
Allan Hills 85085 is an 11.9 g chondrite that contains abundant metallic Fe-Ni and enstatite (Fs1-4), small amounts of olivine, sulfide and glass, and few obvious chondrules. It shows little evidence of weathering except on the outer surface. ALH85085 was tentatively classified as E3 [1]; however, the fine grain size, a lack of Si in the metal and the relatively high contents of FeO in the silicates suggested that further study was warranted.

ALH85085 is extremely fine-grained, and its constituents are present in unusual proportions. Metallic Fe-Ni grains up to ~350 μm constitute 22 vol.%, and have an average size of ~20 μm. Chondrules, microchondrules and their fragments constitute ~10 vol.%, ranging in apparent diameter from 3 to 410 μm with a mean of 5.6 ± 1.0 φ-units (20–10 μm). At least 22 Ca-Al-rich inclusions (CAI) occur in one 0.5-cm² thin section (~0.1 vol.%). CAI range in maximum dimension from 14 to 107 μm with a mean of ~40 μm. Fine-grained dark clasts up to 375 μm in size, together with small amounts of true interstitial matrix, constitute 4.7 vol.% of ALH85085. Irregular patches of anorthitic glass constitute 1.2 vol.%.

Sulfides (0.5 vol.%), ferroan chromian spinel (0.2 vol.%), magnetite (0.2 vol.%), chondrule mesostasis (~2 vol.%), and coarse isolated grains of phyllosilicate (<0.1 vol.%), are minor phases that occur as isolated grains or inside chondrules. Isolated grains of low-Ca pyroxene and olivine constitute the remaining 59 vol.%; at least some of these grains are fragments of larger objects. The total amounts of low-Ca pyroxene and olivine (including isolated grains and chondrule phenocrysts) are 63 and 6 vol.%, respectively.

About 80% of the metallic Fe-Ni is kamacite, containing an average of 58 mg/g Ni, 3 mg/g Co, 2 mg/g Cr and <0.5 mg/g Si (metallic Si was detected only in one highly reduced chondrule). Most of the remaining metal is martensite and/or plessite, averaging 113 mg/g Ni, 4 mg/g Co and 2 mg/g Cr. Rare taenite (~240 mg/g Ni) and tetrataenite (537 mg/g Ni) also occur. Most sulfide grains are troilite (6 mg/g Ni, 4 mg/g Cr); pentlandite (190 mg/g Ni) and extremely rare heazelwoodite are also present.

All of the normal petrographic types of chondrules are present among the microchondrule population, but in unusual proportions: 86% are radial pyroxene or cryptocrystalline, 3% are barred olivine, 11% are porphyritic and <1% are granular pyroxene. None of the major chondrite groups contains >20% nonporphyritic chondrules, but in an unusual mm-size clast in Piancaldoli (LL3) all of the microchondrules are nonporphyritic [2].

The CAI in ALH85085 are not only small but very fine-grained; the largest grains are ≤5 μm in over 50% of the CAI, and ≤10 μm in over 80%. Many (over 68%) of the inclusions are melilitite-rich, and many contain spinel (77%), hibonite (50%) and perovskite (55%). Three inclusions found in one thin section contain CaAl₂O₇, an unusually high frequency for this rare phase. Most inclusions show virtually no alteration, 36% have Wark-Lovering rims of aluminous diopside ± gehlenite ± perovskite, and 64% are fragments of once-larger bodies. Several CAI are tiny microporphyritic spherules in which microphenocrysts of hibonite ± perovskite ± CaAl₂O₇ are set in glass or melilitic matrices.

Two types of dark clasts, both containing fine-grained (< 1 μm) matrix, are present. One is apparently C1 chondrite material and contains frambooids, platelets, spherulites and isolated crystals of magnetite, abundant fine-grained sulfides (mainly pyrrhotite with ~5% cation deficiency), laths of pentlandite, isolated olivine and small amounts of phosphates. Fe-, Mg-, Mn-bearing carbonates are also present, but no sulfates were found. Whereas the
S-bearing minerals differ from CI1 chondrite occurrences, the rest of the mineralogy supports this classification. The isolated magnetite and phyllosilicate grains in ALH85085 may be xenoliths related to the CI1 clasts. The other type of clast contains tiny disseminated grains of metallic Fe-Ni and isolated olivine crystals.

