10.2 Making Iron

10.2.1 Early Iron

Note: I wrote another module about "Early Iron", containing some stuff I learned since I wrote this module, and focussing on *complex* early iron artifacts (=swords) from *smelted* iron
There is also a very readable recent scientific review of this topic

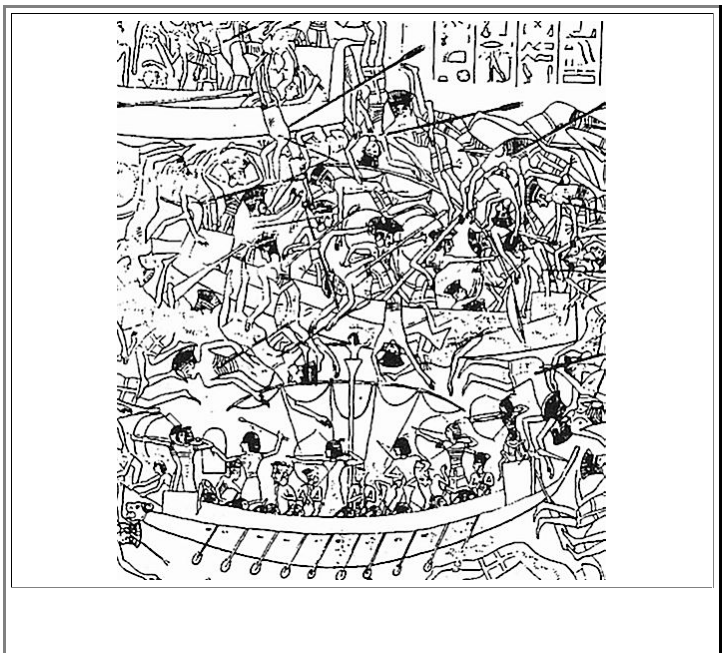
The Collapse of the Bronze Age and the Occurrence of Iron

Smelted iron in *significant* quantities appeared around 1200 BC. If you just scanned through the preceding chapters about making copper, lead, tin and bronze, you know that this was pretty late: about 3500 years after the first smelting of metals and at a time when metal smelting, refining, melting, alloying and casting was already highly developed and about to become a major industry. Moreover, smelting copper must have produced some iron on occasion. So why did iron appear so late? Is there a reason for 1200 BC as the decisive point in time?
What we know is that 1200 BC is a rather ominous date since it signals major upheavals around the Mediterranean, something known as "the **Bronze Age collapse**" followed by the first "dark ages".
In other words; the transition to the **iron age** in the larger Mediterranean was during a time period that was violent, bloody, and culturally disruptive. Severe changes in individual life-style frequently occurred, for example by your sudden violent death. Killing and being killed was a style of live for marauders, pirates, their victims and the people / soldiers / mercenaries fighting them.
What about the rest of the world? No iron was used there in 1200 BC as far as we know (with the possible exception of India). It is thus sufficient to concentrate on the Mediterranean at large.

What happened during the Bronze Age collapse? Extremely bad things. For example, between 1150 BC and 1206 BC we had the collapse of:

- the Mycenaean kingdoms,
- the **Hittite Empire** in Anatolia and Syria,
- the New Kingdom of Egypt in Syria and Canaan.

Of course we don't know exactly what was going on. People about to be killed and their killers leave no written records, and in burnt-down and looted cities a lot was destroyed by definition. We might decry the scarcity of written documents from this era but the people living then were probably more concerned about the violent destruction of about every major city between Pylos (Greece) and Gaza (Sinai). This included major capitals like Hattusa (capital of the Hittite Empire in central Turkey), Mycenae (Greece, near Athens, the major centre of Greek civilization), Troy, and Ugarit (Northern Syria; important trade city and cultural center). The map in this link gives an idea of what was going on. What that also meant was that trade routes were interrupted, causing major economic disasters and severe cultural cuts like a decline of literacy.
The collapse also occurred around the time when **Moses** and the Pharaos Ramses II/III were about - if the former was about at all - and Troy fell to Achilles, **Odysseus** and so on, or at least to somebody. The still mysterious and universally feared "**Sea People**" also had a major hand in this. It wasn't just fun and games to fight them. Here is a tiny part of a well-known sea battle that Ramses III actually won.



Fleet of Ramses II fighting sea people
Parts of a drawing of the 15 m × 2.5 m limestone relief from 1170 BC
in Medinet Habu, Egypt.
Large picture

Source: All over the Net

A first "**Dark Age**" hit the Mediterranean civilizations. In the view of some scholars it was even more disastrous then the dark ages following the collapse of the western Roman Empire. It remains to be seen if it shall have been worse than the dark ages that will follow the collapse of all of civilization in the not-so-distant future due to the present climate crisis. There are even speculations that Hesiod's Ages of Gold, Silver, Bronze and Heroes, preceding the disastrous Age of Iron, recalls the cultural memory of the good old times before 1200 BC.
So what caused the Bronze Age collapse? And why am I harping on that topic considering the headline of this chapter? Well, there is one possible answer to both questions. The bronze age collapsed because of

- Climate change,
- Volcanoes,
- Earthquakes,
- Migrations and raids,
- Changes in warfare,
- *Ironworking*,
- General systems collapse just so - or because some or all of the above occurred together.

I'm not sure that I have covered all bases, but those are the mainstream hypotheses. Pick your favorite one. Plenty of supporters and lots of written material can be found for either one. I'm of course interested in the "Ironworking hypothesis", which states that iron-weapon wielding "migrators and raiders" overcame the conservative bronze-weapon equipped chariot-running armies of the great kingdoms. So there you are!
Now we must ask: Is that true? Did the "invention" of iron cause the bronze age collapse? Or was it rather the other way around: the collapse caused a lot of creativity and inventions like ever so often in times of chaos?

