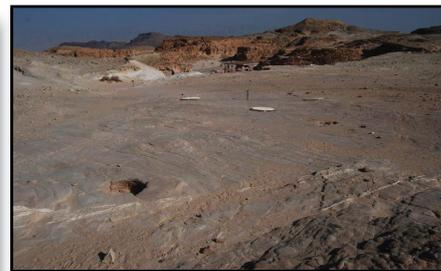


# ANCIENT MINING IN SAUDI ARABIA



We know from ancient sources and archaeological findings that some 10,000 years ago Neolithic hunters and gatherers on the Arabian Peninsula started to use flint stone arrow heads and fist knives for hunting and food processing.

The next stage of development was the finding and recognizing of surface ore deposits and the accidental discovery how they melted upon being hit by lightning. Over time this finally led to an already rather sophisticated production of bronze items such as arrow and spear heads as well as small weapons.

This period was therefore called Bronze Age, which later was followed by the Iron Age when stronger weapons decided who won a fight or battle. Many silex or fire stone surface deposits still can be seen today throughout Saudi Arabia, and when you are lucky you might find some flint stone arrow heads nearby.

We have to say that the lightning storey is not scientifically proven and based more on the imagination of modern man. Tedious research and use of new technologies have recently shown that ancient human beings such as the Homo Neanderthalensis were far more developed than we previously thought and possibly had a much higher level of sophistication in using tools and knowledge about their environment.

It has also been proven that they were able to communicate by detailed speech rather than groans. This is certainly also true for the hominids living in our region 10,000 to 3,000 years ago and the ancient knowledge and sophistication of mining tools and smelting methods.

## First Mining on the Arabian Peninsula

There are very few ancient sources and detailed reports about mining activities in Saudi Arabia, but what we do know is that serious and organized mining first started around 3,000 years ago in Saudi Arabia.

Ancient mining activities in Saudi Arabia were strongly influenced by a varying demand for metals and gemstones to be used for tools and

weapons as well for the construction and decoration of buildings.

Each historical era had its special demands for such commodities and the exploitation of the Arabian Peninsula's natural resources started with the early humans in the Stone Age, to be commercially perfected by the ancient empires such as Egyptians, Assyrians, Babylonians, Persians and Romans between 5,000 to 2,000 years ago.

Neolithic, Bronze and Iron Age mining sites are mainly of archeological interest, but more effort was spent by geologists identifying such places as part of their exploration surveys, targeted to find economically interesting gold, silver and copper occurrences in Saudi Arabia.

Thus during the last 50 years over 1,000 ancient mines and workings were detected and promising sites were studied in detail. Luckily we can say that exploration geologists documented valuable information about the locations and operations of historic mines, but unfortunately this was not taken into consideration that often by Saudi archeologists.

Despite new programs to protect the archeological sites dating back from the pre-Islamic period, we have to suspect that many historic mining sites will successively disappear due to the start of new mining operations usually destroying any remains of the ancient mine workings in the vicinity.

There is no consensus between expert archeologists as to which kind of deposit was first mined by mankind. But it is widely assumed that early hunter and gatherers were attracted by gold nuggets found on the banks and in the sandy riverbeds where they preferred to camp and hunt.

Due to its shiny beauty, endurance and resistance to weathering ancient men regarded gold as a sought after and high value item. They possibly related gold even to immortal religious powers and used nuggets as protective amulets.

Advanced gold refinement and artisan works are known from many ancient empires, but there is a lack of knowledge on how the early metallurgical knowledge like the ore smelting process under high temperatures was obtained.

Certainly the 1,000 ancient mines on the Arabian Peninsula were not all active at the same time, but it proves the enormous efforts undertaken to extract minerals and smelt them into high value products.

Main precious metals, ferrous and non ferrous ores mined and produced were gold, silver, copper, zinc, lead, iron, borax and whetstone to sharpen swords. Also semi precious stones such as onyx, turquoise, amethyst, emerald and quartz were mined and used for jewelry.

## How Mining Knowledge was Achieved?

While prospecting knowledge was certainly taught orally and handed over from one generation of ancient miners to the next, an early Egyptian papyrus from 1,160BC records the first written information about a gold deposit in Egypt.

