

WHY IRON METEORITES CANNOT BE SAMPLES OF PLANETESIMAL SMELTING. G. Kurat, Naturhistorisches Museum, Postfach 417, A-1014, Vienna, Austria.

Beliefs and Consequences:

Widely entertained beliefs see the differentiated meteorites (DMs) as igneous rock samples from differentiated solar system bodies, planets or planetesimals [e.g., 1]. Two observations straightforwardly exclude such a scenario, one known for a long time:

1) A chemically differentiated body of chondritic bulk composition (like Earth) consists of ~1/3 core (metal), ~2/3 mantle (peridotite) and <1 % (by mass) crust (basalt). The meteorite record sees ~38 % irons, ~62 % (by number) basalts and derivatives (HED) and no suitable peridotite. The main mass is missing, a clear signal that DMs cannot be samples of differentiated planets or planetesimals.

2) Hf-W chronology [e.g., 2] shows that irons have the most non-radiogenic (=primitive) W of all matter known, indicating separation of siderophile from lithophile elements very early in the history of the solar nebula. On the other hand, HEDs have much too less radiogenic W to be the product of this siderophile-lithophile element fractionation process that is recorded by the irons. Their W isotopes rather indicate a separation (=fractionation) from a chondritic source, like the irons but some time later. These data definitely exclude any planetary relationship between irons and HEDs. However, they indicate a common source for both: the solar nebula. I take this as another clear message that the planetesimal model for irons and HEDs cannot work. Thus, the first conclusion has to be that irons and HEDs are not the products of planetary differentiations. They rather represent two different and in-dependent fractionation events which took place separately in space and time. What kinds of fractionation processes were involved and where did they take place?

Chondrites and fractionated meteorites:

DMs share with chondrites many features: They are old, contain daughters of short-lived radionuclides, Q-Xe, U-Xe and even Xe-HL (see summary by [1] and [3]). They only differ in their chemical composition: chondrites have solar and DMs have non-solar elemental abundances (with some important exceptions, see below). Comparing DM compositions with those of chondritic constituents (chondrules, aggregates, CAIs, etc.) reveals that the latter can be chemically fractionated to a much higher degree than the former (see summaries by [1,4]) – a clear demonstration of the ability of the solar nebula to chemically fractionate matter even beyond the degree necessary to create DMs.

Major and trace element abundances in eucrites (and their relatives, howardites and angrites) signal vapor fractionation as the principal fractionation process, variably disturbed by post-formational metasomatic alterations [e.g., 5-7]. They apparently are

relatives of CAIs and POIs and their place of formation could have been the solar nebula.

The case of iron meteorites:

In contrast to HEDs, the genesis of irons cannot straightforwardly be deduced from their chemical composition because major and trace element abundances do not carry a simple signal and clearly no signal of conventional condensation. Their message is chaos, with some tendency to form clans (=chemical groups). These clans carry a strong message on elemental fractionation, again in a chaotic way, as each clan appears to follow its own fractionation rules. In, e.g., the Ir vs. Ni projection, chemical iron clans have widely different slopes indicating different crystal/liquid partition coefficients operating in each of the clans – a physical impossibility. Many attempts to model these fractionations in view of the popular planetesimal smelting theory resulted in highly complicated procedures fed by numerous *ad hoc* assumptions [e.g., 8,9].

As already mentioned above, iron meteorites are very old [e.g., 10] and primitive. Beside primitive W they also contain primitive Pb and clear signals of live, now extinct radionuclides such as ¹²⁹I [11], ¹⁰⁷Pd [12] and ⁵³Mn [13]. These are certainly not signals of a secondary process such as smelting of a pre-existing chondritic source.