If you go with the "iron caused collapse" hypothesis, you must now provide some idea about the identity of these "migrators and raiders". Once more you can take your pick. They were:

- the "Sea People" from above, who appear to have been a disparate mix of **Luwians**, Greeks and Canaanites, plus possibly run-off slaves.
- Indo-European tribes, such as the Phrygians, Proto-Armenians, Medes, Persians, Cimmerians, Lydians and Scythians.
- Pontic speaking Colchians, Hurro-Urartuans and Iranian Sarmatians.
- Thracians, Macedonians and Dorian Greeks, who seem to have arrived at this time - possibly from the North - crowding out the "Greek" or Mycenians.
- Semitic peoples, such as Aramaeans, Chaldeans and Suteans – moving in possibly from the South-East.
- People you know but would never have associated with these guys.

Latest news (e.g. in "Der Spiegel", 28, July 2016) cover the hypothesis that the Luwians from above actually had a big empire of their own in West Anatolia that hasn't been properly "discovered" yet. Most of the time they were independent of the mighty Hititte empire to the East and around 1200 they took to sea faring and raided about everything in reach. The "Greeks" (actually the Mycean culture) saw the opportunity to raid the Luwian town Troja while the Luwians were busy elsewhere. They succeeded but their whole empire went down the drain anyway as soon as the got home.
Maybe that's how it was. The champion of that hypothesis is **Eberhard Zangger**, a kind of hobby archaeologist (like me, just more so). He became known by claiming that Troja was actually Atlantis. Again, maybe he is right. I don't know. Mainstream archaeology, of course, is rather sceptical.

Well - as it turned out about 20 months later, mainstream archaeology was right. Eberhard Zangger fell for faked evidence; read this article of "Der Spiegel".

Whoever and whatever. Here we are interested how all that relates to the rise of iron. Latest research or opinion has it that the shift to iron occurred *after* the collapse, not before. Then it would be the disruption of the complex infrastructure needed for bronze making in bulk, in particular the failing tin supply, that forced the metal-men to go for something that could be made with just local stuff, and that means making iron.
And so on. Plenty of hypotheses, plenty of dispute, no certainty so far.

Personally I'm certain that there is some connection between the "Bronze Age collapse" and the dawn of the Iron age but I'm also certain that it is not a simple linear cause-effect relationship.
I do not know how all the events around 1200 BC hang together and why iron became popular then. I do know, however, that some iron objects appear long before this time, and I'm relatively certain that ancient engineers could have made iron before 1200 BC if they would have applied themselves. As we have seen, they quite likely made some iron by accident as a by-product at copper smelting. So let's look at the archeological record - *and* the written record.

Yes indeed! In 1200 BC some people could write very well in several kinds of languages and scripts. Cuneiform was popular and used for international correspondence. But Egyptian or Luwian hieroglyphics, Phoenician, demotic, and so on was also highly developed, not to mention whatever was going on in the Far East and China. Some of the stuff was hammered into stones, carved into clay, written on papyrus, or scratched into wax tablets, and a little bit of what was written survived.
Some people whom I truly admire can actually read and understand it today. Look at some of those old texts and you see why I really think highly of the experts who can make sense out of that:

Luwian hieroglyphics, Phoenician and cuneiform

Source: Photographed at Karatepe / Internet at large

So what do we learn about early (iron) metal science and technology from what the ancients wrote about it? Unfortunately not much! Those guys wrote mostly about other topics, typically about commerce, law suits, religion and advertising (the deeds of the Noble). True, occasionally they were also concerned about serious issues like making beer and left recipes, but metal making? Sorry. No interest there.

- Quite good engineers must have existed as early as 2500 BC. Just try to build a major pyramid with only bankers, lawyers and priests and you see my point. Prolific scribes existed too, who covered every available flat surface in Egypt with pretty hieroglyphics.

  In what must be square miles covered with hieroglyphics, demotic or hieratic script, the total amount of words or symbols dedicated to pyramids and pyramid building, something hard to overlook even in present day Egypt, is exactly zero. Same thing for the extensive copper-tool making business that went with pyramid making. Nada!
  Same thing for the old Greeks, Assyrians, Hittites, whoever. At best there are a few indirect remarks about commerce in metals that are open to interpretation and do not really help all that much.
  I have collected whatever there is - as far as I could find it - and you are welcome to check the module.

Misc. Link

Iron in writing

It remains to ask our standard question now:

Who smelted Iron for the first time?
When and Where?
And how, exactly?

You know by now that this it a rather naive question with no real answer at present (or probably ever). In the copper case, one problem was to differentiate between native and smelted copper, in the iron case we don't have to consider that. While native iron actually exists, it is exceedingly rare and has never been found in Eurasia. Instead we have a new problem! We must differentiate between *smelted* iron and ***meteoritic* iron**!
By the way: So far and in what is coming I use the term "iron" for everything that is *iron-based* - wrought iron, steel, meteoritic iron - nickel alloys, whatever. For a lot of ancient "iron" the composition is not known anyway, and it just get's to cumbersome to differentiate between all the iron manifestations.

Now I have opened a rather large can of worms. While you most likely will not find an iron-nickel meteorite on your next hike, quite a few have been found by somebody else throughout the centuries / millennia. It is perfectly possible that some ancient people not only found a meteorite but used it for making iron things. In fact, there is no doubt that some old iron things have been made from meteoritic iron. However, the attitude of some scientists and curators to pronounce any piece of iron from before about 1200 BC without a detailed analysis to be meteoritic iron is not scientific but lazy. Here is an example.
I give you a special module on meteoritic iron.

Advanced Link

Meteoritic Iron

Here I will only consider iron that is definitely from before 1200 BC - either smelted or meteoritic. It is not an easy thing to do. Most recent articles about early iron typically spend many pages on discussing why some artifact that was supposed to be early iron actually wasn't, why this or that analysis isn't quite right, why some piece thought to be meteoritic iron actually isn't or the other way around. And so on. I could easily compile a much longer "confusing the issue" list than I did in the case of early copper but I won't .
Let's just look at some major objects and discuss a few general conclusions. For more details I will provide links.

