Meteoritic Iron

General Remarks

Advanced

There are most certainly meteorites that consist of an iron-nickel alloy, we have encountered that already in the Widmanstätten Structure Module. There are, however, also meteorites that are simple "rocks", i.e. not containing substantial amounts of iron or other metals. Most meteorites actually are "stony"; the iron meteorites account for only about 6% of what we find.
Assuming that you, like me, have never found any meteorite we probably agree that iron meteorites are exceedingly rare. However, given time and a lot of people, it is not unlikely that the ancient Hittites, Assyrians, Egyptians and so on did run across a decent-sized iron-nickel meteorite every now and then.
Here is a part of a large one (several tons). It is actually one of the three stolen from the Inuit (formerly called Eskimos) in 1894 by the American "explorer" Robert Peary.

One of the "Inuit" Meteorites

Source: Photographed in the National History Museum in NYC

- The major "Inuit meteorites" (known as "the woman" and "the dog") were surrounded with many thousands of hard basaltic "hammerstones", schlepped to the place from far, far away. It is generally assumed that the Inuit chipped off small chunks of iron that then were flattened into blades by cold working only.
  What that would tell us is that meteoric iron, at least that of the Inuit, is rather brittle. You can chip away with a stone or whatever at malleable iron for as long a you like, and you will not *chip* off a piece. At best you can hammer out a sheet that you eventually *tear* off.

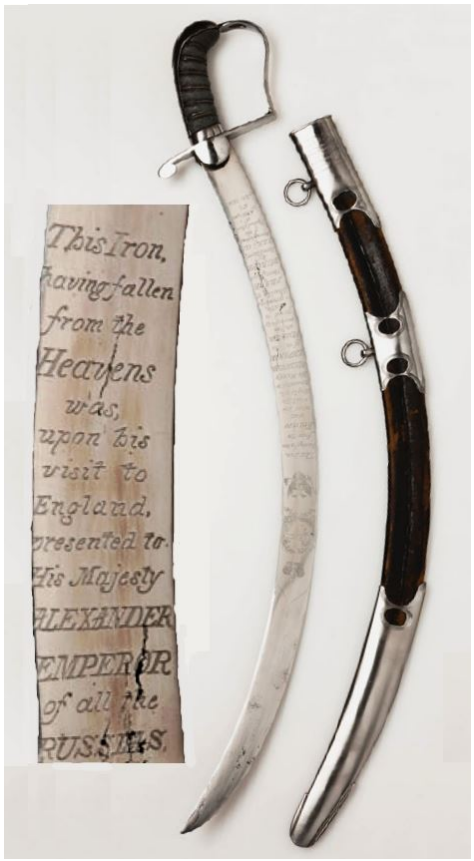
As it happens, most meteoritic iron *is* malleable. The Inuit meteorite certainly was malleable, otherwise you could not possibly produce blades by cold working. So no "chipping off" of pieces there. This is my first example for some of the puzzles and myths surrounding meteoritic iron.

- The puzzle was solved by **Vagn Fabritius Buchwald** in his marvellous book "Iron and Steel in Ancient Times". The first thing to note is that the big chunks now in the National History Museum in New York are just the showy parts of some meteorite shower that hit the earth about 10 000 years ago. Besides the big guys it also delivered scores of small lumps that could be found close to the big ones, and that's what the Inuit collected and used for their blades.
  Thousands of pounding stones imply that thousands of objects have been made from meteoritic iron - but there are only a handful of pictures of the Inuit blades. Below you see about the complete collection of easily found pictures:

Inuit meteorite iron things: A harpoon (with detail) and two knifes

Source: British Museum, Wikipedia, and Buchwald's book

Yes, it's not all that impressive. But as Buchwald illustrates with many examples, the use of meteoritic iron in more recent times (like the 17th and 18th century) outside the Arctic is well documented for many cultures, including the settlers of the USA. In contrast to the Inuit, all these guys knew how to forge iron and steel at high temperatures. This was quite possible with meteoritic iron or better iron-nickel steel - it is malleable!
A fancy sword with a meteoritic steel blade marks the pinnacle of meteorite iron forging. The sword was presented to Czar Alexander I in 1815 for his help in defeating Napoleon's French hordes. As ever so often, the British, Russians, Austrians, and so on fought the French on German ground, in one of the bloodiest wars in history (e.g. the 1813 Battle of Leipzig).
Here is Czar Alexander's meteoritic iron sword:



Czar Alexander's meteoritic iron sword and detail of the engraved blade

Source: Paul Henderson: "James Sowerby: meteorites and his meteoritic sword made for the Emperor of Russia, Alexander I, in 1814", Notes Rec. R. Soc. published online September 4, 2013. The pictures are from The State Hermitage Museum, St Petersburg. (Photograph copyright The State Hermitage Museum. Photograph by Konstantin Sinyavsky.)