Olivine in ALH85085 varies widely in composition. Most grains are in the range Fa$_{0.4-4.8}$ with a mode at Fa$_{1.2-2.4}$ and a mean of Fa$_{3.1}$. Out of 85 isolated grains and chondrules measured, only 3 contain olivine more ferroan than Fa$_{6}$; one chondrule has Fa$_{27-35}$. The mean Cr content of olivine is 3.1 mg/g. Only 6 low-Ca pyroxene grains were analyzed; the mean is ~Fa$_{2}$. These grains have substantial amounts of Al (average, 7 mg/g), Ti (0.7 mg/g) and Cr (5 mg/g).

From our mineral modes and compositions we calculate that bulk ALH85085 has Mg/Si = ~1.1 x CI, Fe/Si = ~1.6 x CI, Ni/Si = ~2.0 x CI and S/Si = ~0.03 x CI. The Mg/Si ratio is like that of carbonaceous chondrites and higher than that of other chondrite groups. The Fe/Si and Ni/Si ratios are very high, indicating that ALH85085 experienced more extreme metal/silicate fractionation than the major chondrite groups. By contrast, the S/Si ratio is far lower than in major chondrite groups.

ALH85085 is petrographically unique because it is finer-grained than any other chondrule-bearing chondrite, rich in metal and poor in sulfide. It is nearly as pyroxene-rich as enstatite chondrites, but is much more oxidized; it contains no Si-bearing metal and no Mg-, Cr- or Ca-sulfides. The mineralogy and petrology seem to form an extension of a trend in ordinary chondrites in which chondrites become finer-grained, more reduced and richer in metal and pyroxene in going from L/LL to H. However, the Mg/Si ratio and much of the mineralogical data are similar to those of carbonaceous chondrites. The olivine, pyroxene and sulfide minor-element chemistry (excluding FeO) closely resemble those of CM2 and CO3 chondrites. The composition of kamacite (Cr-bearing, Si-poor) is similar to that in Colony (CO3); CM2 chondrites are extensively altered, and preserve little metal. ALH85085 cannot be an unaltered CM2 chondrite because its chondrules are too small: <4 vol.% of ALH85085 consists of chondrules >200 µm in apparent diameter, whereas the abundances of such chondrules are more than 3 x higher in CM2.

The large abundance of CAI sets ALH85085 apart from ordinary and enstatite chondrites; those groups have at least a 10 x smaller volume percentage of CAI. Only CM, CO and CV chondrites contain such abundant inclusions. All CAI in ALH85085 are far smaller than the mm- to cm-sized ones common in CV, and are more comparable to (but still smaller than) CM and CO inclusions. They differ from CM inclusions in that many contain melilitite, a phase rare in CM (as well as EH and H-L-LL) chondrite inclusions. Many CAI in ALH85085 are broadly similar in mineralogy and texture to the onjects in CO chondrites. However, the microporphyritic CAI described above and the common occurrence of CaAl$_2$O$_7$ are unusual in all other carbonaceous chondrites.

Thus, properties of minerals and CAI, and the presence of several-% CI clasts indicate that ALH85085 is related but not identical to CM or CO chondrites. We suggest that ALH85085 agglomerated near the formation region of the CM-CO clan, but in an area or at a time when only small objects had formed. The presence of metal and the paucity of sulfide may indicate that the region was >650 K at the time of accretion and that ALH85085 is an earlier nebular product than the CM-CO chondrites. If this model is correct, ALH85085-like material cannot have been volumetrically important; otherwise, later-formed CM or CO chondrites would have acquired lower Fe/Si ratios than are observed.