What I'm going to look at is:

- The Alaca Höyük dagger from 2800 BC - 2500 BC.
- Pharao Tutankhamun's iron dagger from 1323 BC.
- The "Great Pyramid Iron Plate" from around 500 BC (???).
- Some unimposing artifacts from here and then.

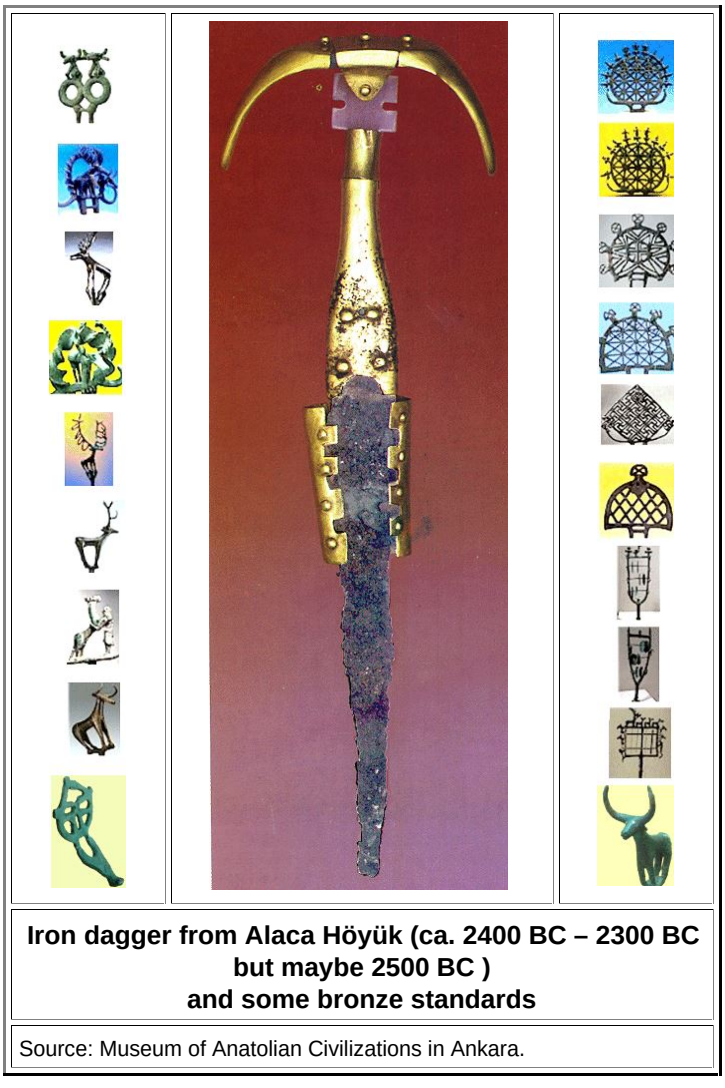
The Alaca Höyük Dagger

Alaca Höyük is the present name of the tell or settlement hill that contains the remains of the capital of ancient Anatolian kingdoms; see the link. Alaca Höyük predates the **Hittite empire**, in which it became absorbed after about 1800 BC. It was discovered and partially excavated rather early in 1910. Its fame comes from several royal tombs that contained rich "treasures", in particular bronze "standards". It is the earliest "iron site" I know; the link gives two more early iorn places.

Advanced Link

Early Iron Sites

Grave K contained the **iron dagger**. Here it is:



**Iron dagger from Alaca Höyük (ca. 2400 BC – 2300 BC but maybe 2500 BC)
and some bronze standards**

Source: Museum of Anatolian Civilizations in Ankara.

Dagger from the Royal Tombs of Ur, ca. 2300 BC - 2600 BC

Source: Internat at large

- The dagger does show some wear and tear after having been buried for 4500 years in a tomb. But all things considered it looks far better than its owner. It is similar to a (copper blade) dagger found in the **Royal Tombs of Ur** as shown. The age of the Ur dagger seems be a bit unclear but it is comparable to that of Alaca Höyük.

Taking 1200 BC as the beginning of the iron age proper, the dagger precedes that date by 1200 years. It's like finding a mobile phone in an 800 AD settlement, sort of early Vikings. In other words: discounting small and completely corroded stuff, the Alaca Höyük dagger is the oldest undisputed sizeable iron artifact known at present.
Does that prove that some smart guys in Anatolia could smelt and process iron that early? Or, considering that Turks are master traders, that the Alaca Höyük guys just knew from where you could import it? Did the smith who forged the dagger use meteoritic iron or smelted iron?

- The last question could be answered, at least in principle - see the link. However, an unambiguous answer needs a detailed metallographic analysis, partially destroying the artifact. This is unthinkable and thus the final word is not yet in. A Japanese team in 2008 published in a preliminary report that substantial amounts of nickel are contained in the "rust" of the dagger. If there is a final report I have failed to find it. A high nickel concentration does indicate meteoritic origin, indeed, but does not unambiguously prove it. Moreover, older investigations yielded much lower nickel concentrations according to **Ünsal Yalçin** [1)].
  More about early artifacts in this link

Advanced Link

Early Iron Things

What can we learn from the Alaca Höyük Dagger? In my opinion, the following:

- Somebody somewhere around the Mediterranean definitely knew how to forge iron around 2500 BC. This leaves open if it was smelted iron or meteoritic iron. Forging the dagger blade from a lump of iron was not easy, and the necessary technique was not known from the copper or bronze casting technology. While it is likely that "somewhere" is not too far away from Alaca Höyük, long distance trade cannot be excluded. It was definitely established (via the Assyrians) somewhat later
- Somebody somewhere possibly knew how to smelt iron or that iron could be produced unintentionally while smelting copper. This conclusion cannot be deduced from the dagger alone. There are other iron finds from Alaca Höyük and elsewhere from the time period in question, however, and while these pieces are small and often fully corroded, they were definitely not meteoritic iron.
- Iron was an extremely precious metal and very rare in 2500 BC. There is only one iron dagger in the royal tombs but plenty of precious bronze standards.