Silicate inclusions in irons are as old as the metal [11,14-16] and have commonly chondritic lithophile and siderophile element contents, indicating a formation independent from the metal [e.g., 17,18]. However, there exist some telling relationships between properties of the metal and those of silicate inclusions. Remarkable are the correlation of silicate Fe/Mg ratios with the bulk Ni content of the metal in IICD irons [17] and the anti-correlation between ¹²⁹Xe in silicates and the bulk Ni content of the metal in IAB irons [16]. Can impact mixing create such relationships [e.g., 19]?

The only model for the irons accepted by mainstream meteoriticists today is the igneous model [see, e.g., 1], in spite of the fact that it contradicts many observations. It thus, unfortunately, has become a major obstacle for meteoritics. Let me give a short, incomplete list of facts that are incompatible with an igneous origin of iron meteorites:

* Most irons are giant single γ -iron crystals with α -iron exsolutions. Growing gigantic metal crystals (m³) from a metal melt is very difficult and takes many tricks to prevent formation of competing nuclei.

* If irons of one clan come from one planetesimal core, why can they have so widely different cooling rates, such as the IVA irons [20]?

* If irons are core samples of impact-destroyed planetesimals, why do they not show any physical

torture and shock features and why do they sample so many planetesimals (>100) and stony DMs so few (<5)?

* Silicate inclusions in irons show no signs of melting and homogenization, even when they are rich in low T-melting feldspars, phosphates or sulfides. At least some pools of eutectic composition (silicates and metal/sulfide) have to form when the inclusions got trapped by the metal melt.

* Silicates and graphite in metal preserve delicate aggregation and growth structures [e.g., 21,22]. They should be destroyed when violently mixed with metal melt and they also should be separated from the metal – even in a very weak gravity field.

* Why did silicates retain large amounts of volatiles such as rare gases and halogens (lawrencite), inclusive ^{129}I ?

* Why do isotopic inhomogeneities exist? Rare gases, C and N have several carriers instead of one [e.g., 23-27].

* Why do bulk chemical inhomogeneities in metal exist? Some irons have variable composition on a grand scale, like Canyon Diablo [28], and on a small scale, like Acuna [29] and the Canyon Diablo and Campo del Cielo graphite-metal rock inclusions [30].

* Schreibersite is commonly out of equilibrium with metal (texturally and chemically), its chemical composition varies widely and is correlated with size [e.g., 31,32], inclusive trace elements [33,34].

* Schreibersite and metal in Canyon Diablo and Campo del Cielo have strongly fractionated refractory siderophile element abundances which are incompatible with fractional crystallization and fractional condensation [30,33,34]

* Olivine and pyroxene are usually out of equilibrium in silicate inclusions [e.g., 35] with fa<fs, indicating a late reduction event without subsolidus equilibration, in spite of very slow estimated (and expected) cooling rates.

A possible solution:

A possible way to overcome most, if not all, problems is to have the metal (and other phases) precipitate at subsolidus temperatures. As conventional condensation from a vapor of solar nebula composition is clearly excluded by the chemical composition and other features of irons, a derivative process such as chemical vapor deposition could do the job. Such a process could precipitate metal in a very gentle way, could fill all pore spaces and would be capable of growing huge crystals. A possible process - as originally proposed by [35] and recently advertised by [30,34] - is precipitation of metal from metal carbonyls:



Such a scenario explains in a natural way formation and preservation of chemical and isotopic inhomogeneities, the fractionation of refractory siderophile elements, the association of metal with

large quantities of isotopically fractionated C (from the breakdown of 2CO to $\text{C} + \text{CO}_2$), the abundant presence of lawrencite (FeCl_2) and live ^{129}I (from halogen carbonyls), the correlation of fs with Ni (in metal – indicating that the Ni/Fe ratio of the metal precipitated is governed by the O fugacity prevailing) and many more. It also provides a simple solution to the paradox created by the Hf-W data: old metal encloses younger silicates! The solution is, that the precursor carbonyls for iron meteorites formed before but precipitated metal after chondrites formed.

Acknowledgements:

Supported by FWF and Ermann-Fonds, Austria.

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