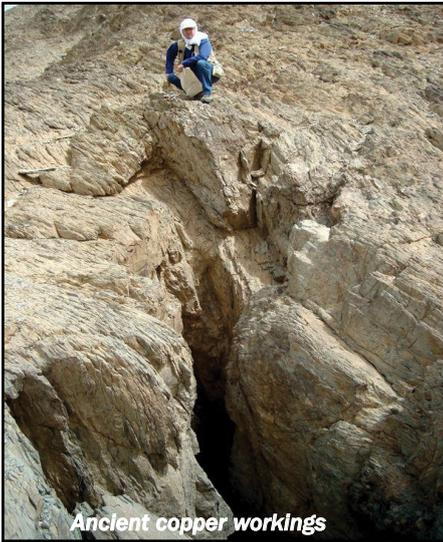
It is the earliest preserved geological map found to date. It provides detailed information about the topography, local distribution of hard rock types, which are indicated by color. Even wadi lithology indicated by hatching and settlements and quarrying sites are marked on the map, as well as the location of the gold mine Bir Umm Fawakhir.

Recently an Egyptian rock inscription was discovered near the ancient Saudi oasis of Tayma in the northern Tabuk province showing the royal hieroglyph cartouche of Pharaoh Ramses III who ruled from 1,192 to 1,160BC.

These royal Egyptian cartouches indicate the presence at the time of Ramses III and early Egyptian activities in Saudi Arabia along the old trading route that connected the south of the Arabian Peninsula with Egypt, Babylonia and the countries further north.

Today we know that trading and exchange of artisan knowledge was much more advanced and active in antiquity than previously thought. It is known that many goods such as incense, copper, gold and silver were transported on this route and it can be assumed that some of the ancient Saudi Arabian mining sites provided refined metals to the trading centers such as Tayma.

Archaeologists have already



*Ancient copper workings*

proved that precious and base metals like gold, silver, copper and zinc have been mined in the Middle East for at least 5,000 years.

Many of these mines were close to the later built Darb Zubaydah pilgrimage route from Bagdad to Makkah, reason possibly being that mines needed water as did pilgrims in later times. These mining operations were owned and run by clans and tribes and in Islamic times became the first public private partnerships with the new Islamic state raising 2.5% Zakat taxes.

They were very labor intensive and therefore large scale operations employing over 1,000 workers. Mahd al Dhahab was a major Saudi mine in operation already over 3,000 years ago. Its mine tailings suggest that over one million tons of ore were mined in medieval times, so it can be assumed that this mining operation produced 1.5 million ounces of gold during its operational life - valued today at over US\$ 2billion.

For its owners, Mahd al Dhahab was a real "gold mine" but please remember that Nabataean traders from Madain Saleh earned more in sourcing pepper spices from India and selling them to the Roman empire 2,000 years ago. Pepper and incense were higher valued than gold at the time.

### Historic Mining 3,000 Years Ago

The mysterious King Solomon mine believed to have been in operation in the Wadi Araba area north of the Gulf of Aqaba about 3,000 years ago has not yet been discovered.

The annual gold production was reported to have reached 600 talents or 35 tons of gold measured heavier common talents of 58.9 kilograms. This was enormous volume at the time when 100% of production was still manual and must have required a huge workforce, possibly slaves.

In connection with this, legendary Queen Sheba of the Yemini based

Saba Kingdom visited King Solomon around 900BC and presented him with six tons of gold as a present for her extended stay. We do know that the Sabaeen kingdom was the only kingdom in history which essentially extended over two continents, as it also owned and controlled large areas in Somalia.

The huge and richly decorated palace of Queen Sheba has not yet been found in either part, so we actually do not know where the gold came from, or whether or not it was acquired from rich earnings from the sale of highly priced incense.

If we consult our history books we will see that ancient civilizations and their rulers built up enormous wealth through mining and our Arab origin Nabataeans were no different. To secure and maintain their trading routes they regularly paid off their attacking enemies to leave them in peace.

The first time this was recorded was in 312BC when they paid 500



*Sampling ancient copper workings*

talents of silver (equal to 13 tons measured in lighter Greek talents of 26 kilograms) to Greek Antigonos, the one eyed general of Alexander the Great.

Later in 62BC Nabataean King Aretas III paid Roman general Marcus Aemilius Scaurus to relieve his siege on Petra with a peace treaty and a tribute to Rome of 300 silver talents. Only seven years later Aulus Gabinius marched on Petra again and was paid off with the same amount of 300 silver talents, which meant that Nabataean mining business was thriving.