The Iron Dagger of Pharao Tutankhamun

Pharao Tutankhamun, or **King Tut** in short, was one of the least important Pharaos then but is the most famous Pharao now. His present fame stems from the fact that his tomb is the only one that has been found with all his grave goods still there.

- Tutankhamun "ruled" nine years from 1332 BC – 1323 BC and died when he was about 20. From a recent DNA analysis it is all but certain that the "enigmatic" Pharao **Akhenaten** was his father. Akhenaten abandoned traditional Egyptian polytheism in favor of monotheism (first time that happened!) and moved the capital out to the sticks in **Armarna**. His "official" name was Amenhotep IV or Amenophis IV. This means "Amun is satisfied" while Akhenaten means "living spirit of Aten"; with Aten a kind of sun God and the only one. His father was Amenhotep III of the **Armarna letters** fame.

King Tut's grave contained a lot of amazing stuff but here we are only interested in his two daggers. They were found close to his body in the gold sarcophagus making clear that they were among his most precious belongings. One of the daggers had a gold blade, the other one a blade of iron.
Here they are:

King Tut's gold and iron dagger
Large picture

Source: All over the Net

- King Tut's dagger ties right in with the "Amarna letters", the archive of Amenhotep III, written in cuneiform and found in Amarna. One of the letters from the Mittanni King *Tushratta* (a kingdom at the southern edge of the Hittite empire in Anatolia and eventually absorbed therein) from about 1370 BC mentions the shipment of gifts to Egypt, including daggers with *steel* and *iron* blades. It is quite possible that King Tut's dagger is actually the one his grandfather obtained, or a new one from the same source.
  King Tut's dagger is certainly the best conserved iron artifact from early antiquity. It is also enshrouded in mystery: it was never properly investigated as far as I could tell - *when I wrote this in 2014*. Now, in May 2016 things have changed. The dagger has been investigated (up to a point); here is the original paper of Daniela Comelli and 12 coauthors. The study is of very high quality and leaves no doubt:

King Tut's dagger was made from meteoritic steel!

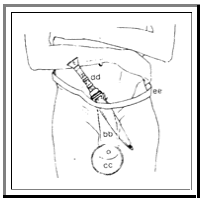
- The same result was found once more by A. Jambon and published with great fanfare in Jan 2018. Here is the article by the Süddeutsche Zeitung, Germany's leading newspaper. The article can also serve as a prime example for making all the usual mistakes concenring the smelting of iron - and it contains a few idiocies of its own!

Considering that the dagger was found in 1922, there would have been ample time to investigate before 2016. Why did it take so long? There are two reasons I can come up with:

1. As soon as one visits the world-famous Egyptian Museum, the pyramids, etc. one perceives right away that most present-day Egyptians, including the heads of the Antiquity ministry etc., are not scientifically interested in what they have. They are only interested in how to make a buck out of it.
2. Methods for non-destructive analysis of artifacts did not exist many years ago. The powerful modern techniques (essentially X-ray based) that give unambiguous results are relative recent achievements.

So what do we know about King Tut's dagger?

- It was often supposed to be of meteoritic origin. There weren't any data substantiating this claim, until now. Contrariwise, many scientists up to now supposed that it was made from smelted iron. That was a reasoable assumption given the **Armarna letters**.
- Iron was *still* an extremely precious metal and *still* very rare in 1323 BC, about 1200 year after the Alaca Höyük dagger. King Tut's iron dagger was his most valuable possession and degrades the other stuff in his tomb, including all the gold, to just high-class junk. Just look at where if was found. One is tempted to invoke certain symbolic meanings of swords (or daggers in the case of boys).
- Somebody somewhere definitely knew how to forge iron around 1400 BC. And so on. See above.
- It is obvious that the Egyptians made the hilt. They made it to match the hilt of the gold dagger, and they made it small (for the small hands of the Boy-Pharao Tut?). A part of the tang of the blade is clearly visible. This may indicate that the Egyptian craftsmen did not know how to shorten the tang.



The third point in the list above is of considerable interest. Did the person who made the dagger learn the forging technique by working with meteoric iron only? That seems not very likely. We might rather assume that some iron was actually made by smelting, either intentionally or as an (unwanted) by-product of copper smelting. Forging techniques may have emerged by fooling around with this (inferior) stuff. The **Armarna letters** also indicate that iron could be made somewhere in the Hittite sphere of influence. However, an object as large and as uniform as King Tut's dagger could "obviously" not be made with the smelted iron from around 1300 BC.

The Ceremonial Axe of Ugarit

Ugarit was an ancient port city in northern Syria; its ruins are called Ras Shamra. Ugarit had close connections to the Hittite Empire, sent tribute to Egypt at times, and maintained trade and diplomatic connections with Cyprus. The city state was at its height from about 1450 BC until its destruction around 1200 BC by the Sea Peoples during the Bronze Age collapse as related above.
Archaeological, Ugarit is considered quintessentially Canaanite. A brief investigation of a looted tomb was conducted by Léon Albanèse in 1928 and serious digging was done since 1929 by archaeologist Claude Schaeffer from the Musée archéologique in Strasbourg. Work continued under Schaeffer until 1970, with a break from 1940 to 1947 because of World War II.

The axehead shown below is dated to the 14th - 13th century BC. It was found there quite early and already described as having a *meteoritic* iron blade with a bronze socket inlayed with silver and gold.
On the back of the axe we see a boar, while the axe bade is sort of coughed up (or "roared out") by two lion heads. The animals are rendered quit well, the gold and silver inlays, however, are a bit haphazard and leave something to be desired.

