THERMAL HISTORIES AND ORIGINS OF GROUP IIE AND IAB IRON METEORITES AND THEIR PARENT ASTEROIDS. Edward R. D. Scott[1] and Joseph I. Goldstein[2]. [1]Hawai‘i Institute of Geophysics and Planetology, University of Hawai‘i at Manoa, Honolulu, Hawai‘i 96822, USA (escott@hawaii.edu), [2]Department of Mechanical and Industrial Engineering, University of Massachusetts, Amherst, MA 01003, USA.

Introduction: Iron meteorites in groups IIE and IAB contain abundant silicate inclusions and lack fractional crystallization trends for minor and trace elements in metallic Fe,Ni [1, 2]. They probably come from asteroids that accreted >2 Myr after CAIs when there was insufficient ^{26}Al for metallic cores to form. Metal and silicate were mixed in impacts when the parent bodies were disrupted or cratered. About one-third of the ~20 IIE irons contain irregularly distributed, angular chondritic silicate inclusions, one-third contain globules of differentiated silicates and one-third lack silicates [3, 4]. For the ~80 main group IAB irons, about 10% contain angular chondritic silicates, one of these also contains differentiated silicate clasts [5, 6]; the remaining main group IABs lack silicates. Silicate inclusions in IAB irons have chemical and oxygen isotopic compositions showing that they are derived from winonaite-like metamorphosed chondrites. The parent asteroid may have been impact melted [5], partly melted prior to impact disruption and reassembly [6], or else metal segregated into deformation zones [7], possibly during a hit-and-run impact during accretion [8]. The lack of shock deformation in IAB silicates and winonaites [6] precludes significant hypervelocity impact heating favoring a hit-and-run glancing impact [8].

Group IIE irons probably formed by related processes but their origin and formation are less clear. Oxygen isotopic and chemical compositions of silicates in chondritic inclusions in IIE irons favor a link with an H chondrite parent body, or more plausibly, with the slightly more reduced, so-called HH chondrites like Burnwell [4, 9, 10]. Various types of precursor bodies have been proposed. The IIE parent body may have been composed entirely of unmetamorphosed chondritic material prior to impact melting [11], or it may have contained a partly molten interior and an incipient metallic core [2]. If ^{26}Al and impact heating both played a role, then other possible origins can be envisaged. Here we constrain the thermal histories of IIE irons and compare them with those of IAB irons and winonaites.

Results: Cooling rates at ~300°C were inferred from measurements of high-Ni particle sizes in cloudy taenite in two IIE irons, Colomera and Miles, using the proceedure of Yang et al. [12]. Both meteorites contain broad, well-developed cloudy taenite margins adjacent to kamacite, indicating slow cooling around 300°C when cloudy taenite formed. Regions in Colomera containing sulfide-rich impact melt were avoided. Mean cloudy taenite particle sizes are 123±2 and 103±2 nm for Colomera and Miles, respectively. Metallographic cooling rates of irons derived from central Ni contents, which are correlated inversely with cloudy taenite particle size [13], imply that the two IIE irons cooled at rates of 5 and 10 K/Myr.

Cooling rates during crystallization of Fe-Ni metal can be inferred or constrained using dendrite arm spacings [14]. For Mount Howe 88403, which contains ~30 vol.% troilite droplets, the arm spacing of 1 mm implies a cooling rate of ~5°C/hr during crystallization. Colomera lacks troilite nodules but the maximum size of its parental taenite grains of 8 cm [15] implies an arm spacing of >1 cm and a cooling rate of <50°C/yr during crystallization. Specimens of Mont Dieu show diverse textures [see images in Met. Bull. Database] with some samples having troilite nodule spacings of several mm to several cm whereas in other specimens there are troilite-rich regions with ~2-5 mm wide rounded metallic grains partly enclosed by ~15 vol.% troilite. Crystallization times probably varied from months to years.

Discussion:

Thermal histories. The cooling rates at 300°C of 5-10 K/Myr inferred from cloudy taenite particle sizes for the IIE irons, Colomera and Miles, are comparable to the metallographic cooling rates of main group IAB irons of 10-20 °C/Myr [16]. These rates are much lower than those of irons in groups IIIAB, IVA, IVB, presumably because these groups formed from core metal that was separated from silicate mantle materials by hit-and-run impacts during accretion. The very slow cooling rates of the two IIE irons are consistent with the large size of the parent asteroid that can be inferred from the frequency of Ar-Ar ages reflecting impact resetting during the late-heavy bombardment [8]. Three IIE irons have 3.5-4.0 Gyr Ar-Ar ages whereas four others have 4.5±0.1 Gyr ages [17].

Colomera and Miles have mm-wide kamacite lamellae and grains whereas Kodaikanal, which has a similar bulk Ni content of ~8% but much finer kamacite bands ~0.1 mm in width [15], cooled more rapidly at 500°C. Mt. Howe 88403, which crystallized in a day, also cooled more rapidly at 500°C than other IIEs as the troilite is separated from fine plessite by 50 μm wide swathing kamacite and cloudy taenite is not visible. We infer that IIE irons cooled at very diverse depths. Mt. Howe may have been formed in a separate impact as its thermal history and S content are so different from those of other IIEs.

Diverse troilite contents. Four IIE irons, Mont Dieu, Barranca Blanca, Taylor Glacier (TYR) 05181, and Mt. Howe 88403, have abundant troilite nodules whereas most other IIE irons lack troilite nodules. These four IIE irons have very different properties. Mont Dieu contains chondritic silicates whereas TYR contains differentiated silicates. Barranca Blanca and Mt. Howe both lack silicates, but the former contains 5-50 mm wide kamacite grains [15] cf. 50 μm in Mt. Howe. We infer that several processes control the S contents of IIE irons: rapid crystallization probably limits S vaporization and aids trapping of S-rich melt. S-rich metallic melts may be excluded during "filter press differentiation" that has been invoked to separate silicate crystals from melt [18].

Nature of IAB, IIE, and H chondrite parent bodies. If cm-sized metal veins in Portales Valley and mm-wide metal veins in other H chondrites formed by segregation into deformation zones at depth in a metamorphosed chondritic material [7], the IAB irons may have formed by more intense deformation in the winonaite parent body. Given the occurrence of transitional IAB-winonaite textures, e.g., in Campo del Cielo (Fig. 2c,d in [2]) and Caddo County. (Fig. 2 in ref. [6]), it seems plausible that IAB irons are derived from meter-to-decimeter wide metallic veins in metamorphosed chondritic material from which winonaites are derived. Heating may have resulted from frictional melting in pseudotachylite veins during hit-and-run impacts.

For IIE irons, we invoke similar but more intense impact deformation in veins in an HH chondritic body. Since differentiated silicates in IIE irons are not related to any achondritic meteorite, silicate melting in the IIE parent body may have been highly localized in deformation zones instead of being pervasive throughout the interior of the parent asteroid [2]. In the former case, we might expect to find IIE irons with both chondritic and achondritic inclusions, which are not observed. However, two IAB-related irons do contain such mixtures [6] suggesting that they may also be found in IIE irons.

These models should be tested with spacecraft observations of S type asteroids to see whether they contain fragments with metal-rich veins. In addition, spacecraft and astronomical observations are needed to search for asteroids consisting of mixed chondritic and differentiated materials predicted by refs. [2] and [20].

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