At a later stage Nabataeans lost their lucrative Dead Sea bitumen business to the Egyptian Queen Cleopatra. King Malichus had to lease it back from her for an annual amount of 200 silver talents.

### Development of Mining in Saudi Arabia

Mining started in Saudi Arabia on a really big scale about 1,500 years

ago between 430AD to 830AD. At that time the Jabal Makhiyat was one of the mines in production. The Al Hamdah mine assumed to have produced over time more than one million ounces of gold at today's value worth over US\$1.5 billion.

Mining at the time was done by digging shallow open pits to recover visible surface deposits. And when these resources were exhausted, horizontal shafts of up to 100m in length were dug into hills and mountains, or even vertical shafts of three to eight meters in depth.

Today we know of over 1,000 tunnels with a depth of up to 100m dug into the Saudi Arabian escarpments. Sites of many kilns to extract metal have been discovered close to these ancient mines. Charcoal was used to fire these old kilns to achieve the necessary high temperatures of 1,063°C, the melting point of gold.

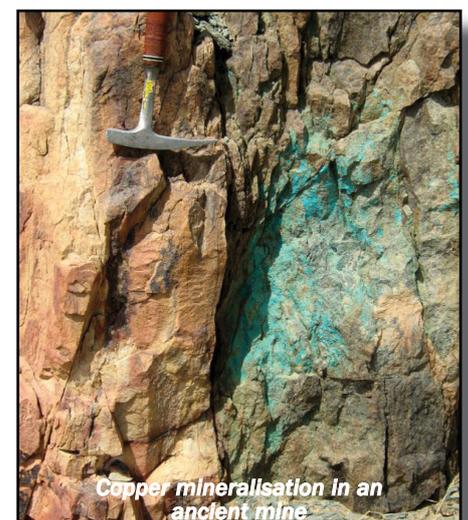
Next to the kilns, tailings and slag piles were found, which tell us more about the composition of ore and its mineralization. Geochemical slag samples show the ore type, flux and the trace elements of metals extracted.

### Life of Early Miners

Early Egyptian recordings were found on a stone stele. The Roman Diodorus Siculus around 56BC describes ancient Egypt miners following with lamp and pick the veins of gold in the earth, children carrying up the heavy ore, stone mortars pounding it to bits, old men and women washing the dirt away.

His record explains the social environment of the miners and certainly was not very different from the conditions presumed to have existed on the Arabian Peninsula around the same time.

"The kings of Egypt collect condemned prisoners, prisoners of war and others who, beset by false accusations, have been in a fit of anger thrown into prison. Ancient Egypt miners, sometimes alone, sometimes with their entire family they send to the gold mines



*Copper mineralisation in an ancient mine*

as miners, partly to exact a just vengeance for crimes committed by the condemned, partly to secure for themselves a big revenue through their toil....

As these miners can take no care of their bodies, and have not even a garment to hide their nakedness, there is no one who, seeing these luckless people, would not pity them because of the excess of their misery, for there is no forgiveness or relaxation at all for the sick, or the maimed, or the old, or for woman's weakness; but all with blows are compelled to stick to their labor until, worn out, they die in their servitude. Thus the poor wretches even account the future more dreadful than the present because of the excess of their punishment, and look to death as more desirable than life."

During the reign of the Caliphates, mining in Arabia was conducted by tribes skilled in exploration and mineral processing. Of these, the Banu Furan and Banu Salim were paramount and often had mines named after them.

A recent study made on skeletons in a Roman copper mine in Jordan revealed the unhealthy environment to which the miners were exposed. The study shows that many of the bones analyzed had a substantially higher concentration of copper and lead than modern individuals retain when exposed to metals through industrial processes.

The toxic effect of lead and copper on the human organism is well known today and thus we can conclude that the health conditions for miners and their families were really miserable.

### Ancient Mining Infrastructure

Many mining villages to house the needed huge workforce were built close to the mines and closely resemble military housing structures leading to the assumption that slaves were used for this hard labor.

Some villages were even fortified taking into consideration the mineral value they produced and possibly also stored on site over longer periods. A few mining villages grew to towns with more elaborate infrastructure including a palace, market place and mosque.