Iron axe from Ugarit; 1400 BC - 1300 BC
Aleppo National Museum (we hope)

Source: Beyond Babylon: Art, Trade, and Diplomacy in the Second Millennium B.C. , Aruz, Joan, Kim Benzel, and Jean Evans, eds., Metpublications, 2008 (free access)

- Very recently (end of 2017), Albert Jabon, mentioned right above, confirmed that the iron is of meteoritic origin. Once more we have to accept that the axe is bo prove for the existence of an iron smelting technology before about 1200 BC. It does, however, prove once more that some people knew how to forge iron rather early on, possibly before they knew how to smelt it.

The Great Pyramid Iron Plate

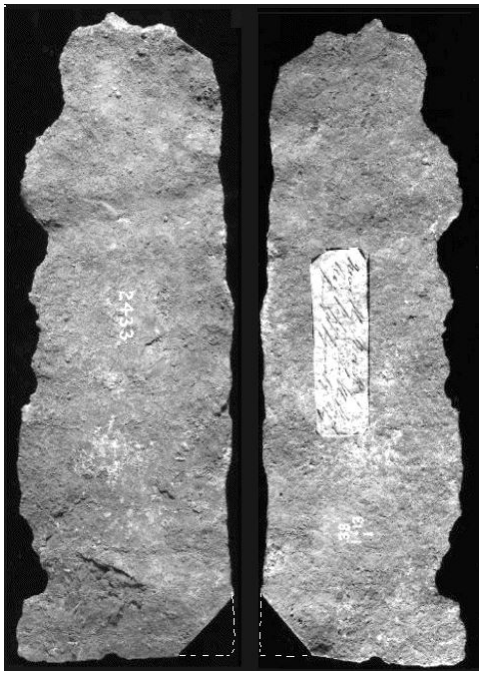
The Great Pyramid of Giza or the Pyramid of **Khufu** (also called **Cheops**) has exercised scientists, normal people and crackpots mightily for thousands of years. In the millions of Internet sites to the Great Pyramid, the contributions of real scientists (as opposed to self-proclaimed ones) are about as frequent as engineers in a fashion show. Interestingly, the other pyramids in Egypt are of only little interest to "Great Pyramid" fanatics, notwithstanding the fact that some of them are almost as big and complex as the "Great" pyramid.

- Some issues around the Great Pyramid even have the potential of turning real scientists into particular craggy crackpots; witness, for example, Charles Piazzi Smyth and his "pyamid inch".
  The issue of interest to us here is the "*Great Pyramid Iron plate*".
  The history of this piece of iron is quite fetching. In 1837, Colonel **Howard Vyse** blasted away parts of the structure around the supposed endings of the "air shafts" leading up through the bulk of the pyramid to outlets high up on the outside. Here is the present-day ending of the southern air-shaft from the King's chamber. At least two layers of stones are missing.

The coming-out of the air shaft of Khufu's pyramid

Source: Rudolf Gantenbrink 1999 Internet page (http://www.cheops.org)

- On Friday, 26 May 1837, after dynamiting away for two days, a man in Vyse's team, one J.R. Hill, discovered a flat iron plate about 26 cm × 8.6 cm in size with a thickness ranging from 4 mm to nearly zero.
  Vyse proclaimed it to be "the oldest piece of wrought iron known" and set off an ever-lasting dispute. The iron piece was brought to the British Museum where it still resides.
  Here it is:



The Great Pyramid Iron Plate - front and back
The missing corner was sacrificed for analysis.

Source: British Museum

I will not enumerate all the opinions put forth by half-way knowledgable or at least prominent guys in the 150 years or so after the discovery of that unassuming iron artifact. I will only mention two:

- The mining engineer **Herbert Hoover** (1874 – 1964), together with his wife, translated in his spare time the famous book "**De Re Metallica**" by **Agricola**, from Latin to English. in 1912. In some footnotes he offered his thoughts on the history of iron, in particular that the iron age began much earlier than is usually assumed. The iron plate of Gizeh was interpreted as a clear hint that very early Egyptians could produce iron. And yes, H. Hoover was also the 31st President of the United States from 1929 to 1933.
  Those were the good old times when American Presidents could afford to be intellectuals. But then as now, they were not necessarily always right with their opinions.
- **Oleg D. Sherby**; Emeritus Professor of Materials Science and Engineering, Stanford University, and **Jeffrey Wadsworth**, President and CEO of Battelle Memorial Institute since January 2009, are not exactly crackpots but eminent and well-known Materials Scientists. They go right along with President Hoover's view of the early prominence of iron in a number of papers and also refer to the Great Pyramid Iron Plate as an important artifact supporting their views. They actually go as far as to suggest that Neanderthal man might have known how to make iron more then 40.000 years ago [4)] .

If these eminent men view the Great pyramid Iron Plate as the pivotal point for a new and revolutionary view on human history, it behooves us here to consider what we know about that piece of iron. Quite a lot, as it turns out. There have been two in-depth metallurgical investigations. The specimen were cut from the plate, witness the "missing corner" in the picture above.

The **first analysis** was done in 1989 by El Sayed, El Gayar and M.P. Jones [2)]. They reported that

- "*The plate consists of numerous laminates of wrought iron and that these laminates have been inexpertly welded together by hammering. The various layers differ from each other in their grain sizes, carbon contents, the nature of their non-metallic inclusions, and in their thicknesses...*"
  In addition, they also found
- "*small, but significant, proportions of gold ... in one of the oxidized layers and it is thought possible that the plate may, originally, have been goldplated*".
- Their final conclusion was:
  "*It is concluded, on the basis of the present investigation, that the iron plate is very ancient. Furthermore, the metallurgical evidence supports the archaeological evidence which suggests that the plate was incorporated within the Pyramid at the time that structure was being built*".

So there!