- We learn that it is perfectly possible to forge high-quality blades from meteoritic iron. However, not all meteorites are born equal. Even the small subset of iron-nickel meteorites can differ very much with respect to their constitution like the nickel concentration, the uniformity, the presence of large inclusions, and so on. Nickel concentrations around 8 % are common but 5 % or 20 % are also found. Less than about 5 % nickel is rare to non-existent, though.

Now to the next myth. While man-made stainless steel often contains substantial amounts of nickel (Ni), the reverse is not true. Steel containing substantial amounts of nickel, like meteoritic steel, is *not* necessarily "stainless", i.e. not rusting. It is typically the other way around: meteoritic steel rusts easily because of its inhomogeneous structure. This might lead to cracks and fissures, allowing to pry the thing apart without too much effort. The sword blade above seems to have developed such cracks.

Use of Meteoritic Iron in Ancient Times

So you are the smith in ancient times once more. You know how to make your bronze, cast it, and work it into art or weapons. Now consider that your boss brings you a big lump of some "metal" that some goatherd saw coming down from the heavens or the sky (there is a difference). He wants you to turn this gift from the Gods into something special or else.
Can you do it? Could you, for example, make something like the dagger of Alaca Höyük, long before iron smelting was invented? In other words: can you work with a metal that you have never seen before? Well, you can give it a try. Of course your first attempt would be to melt the metal from the sky and cast it into something useful.

- Surprise! You can't melt it. So you try to bang it into shape. If that is difficult at ambient temperature, you heat it. After all, that's what your great-great-....-great grandfather did with native copper a few thousand years ago, and that's what your colleague, the goldsmith, still does for some of the stuff he makes.
  You will experience a lot of unpleasant surprises, especially if you try to make something large like a blade. For starters, banging a lump of "good" iron into blade shape is not all that easy, and your metal from heaven might offer a number of new problems, like big inclusions of some rocks.
  But it can be done. And it has been done. There are old iron artifacts that have been made from meteoritic iron for sure. There are, however, artifacts just as old that have been made from smelted iron for sure. The problem is that a lot of old artifacts were pronounced to have been made from meteoritic iron *without* knowing for sure.

Proclaiming very old iron to be meteoritic is just too tempting for Museum curators. If you run across some iron that is definitely from well before 1200 BC, declare it to be meteoritic iron and you do not have to explain how come you have a piece of iron from an era where smelted iron didn't officially exist. Even better, don't mention the origin of the iron at all.

The "ring crown" is iron

Source: Metropolitan NYC

- This mannikin in the Metropolitan Museum in NYC from around 2000 BC illustrates that. First, the description doesn't explain anything. If one inquires, the information about the iron is: "It is assumed to be of meteoric origin since the technology necessary for the extraction of iron from iron ores would not be known until the 1st millennium BCE. No analysis has been carried out". That's correct and fair but nevertheless a bit unsatisfying. For the full story use the link.

How can one tell if some old iron object was made from meteoritic or smelted iron? Let's make a list:

- **1. The nickel (Ni) concentration.** If the iron in question contains substantial amounts of nickel (more then 1 %), it's assumed to be meteoritic.
  The beauty of this criterium is that you can measure the nickel concentration without even touching, not to mention destroying the object. Just use some miniaturized portable X-ray equipment. The problem is that the criterium is not necessarily true. While not much nickel-rich smelted iron has been found so far, it is perfectly possible to get some by (accidentally) co-smelting iron ore with some nickel ore. We might even surmise that in the early phase of iron smelting all kinds of "accidents" happened that did not occur anymore after iron smelting came into its own and enough experience with the new material had been collected. This means that very old iron would tend to be weirder in its composition than mainstream iron at a later time. That's what happened with

copper, as we know. Since meteorites almost never have nickel concentrations below 5 %, the 1 % limit is too low, anyway.
The 2500 BC iron dagger from Alaca Höyük, for example, supposedly contains around 5 % nickel according to the newest analysis [1)]. Older investigations yielded much lower nickel concentrations, however. Five percent nickel would point towards meteoritic iron, indeed.
However! This analysis was given in a preliminary report from 2008. If there is a final report I have failed to find it. I will not question the result but wouldn't be surprised either if it will be challenged in the near future. And even if it is confirmed, there is still a small but definite possibility that it was made from some Ni-rich smelted iron imported from God knows where.

- **2. The extremely typical Widmannstätten structure.** The link gives details and the picture below illustrates what we are looking at here. The Widmannstätten structure cannot be made on earth. If you see it you know that you look at an iron-nickel meteorite. What's more, the structure does not change too much during forging. The picture below shows a modern blade forged from meteoritic iron - the Widmannstätten structure is still there.
If you find that structure in ancient iron, you know that it is definitely meteoritic iron. No doubts there. There are catches, however.
The first catch is that you must polish and etch a large enough part of the artifact. You must "mutilate" the specimen to some extent, something frowned upon by all museum curators. The second catch is that the *absence* of a Widmanstätten structure does not prove that the metal in question is *not* from a meteorite. As stated above, some iron-nickel meteorites do *not* display that structure.