Many wells close to the mines were discovered and were needed to wash the ore, as well as supply the needs of the workers and their families. The Al Abila mining operation site consisted of a village with 300 residential buildings for around 1,000 workers. The Al Aqiq mine was smaller with 100 houses for approximately 350 workers.

### Mining Tools and Methods

Ancient mining was a very hard and labor intensive job. Ore needed to be extracted, transported to the surface, crushed to small pieces, washed and finally melted and poured into forms. Thereafter artisans took over to give ingots their final shape and added value as final product.

For this heavy mining work large stone hammers, iron picks, pestles and shovels were used to extract the core ore. Oil lanterns illuminated the underground mining shafts and were also used as safety measure to prevent fainting for lack of oxygen. The same stone hammers were used to crush the ore to smaller pieces which were further reduced using huge mill stones.

### Gold for Gods and Rulers

All of the sites mined in antiquity were gold and copper mines producing the principle commodities of ancient trade. Gold was highly valued by ancient empires and it said that copper and iron were used to win a war, but gold was needed to finance it.

Mines still under operation in Saudi Arabia today are Mahd Adh Dhahab, Al Amar, Al-Hajar, Bulgah and Sukhaybarat.

In Saudi Arabia precious metals like gold and silver often occur together with copper in one deposit. The solved elements crystallized in veins and formed mineral associations that were composed of abundant quartz, barite and carbonate together with minerals that contain gold, silver, copper, iron and zinc.

While the precious metals occur in native form or as alloys for gold, silver, and palladium, the base metals occur as sulfide or oxide compounds. Silver is found together with the gold in the epithermal deposits. Silver in antiquity was needed to mint coins which started around 3,000 years ago.

Recent studies of the Mahd al Dhahab mine reveal that gold, silver and copper were recovered from this region during the reign of King Salomon who ruled from 961BC to 922BC. Today silver is gained as a byproduct of the gold production.

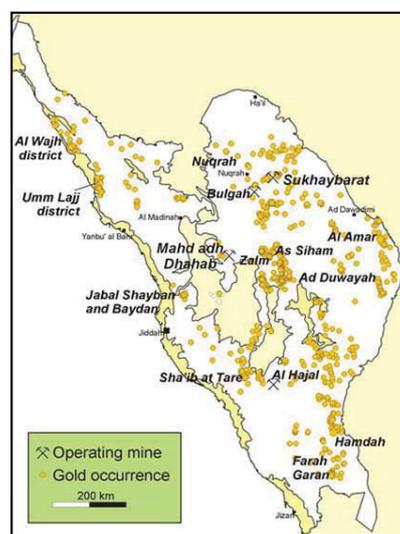
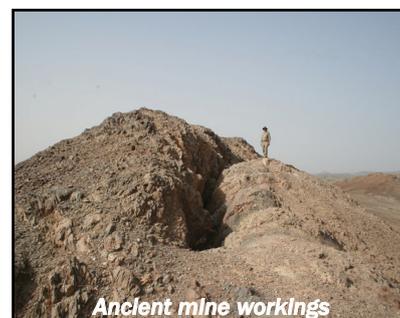
### Copper for Weapons

Radiometric dating of charcoal from slags near copper mines in Saudi Arabia, as well as the study of ancient glazed pottery remnants, suggests that mining activity may have begun around 3,000 years ago.

Copper was first was used in native form to craft tools and weapons and later as a metal alloy. So-called Early Bronze is an alloy of copper with arsenic. As arsenic minerals occur in the copper deposits naturally, it can be assumed that the first alloys were incidentally produced.

Even small amounts of arsenic as low as only one percent, can increase the hardness of copper drastically and the earliest bronze findings in the Middle East are made of arsenic copper alloys.

So-called Classical Bronze contained about ten percent tin, but even two percent tin produced noticeable positive effects. Tin is rare in the Near East and the sources of tin during the Bronze Age is still under discussion.