The **second analysis** was published in 1993 by Paul Craddock and Janet Lang of the British Museum [3)]. The authors went through all the proper moves of an in-depth analysis of both a fresh piece and the old piece investigated 4 years earlier. Their major findings were:

- "*The structure of the iron in both sections is very similar and we are in broad agreement with El Gayar and Jones on its identifications if not interpretation*".
- "*We must report that despite extensive searches no trace of gold could be detected, and it is our firm opinion that the original report of gold is incorrect*".
- The iron comes probably from a post-medieval and still crude cast-iron technology plus a "fining process" for making steel.
- "*This* (the findings) *strongly suggest that the plate of iron from the great Pyramid is of no great antiquity*".

So there???

While I'm inclined to go with the second analysis, the issue remains open. Is that piece of iron very old or not? Determining the age by a radiocarbon analysis might provide certainty in the future, maybe. Until then we need to wait. We might ask ourselves another question: does it matter if that piece of iron is about 4500 years old or rather recent? Obviously it matters very much to Sherby and Wadsworth and everybody else who believes that the "official" history of metals in general, and that of iron in particular, as put forward by archeologists and their ilk, is majorly flawed.

We already faced the "really no gold use before about 4500 BC ?" enigma, and now we have the "smelted iron use well before about 1500 BC - yes or no?" controversy. Would the Great Pyramid Iron Plate, if really about 4500 years old, tip the scales in one way or other?
I doubt it.
First of all, both investigations agree that the plate is made from smelted but very "bad" iron. It does thus not attest to a well developed technology.
Second, there are a few more but less well-known iron artifacts from well before 1500 BC (mostly disputed, of course) that indicate that early mankind occasionally did make iron. This could have happened accidentally during copper smelting or because somebody experimented a bit without a clear goal in mind. We don't know.
We do know, however, that iron objects were considered to be extremely precious at least up to 1300 BC, witness King Tut's dagger and the royal correspondence concerning iron. As far as I'm concerned, this proves beyond reasonable doubt that no significant iron smelting and working occurred in the "larger" Mediterranean before about 1200 BC. The pyramids, in other words, have not been made with iron / steel tools.
On the other hand we cannot rule out with certainty that the Neanderthals, or other very early cultures might have made iron that either has vanished without a trace by now or hasn't been discovered yet. It is just is not very likely; just as in the gold case.
The real enigma thus is:

Why was no iron made before about 1200 BC?
The technology for smelting iron was available!

To put it in other words: Why did the iron age "proper" start around 1200 BC and not much earlier? That brings us right back to the beginning of this chapter.
The answer, whatever it will be in the end, must include an often overlooked part:

It is a long way from smelting some iron to making an iron artifact like a knife blade

- Iron smelting going well always produced *solid* iron. If it resulted in something *liquid* it was cast iron and that was quite useless in antiquity (with the exception of China). While liquid metals as in copper smelting etc. just "run out" of your furnace if you open a tap hole, or will be found neatly solidified at the bottom, you now must learn how to get this solid iron called a "bloom" out of your smelter. Then you must learn how to refine this (very dirty) bloom in several stages, all involving "smithing" and requiring a suitable hearth. Finally you must learn how to make objects exclusively by "banging" your iron with a hammer, and how to make big pieces by joining smaller ones by fire welding. On top of that comes the art of thermal treatments, including hardening by quenching.
  All of that is competely new. Nothing remotely similar is needed for copper and bronze technologies. Many amateurs and professionals are out there doing iron smelting and iron working experiments right now, and they all learn the hard way that the whole "**technology chain**" is far more difficult to master than you could possibly imagine! It is not something that you learn during a weekend with the boys.
  This simply means that it takes a while before the technology is established by trial and error. But after that has happened in a few places, it can be passed on from master to apprentice and start to spread.

Before I go deeper into all this, I will quickly run through a few more old iron objects.

Old Iron - Odds and Ends

Ünsal Yalcin in his 1999 paper[1)] lists more than 10 iron objects from 10 Anatolian sites from before 1200 BC. The Alaca Höyük dagger is there, of course but typically the description is "needle", "jewelry", "fragments of unclear uses", "weapons" or "knifes". Some of the needle heads were gilded, and the meteoritic origin of some objects could be ruled out because they contain no appreciable nickel. Some objects are likely not really iron, and others are completely corroded with hardly any iron left inside (easy to find out because they don't react to a magnet).
Jane Waldbaum in her masterly review from 1999 lists around 150 early items from all over, again with denominations like anklet, bracelet, ring, pin (or jewelry in other words), piece, lump, fragment, wire, rod, etc. Nothing very substantial. She discusses these artifacts at length and I can't resist to give a few quotes:

- "*With the exception of* ...(some 10 objects) ... *all the recent additions* (about 50) *to the repertoire* (about 100 objects) *are either jewelry pieces or fragments that cannot be identified*".
- "*(...) several pieces, earlier said to be iron, have been shown not to be on recent examinations*".
- "*The point* .... (if Ni always signals meteoritic origin) .. *has also been raised by Piaskowski (1982) who performed metallographic analysis on a series of nickel-rich iron objects .... and showed that they had, in fact, been smelted*" .
- "*Analysis of several 100 Late Bronze Age artifacts from .... Timna .... of southern Palestine, in fact, showed 'substantial quantities of metallic iron in the copper' (Rothenberg 1988:12), while analyzed iron artifacts from the site contained significant amounts of copper*".

I could not find any pictures of the early stuff, but the picture below probably comes close. It shows rings and needles from the Karagündüz necropolis in the Van area (eastern Anatolia) from the 10 / 11th millennium BC, a time horizon when iron in this area became rather common. The older stuff mentioned above is rather less well conserved.

Small iron things (jewelry) from 1100 - 1200 BC (Karagündüz, Turkey)
Large picture

Source: Hadi Özbal, Istanbul University:"Ancient Anatolian Metallurgy", a Powerpoint presentation in the Net.

What do we learn? In the first place, we see how science works. It will eventually arrive at "The Truth" or at least get very close, but rarely in a straight-forward way. Typically we get there with a lot of back-and-forth movements, long pauses, plus a few excursions into mined areas. The path is lined with fallen warriors and memorials for the heroes; not all of them deserved.