Widmannstätten structure of meteorite "as found" and in a forged modern blade

Source: Wikipedia and KD Meteorites (where you can buy the blade).

- **3. Absence of slag inclusions.** Almost all old iron or steel contains slag inclusions, typically elongated from the forging. The absence of these inclusions, together with possibly inclusions of "rocks", strongly implies that you are looking at meteoritic iron.
The catch is clear: It's a destructive analysis once more. Moreover, crucible or wootz steel that was liquid once, may not contain slag inclusions either.

For us innocent bystanders there is no choice but to be patient and wait. Sooner or later (probably later) the archeometallurgist will have analyzed a sufficient number of samples to arrive at my conclusion:

Both smelted iron and meteoritic iron was used on rare occasions in the second and third millennia BC

- It's not just my conclusion. Most archeometallurgist in the field seem to agree, they just have to be more careful about making blunt statements like this.
- But hey - as a big surprise in 2016, it turned out that King Tut's famous iron dagger was made from meteoritic iron. it only took the archaeologist 14 years to figure that out! More about that here.

There is one more time-honored if questionable way to determine how things were made long ago: read the old literature. Alas! There isn't much!.
We know, however, that the Hittites, some Sumerians, and the Egyptians referred to iron / steel as "**iron from heaven**".
So mission accomplished, the case is closed. Very old iron is meteoritic.

- Not quite. "Iron from heaven" in Hittite is "An.Bar Ge", derived from "An.Bar" = (smelted) iron. We also have "An.Bar Sig" = good iron, "An.Bar Baba" = white (?) iron, and so on. One doesn't need to be fluid in Hittite to realize that you only can name some kind of iron "An.Bar Sig" if you *know* An.Bar = iron in the first place.
  Not to mention that some meteorite found somewhere does not bear the inscription "I fell from heaven" on it.
  Moreover, the "iron from heaven" denomination appears relatively late (Hittite 1400 BC; Mari /Sumeria: early 2nd millennium; Egypt: 19th dynasty; 1292 BC - 1187 BC), and since at least the Hittites on occasion use expressions like "a heaven / sky of iron", it might just be symbolic like the "brightly shining *silver* star" in, e.g., Muslim nursery rhymes.
  Moreover once more: Since there are some ancient meteoritic iron objects, and since conceivably somebody saw a meteorite coming down, the Old Ones had every right to talk about "iron from heaven", because they knew it was iron, having some self-made stuff "from the earth" at hand. In other words: "Iron from heaven" simply may have been the name given to for meteoritic iron *after* smelted iron was recognized as something special.
- Last, we might also consider that those old Hittites etc. were just lying. A heavenly origin of whatever always makes that object exotic and precious, and obviously meant only for rulers, high-priests and other top dogs. Those guys, after all, frequently claimed some kind of heavenly origin for themselves, or at least that they would ascend to heaven after they died. Why shouldn't they lie about their precious objects too, in order to have easier control over the stuff?

To conclude: Assuming that *every* iron object made before 1200 BC consists of meteoritic iron is definitely wrong. That does no exclude that *some* iron objects were made from the heavenly stuff.
It also doesn't matter all that much. In any case the basic questions and problems, as formulated by **Jane C. Waldbaum** in her 1998 exhaustive review of early iron [2)] remain:

- "At present there is not sufficient evidence to either support or refute conclusively any one of the hypotheses regarding the start of the iron age. Any hypothesis, new or old, has to account for the fact that iron was a known metal, and smelting was a known technique, well back into the bronze age though neither the metal nor the technique seems to have been appreciated for its utiliarian potential for a long time".
- "We still do not really know why the iron age began".
- "We also do not know whether the proper technology for producing steel began to be conscientiously applied in in just one area, from which it spread to others, or whether it developed empirically in several regions".

- That was 1998. I doesn't seem that answers to the puzzles above have been found in the meantime. It's rather the other way around. The more we learn about the intricacies of early copper smelting and bronze technology, the less we understand why iron wasn't produced and used much earlier than 1200 BC.
- However, puzzles related to the more technical issues, like fluctuating levels of "carburization" that are addressed indirectly in Jane Waldbaum's review and in other writings about the topic, look different from today's perspective; I will deal with that in the backbone.

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1) I. Nakai, Y. Abe, K. Tantrakarin, S. Omura and S. Erkut: "Preliminary Report on the Analysis of an Early Bronze Age Iron Dagger Excavated from Alacahöyük". Anatolian Archeological Studies, Vol. XVII (2008) p. 322

2) Jane C. Waldbaum: The Coming of Iron in the Eastern Mediterranean". In "The Archaeometallurgy of the Asian Old World", edited by Vincent C. Pigott, University of Pennsylvania Monograph (1999), p. 27 - 57