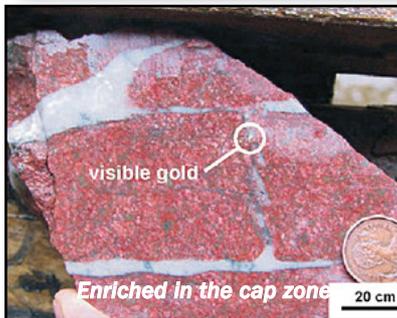
Cu Timna smelting furnace



Traces of copper



Cu Timna workshops & store rooms



Enriched in the cap zone



Remains of ancient mining village



Though tin occurrences in Saudi Arabia were described by geologists recently, no information about ancient tin mining is documented. Eventually the tin was mined from placer deposits. It is known, that by the mid third millennium BC, native gold and cassiterite, a tin oxide, were panned together from Himalayan riverbeds and transported to markets in the Near East.

One suggestion of tin sources is via the Meluhha Culture with its main trading cities Harappa and Mohenjodaro in the Indus Valley which was already a trading partner since early Dilmun times. Tin was also mined in Turkey at that time and at the time became the catalyst for international trade.

### Mining Technology

Miners used stone hammers and fire to shatter the rock, often to depths of fifteen meters and occasionally up to eighty meters. The ancient workings at the Al Hajr gold mine for example can be classified into three types: linear trenches, inclined shafts and vertical shafts. The trenches vary in width from one to three meters and in length between ten and hundred meters.

The vertical shafts have an average cross sectional area of one meter square and reach the depths of ten to fifteen meters. The average cross sectional area of the inclined shafts is about one meter square and reaches a maximum depth of twenty five meters. The inflow of groundwater at greater depth usually caused mining to cease.

### Processing and Metallurgy

Maybe early humans discovered by fortune that ores can change their form when put into a fire and that metals like lead, copper or gold can be cast and forged into other forms with primitive tools.

Archaeological findings of cast lead beads from Çatal Höyük in Anatolia are dated as early as 6,500BC. The transformation process from one metallurgical state to another must be a miracle for the people at that time and probably this was a sacred procedure and attributed to and with the mighty forces of gods to be worshipped.

This was not an uncommon habit of the early humans, when they needed to explain natural phenomena. But how they gained the knowledge about the ore smelting process is still under scientific discussion.

At some stage there must have been a breakthrough in knowledge of metallurgy and ore processing techniques. Additionally, there must have been a continuous process of development to improve the smelting of metals by using concentrates rather than mineral mixtures, plus roasting carbonates and sulfides at temperatures of 250°C to 350°C to produce oxide precursors that can be smelted directly.

The improvement process included the construction of special ovens favoring the reduction of the oxides with charcoal, and finally the application of fluxes to speed up smelting and to chemically bind unwanted impurities or reaction products.

Metallurgy knowledge was certainly developed gradually by trial and error and by observation, with ores being selected by their color, or being taken from specific mining site. In Saudi Arabia the ore was processed mostly in the direct vicinity of the mine, or was transported to nearby villages that had fuel and water and the necessary expertise.

A number of authors of the Caliphate period, such as Abu Bakr al-Razi, wrote volumes on mining and metal working. This was later translated into Latin, spreading the technology. Mineral processing was done by crushing and grinding ore, using hammers and stone querns.

The mineral mixture then was washed and concentrated for the smelting process. In the Black Sea area for example, sheep skins were used to concentrate the gold particles, which probably was the cause of the legend of the "Golden Fleece" famous during the Middle Age.

Smelting to extract metal from the ore was almost always found on-site, no matter what was being mined. Copper ore was extracted and broken into small pieces and mixed with charcoal in a fire on the ground or in a shallow pit.

This method produced temperatures of between 700°C and 800°C, enough to separate the metal from the rock, but not hot enough to reduce it to a truly molten state.

After sufficient time had passed, the charcoal remains were removed and the resulting bits of freed copper were gathered up. Later, smelting operations utilized furnaces and bellows sometimes powered by horses or camels, causing the copper to become truly molten and allowing casting of the copper into ingots for easier transportation and measurement. Salt or fluorite was used as a flux.

### Conclusion

We hope that this article gives you a better idea about the Saudi geology when you visit the desert and stop to look at that beautiful landscape.

Look a bit closer and longer at the landscape and you may see the fault lines where rock color and type changes and, who knows, you might just discover some surface deposit of one of the many minerals this country has in abundance.

After close to 50 years of being an oil focused economy, Saudi Arabia is now changing course and plans to become the worlds 4<sup>th</sup> largest gold producer. Certainly this would not be possible without the ancient mining activity and ample proof of rich deposits.