Otherwise we learn once more what we already know or at least suspected:

- There was definitely non-meteoritic iron in use early on.
- Early iron was rare and therefore often used for jewelry. Then as now, only the elite could afford expensive jewelry.
- Copper smelting quite likely did produce some iron every now and then. It's not "good" iron but still usable for small things.

All in all, I'm inclined to make a strong case for:

There was no sizeable iron production anywhere on this planet before - roughly - 1200 BC !

That's a strong statement. It might be wrong but for the time being I'll stick with it. The question, once more, is: why? Why was the iron age kicking in so late? Let's look at some of the explanations offered.

What Started the Iron Age?

The *first hypothesis* assumes that people had no choice.
They still would have preferred to make bronze but the mayhem of the bronze age collapse, with constant warfare and breakdown of trade, in particular the *tin trade*, put an end to that. If you can't get tin, supposedly always coming from far away sources like Cornwall / England or Afghanistan, you can't make bronze.
This hypothesis rests on two assumptions:

1. People preferred bronze to iron. That implies that they actually knew iron and how to make it but wouldn't do that as long as they had bronze.
2. Tin supplies broke down. This implies that there were no relatively near-by tin sources that could be exploited even under adverse circumstances.

Let's look at these two points in some detail.

1. People didn't like iron? Could that be true? After all, the few early iron pieces found were obviously considered to be of tremendous value, and the rich and powerful used early iron for jewelry or other showing-off items!
That is certainly true - but does not exclude the possibility that *normal* people didn't like iron for everyday things.
There are a number of possible reasons for this:

- Any iron / steel produced in whatever way and for whatever reason, could *not* be melted and cast. If casting is your main metal-working technology, you do not like that. Making metal objects by *forging* instead of *casting* needs all kinds of skills and tools that people simply didn't have.
- If some *cast iron* was accidentally produced (unlikely but possible), it could be cast but was brittle and very hard and thus not all that useful. It could certainly not replace most bronze objects.
- The iron produced as a by-product of copper smelting always contains substantial concentrations of copper. Unfortunately, copper in iron makes for rather bad steel, difficult to forge. Many an early smith or metal worker who tried to make something from the stuff probably gave up in frustration. The rest made small things like rings and pins that could be sold to the lazy part of the population that didn't need real tools.
- Attempts of direct iron smelting might have produced wrought iron in a solid "bloom". The chain of processes needed for making anything from that (starting at removing the bloom, compacting it while still hot,...) was neither well-known nor obvious. It involved a lot of work, and final products were no better than bronze counterparts. Wrought iron is not harder than bronze, remember? So why bother? The fact that the bloom was most likely a very inhomogeneous mixture of all kinds of steel didn't make things easier either.
- All that iron stuff corrodes or rusts. Some kinds more than others, but all kinds far more than almost completely corrosion-resistant bronze.
- Iron smelting in all early versions is far less efficient than copper smelting. You put a lot of valuable charcoal, ore and flux into you smelter and get only a little bit of iron, if any at all.

Quite a list! Looks rather convincing to me. At least it is easy to see that iron might have had a bad image with early metal engineers. Now let's consider the positive points:

- From iron one can make silvery or silvery-white objects. Considering that this appearance was much in demand, it might have had a small but important market. Not only could it replace silver to some extent for

making jewelry, it was somewhat different, more expensive and exotic, always a good point when selling to the rich. Even today the really rich go for platinum jewelry instead of just bourgeois silver.
- With luck, some good carbon steel could be produced on occasion. With even more luck, objects forged from it would case-harden if quenched. The final product then might have been far superior to the best bronze stuff., especially if used for knifes and swords.
- Smelting and working wrought iron is easy - *if you know the tricks*. Very simple furnaces, fed with local stuff, would do. Almost everybody could do it, and you didn't need to import anything (like tin for bronze). While wrought iron swords and knifes were no better than bronze stuff, they were no worse either and you, or your local smith, could make them. And wrought iron was just fine for all the everyday stuff like pots, pitchforks, hooks, nails or chastity belts.

I think we have sufficient reasons to accept that people might have switched to iron when tin supplies broke down. But did that really happen?

2. Until about 20 years ago, archeological research had identified only a few places where tin mining took place in antiquity, all of them rather far away from the centers of bronze technology. Meanwhile major tin sources, going back to the third millennium BC, have been found in Anatolia, e.g. the Kestel mines in Göltepe. There might be more tin sources not all that far away from the bronze makers not yet identified, and this means that tin trading could still have occurred.
Moreover, with modern techniques it is possible to determine where the tin in some old bronze objects came from. Results of analyzed bronze objects from around 1200 BC or even younger seem to indicate that the tin trade was *not* suffocated in a major way around 1200 BC. And we do know that bronze never disappeared; a lot of bronze was made parallel to iron all the time.
The last word isn't in yet but we might conclude:

The iron age did not start because a lack of tin after 1200 BC.

The *second hypothesis* suggests that people on Cyprus or Palestine mastered the production of steel around 1200 BC, including quench-hardening, and that the new *and superior* technology spread from there.
This pronouncement is based on many *steel* objects found in Cyprus, dating to the early 11th century. Some knifes even must have been quench-hardened *and* tempered! Similar findings are reported from Palestine, and I take this information (like much of the rest) from Jane Waldbaums's article. The link provides for the aticle; here is the quote

> However, the carbon concentration varied quite a bit between all the artifacts investigated. It is thus not clear if the production of good steel was accidental or the result of determined efforts that were just not always applied or failed on occasion. It is conceivable, of course, that some metal engineers became aware of the stupendous possibilities of iron /steel, and dedicated time and effort into finding out how one could produce the good stuff in a more systematic way.

