ILAFEGH 009: A NEW SAMPLE OF THE DIVERSE SUITE OF ENSTATITE IMPACT MELT ROCKS

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Introduction. Enstatite meteorites in the world's collections appear to be samples of at least 4 parent bodies, the EH, EL, aubrite and Shallowater bodies (1,2). However, there are a small number of unusual and anomalous enstatite meteorites and clasts in enstatite chondrites whose origins are less certain: Some may be new lithologies, possibly from additional parent bodies, whereas others may be impact melts rocks from the EL and EH parent bodies. The stony-iron Mt. Egerton and the Si-bearing iron Horse Creek, for example, are probably samples of the deep interior of a differentiated enstatite meteorite body (3). Tucson, a unique iron containing highly reduced silicate inclusions, does not belong to the enstatite meteorite clan, as indicated by its different oxygen isotopic compositions (4), but may be a sample of yet another highly reduced parent body. LEW 88055, whose genesis is unclear, contains an enstatite assemblage in Si-free metal (5). Happy Canyon and dark clasts in Hvitts have roughly EL6 bulk compositions but achondritic textures and probably are impact melt rocks from the EL body (1,6,7). A clast in Parsa (EH3) may be an impact melt rock from the EH body, but no comprehensive study has yet been carried out of it (8,9,10). Here, we present results of our study of Ilafegh 009, yet another member of this group of unusual enstatite meteorites. It has been classified as an EL6/7 (11) and an EL7? chondrite (12). Although Ilafegh 009 is compositionally similar to the EL6 chondrites and has some of the textural features of Shallowater and Mt. Egerton, we suggest it is an impact melt rock from the EL parent body, grouping it with Happy Canyon and the clasts in Hvitts. However, differences between these three samples indicate a diverse range of impact melt products on the EL parent body.

Results. Chemical and isotopic data. The modal mineralogy of Ilafegh 009 is EL-like (13), containing (in wt.%) 52.4 ortho-enstatite, 3.2 twinned enstatite, 7.1 plagioclase, 27.2 metal and 8.1 troilite(+daubreelite) and 0.5 alabandite. No diopside was observed as either separate grains or as exsolution lamellae in ortho-enstatite. The mineral compositions are also similar to those of EL6 chondrites (13): Enstatite has 0.13 wt.% FeO and 0.89 wt.% CaO, plagioclase is oligoclase (Ab77.4An19.7Or2.9) and kamacite contains 1.6 wt.% Si (11). The oxygen isotopic composition (δ18O = 5.43, δ17O = 2.90) is within the range of enstatite chondrites and aubrites (12). Preliminary INAA data, including the volatiles Na and K, are consistent with a chondritic origin. We determined an 39Ar-40Ar age of 4.44 Ga and found that the rock does not contain trapped argon.

Textural information. In hand sample, Ilafegh 009 is light in color, apparently due to the larger average grain sizes of its opaques and silicates, in contrast to the generally dark color of the finer-grained enstatite chondrites. In thin section, no relict chondrules are observed, and the meteorite is dominated by large (up to 0.75 cm in length), interlocking laths of ortho-enstatite, somewhat resembling a fine-grained version of Shallowater. Twinned enstatite of the same composition occurs throughout the meteorite. Undulatory extinction is a ubiquitous feature of both types of enstatite, and planar fractures are common, suggesting the rock was shocked after crystallization. The enstatite contains remarkable inclusions, round and irregular in shape, that consist of plagioclase ± metal ± troilite. These inclusions range from a few to hundreds of μm in size. Оpaque phases (metal, troilite, alabandite) occur predominantly as interstitial phases to the large, euhedral enstatite crystals, resulting in a variety of unusual metal shapes. These include highly irregular outlines where enstatite invades the metal; triangular metal trapped between three intersecting enstatite crystals; and laths of metal trapped between two parallel enstatite crystals. Mt. Egerton, where the metal occurs interstitially to the enstatite (14), also displays angular metal shapes, but on a much larger scale.
Discussion. Impact melt origin. Oxygen isotopic, bulk and mineral compositions suggest that Ilafegh 009 is of EL parentage; we suggest an impact rather than internally-driven melting episode to be responsible for the igneous texture of the rock, for the following reasons. Rapid, isochemical melting, followed by rapid cooling must have occurred to prevent fractionation by gravitational segregation of metal and sulfide or, perhaps, loss of plagioclase by explosive volcanism (15). Rapid subsolidus cooling is also indicated by the relatively high CaO content of ortho-enstatite but lack of diopside exsolution. No lithic clasts have been observed, so total impact melting is indicated. Superheating of the impact melt may have destroyed all pre-existing nuclei, and subsequent rapid crystallization may be responsible for the hypidiomorphic texture. During rapid crystallization, growing enstatite crystals trapped magmatic inclusions. These would then crystallize enstatite indistinguishable from the host, as well as plagioclase, metal and troilite; the latter crystallize equigranular to the large enstatite, yielding the somewhat unusual shapes. In contrast to EL chondrites, Ilafegh 009 contains no trapped argon, in consort with its origin as an outgassed impact melt of EL parentage. The 4.44 Ga age suggests that the impact melting occurred early in Solar System history.

Comparison with other impact melt rocks of EL parentage. Comparison with Happy Canyon and the Hvittis clasts is preliminary at this time, because we only recently began study of the former and do not yet have access to sections of the latter. A near-surface impact melt origin of Happy Canyon was originally rejected, because pure enstatite at the lize enstatite indistinguishable from the host, as well as plagioclase, metal and troilite; the latter three minerals occur together in some melt pockets. Late crystallizing oxides form interstitially to the large enstatite, yielding the somewhat unusual shapes. In contrast to EL chondrites, Ilafegh 009 contains no trapped argon, in consort with its origin as an outgassed impact melt of EL parentage. The 4.44 Ga age suggests that the impact melting occurred early in Solar System history.

The enstatite impact melt rocks are surprisingly diverse, considering the small number of samples, and have varying abundances of clastic material; experienced differing degrees and types of fractionation; and crystallized different textures under varying oxygen fugacities. Specifically, Ilafegh 009 and the large 16 kg Happy Canyon specimen appear to contain no clastic material and, thus, crystallized from total impact melts; only the smallest object, clast A in Hvittis, contains clastic material. Ilafegh 009 shows no indication of fractionation during melting and crystallization, whereas clast A in Hvittis is depleted in metal and sulfide, as are most impact melt clasts in ordinary chondrites (16). Happy Canyon may have experienced some fractionation of its plagioclase component, although apparently not of its oxides (6). Ilafegh 009 consists of interlocking laths of enstatite crystals that may have crystallized from a superheated impact melt. Happy Canyon, on the other hand, consists of numerous small, equigranular enstatite crystals, possibly because it crystallized from a melt that was not superheated and, hence, retained many enstatite nuclei. Finally, the metal in Happy Canyon does not contain Si in solid solution (6). If the precursor was EL chondritic material, as seems reasonable in view of bulk and mineral compositional similarities, the Happy Canyon melt must have crystallized under higher oxygen partial pressures than did the EL's. This is a complex scenario to envision, unless the impactor itself was volatile-rich and altered the ambient oxygen fugacity. It should be noted that a microporphritic melt breccia clast in the Norton County aubrite has higher FeO content of ortho-enstatite than the host (17), suggesting that alteration of ambient oxygen fugacity during impact melting may be more widespread than previously thought.

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