 150 K) of the schreibersite-free α-phase in order to explain observation a). It is therefore likely that the α-lamellae we have studied represent a second generation [3] of α-lamellae nucleated after the first set of lamellae, which nucleated on preexisting schreibersite.

Kamacite depletion profile cooling rates The Ni concentrations in the α-phases close to the phase boundary are very low. These low Ni concentrations suggest that the cooling rate at low temperatures was very low, in conflict with observation c) above. The Ni levels in the kamacite suggest that the cooling rates were less than 1 K/My, whereas the taenite profiles suggest cooling rates of the order of 10 K/My. Since the Ni concentration profiles in the γ-phase can be determined with greater accuracy than profiles in the α-phase and the phase diagram is better determined for the γ-phase, we find it more likely that the cooling rate was of the order of 10 K/My at low temperatures and that the discrepancy between calculated and measured Ni concentrations in the α-phase is probably a consequence of uncertainties in our measured Ni concentrations and/or the phase diagram [4].

Conclusions The five group IIF iron meteorites experienced identical thermal histories during Widmanstätten pattern formation. The variation in α-bandwidth is not due to a variation in cooling rate through the group as previously suggested but rather to the presence of schreibersite in the cores of the more P-rich high Ni members. The identical thermal histories are consistent with a cooling in a common central core. The calculated cooling rates of 10 K/My are consistent with a parent body radius of 50-100 km [5].

References [1] Kracher et al. (1980) *GCA* **44**, 773-787. [2] Buchwald (1975) Handbook of iron meteorites, University of California Press. [3] Rasmussen (1981) *Icarus* **45**, 564-576. [4] Romig and Goldstein (1980) *Metall. Trans.* **11A**, 1151-1159. [5] Haack et al., (1990) *JGR* **95**, 5111-5124.

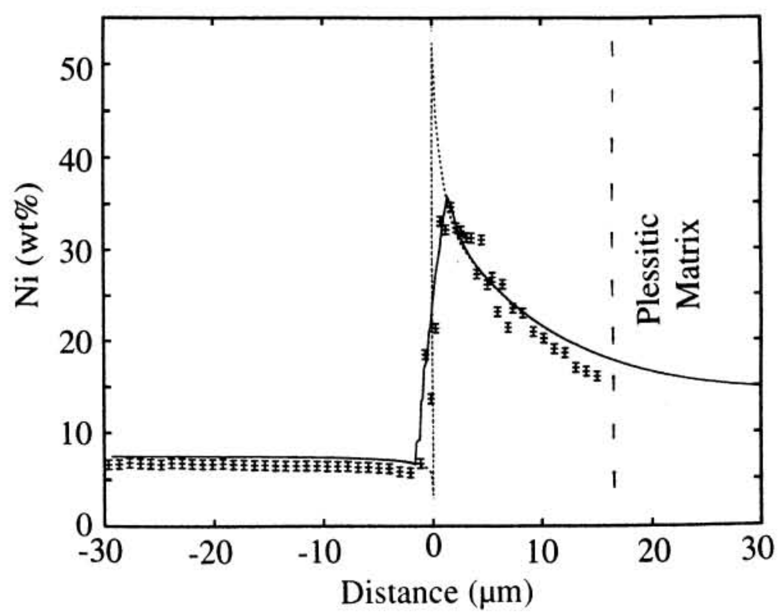

Fig 1. Typical Ni profiles measured from the middle of an α-lamella across the α/γ-interface in the IIF iron meteorite Repeev Khutor (data points with $\pm 1\sigma$ errorbars). The dashed line shows a calculated profile assuming a cooling rate of 10 K/My and an undercooling of 130 K. The solid curve shows the calculated profile smeared to simulate an electron probe beamwidth of 3 μm.