> There are parallels to this in modern science. The potential of semiconducting materials for "electronics" was recognized around 1930 but the science of semiconductors was not well understood. Nevertheless, some products based on semiconductors were made and sold, e.g. the early "crystal detector" radios or the selenium (Se) based "diode" rectifiers still used in electron tube devices in the 60ties of the last century. Nobody quite knew how these things worked but that didn't prevent their large-scale use.
> Even more to the point, the first "real" commercial transistors, based on a well-understood theory, were made from germanium (Ge) in 1950 / 60. Silicon was just not up to the job, even so it "occasionally" did produce much better products. We (I include myself here) first had to learn how to make it "just right", and how to process it. After that silicon completely crowded out germanium, just like iron / steel crowded out bronze.
> My conclusion is

Iron crowded out bronze for "cheap" objects after the complete technology chain became known.

The *third hypothesis* invokes ecological reasons. In particular **Theodore Wertime**, one of the great old men of archeometallurgy, argued that the bronze industry around 1200 BC had exhausted the supply of wood / charcoal and was forced to switch to the more fuel efficient iron smelting. Two questions come up in this context

1. Is there archeological evidence for heavy deforestation in the areas of concern?
2. If yes, would iron smelting indeed provide a way out of the problem?

- The answer to both question is: No! There is evidence for some deforestation but it is not conclusive. And iron smelting is not more fuel efficient than copper smelting, in particular if not yet optimized. The demands on charcoal are just as large than for copper smelting, at best there is a marginal advantage. This is the present view of mainstream archeology.
- I have a personal view on this. If charcoal supply to a metal making and working center becomes difficult because the stuff has to be transported over larger and larger distances, iron smelting does offer an advantage: Moving your smelter and the "smithy" to where the charcoal is will be far easier than moving your bronze production place, and the chances of finding iron ore nearby are much larger.
  The smelter may be less efficient but is smaller and easier to make, and you don't need the mould makers, the people needed for alloying, melting and casting the bronze, not to mention the traders for charcoal, ore and tin. All that is either not needed or available close by. The infrastructure for making iron things is simply far less involved than that for making bronze things.

The issue thus may not only concern the charcoal supply. The advantage of iron is that *decentralizing* the whole metal business, advantageous for several reasons in times of turmoil and chaos, was easier done for iron in comparison to bronze.
Of course, the people involved did not get together and decided that it was time to decentralize, and to do that by switching to iron technology. It just happened by straight evolution. Some yokels entrenched in remote woods could still produce (bad) iron when the big metal center close to the city was overrun and destroyed by some foes together with the city. Survivors took what they could get - a not-so-good iron knife / sword, after all, is still better than no knife / sword, and the increased demand triggered improved technology.

- We might conclude:

Making iron is easier than making bronze with regard to the necessary infrastructure. That is advantageous in times of chaos, crumbling empires and general warfare.

I'm sure that there are more possible scenarios that have been put forward by experts - but I will stop here. You are free to subscribe to any of the three hypotheses discussed. You will be in good company and you will have some adversaries.
As far as I'm concerned, I believe that everything mentioned above played a role somewhere and sometime, but not everywhere and all the time. It is a simple game of **evolution** once more. Smelting processes always contain a certain **mutation** rate, i.e. variations in the process for all kinds of reasons. On occasion a mutated Cu smelting process produced some iron, for example. Maybe the quality of the charcoal was a bit different, maybe some worker made an error in the amount of flux (often iron oxide) put in the smelter, whatever. Some of those mutations produce a little iron, some produce something else, and some do not noticeably change the product. As long as the environment is stable, mutations in the output are thrown away and thus do not survive. There are long and learned papers to a Darwinian evolution / mutation process concenrng the makin of iron [4)]
If the environment changes - your empire breaks down, no more tin coming in this month, your charcoaler has been killed by enemies, your local elite-customers ran out of money - mutations are seen differently. "Natural selection" will now see to it that those mutations thrive that allow the people involved to cope better with the challenges of the changed environment. In time the mutations take over. This can happen rather quickly because in troubled times the "mutation rate" in bronze technology must have gone up, since people were forced to experiment. You can't get your usual ingredient for flux anymore? Before you stop operations you try some alternative. You have mutated the process! The old process is kept for whatever it could still do better. Bronze never went quite out of style, and Roman officers still had bronze swords in use, for example.

- Nobody knows what really happened 3200 years ago. And nobody will ever know in detail. We don't know exactly what caused the first and second world war either, otherwise there wouldn't be so many books and conflicting opinions. Why did the age of electronic computers start in the second half of the 20th century? Was the technology invented at one place and then spread? Views differ widely, something quite amazing because electronic computers were clearly a German invention, of course.
  Seriously now: major inventions leading to completely new products and life-styles - cars, electricity. computers, refrigerator, washing machines, television, oral contraceptives, ... - are always coming up more or less independently at several places around the same time. All that is needed is a bit of communication across the borders. I see no reason why it should have been different 3200 years ago.

Now that we have finally started the Iron Age, let's smelt some iron and steel.

1) Ünsal Yalçin: "Frühe Eisenverwendung in Anatolien", Istanbuler Mitteilungen, Band 48 (10998) p. 79 -95

2) El Sayed, El Gayar and M.P. Jones: "Metallurgical investigation of an iron plate found in 1837 in the Great Pyramid at Gizeh, Egypt" ,Journal of the Historical Metallurgy Society, Vol. 23 No. 2, 1989, pp. 75-83.

3) Paul Craddock and Janet Lang: "Gizeh Iron Revisited", JHMS 27/2 (1993), pp. 57 - 59.

4) Oleg D. Sherby and Jeffrey Wadsworth: "Ancient blacksmiths, the Iron Age, Damascus steels, and modern metallurgy", J. Mat. Processing Technology, Vol. 117 (2001) pp. 347-353.

5) Michael F. Charlton, **Peter Crew**, Thilo Rehren and Stephen J. Shennan: "Explaining the evolution of ironmaking recipes – An example from northwest Wales", Journal of Anthropological Archaeology 29 (2010) pp. 352–367

6) 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