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HISTORY OF GOLD IN ANTIQUITY

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Abstract: The work presents a history of the exploitation and processing of alluvial gold in Antiquity by the first civilizations of mankind. But those who developed and perfected this technology were the Romans, in Hispania and Britannia, where they mined gold both outcrops and underground. The technology they used was so advanced that it remained unchanged for more than a millennium. **Keywords:** gold, alluvial gold, vein gold, gold artefacts, gold mining methods.

1. The genesis of gold

About 65 million years ago, at the end of the Cretaceous, the molten material in the Earth's mantle began to boil and stir in circular currents. As the continents were moved by the tectonic forces generated by boiling molten magma, there were places where the melt was pushed up to the surface. Then heavy metals appeared in the crust, associated with quartz, including gold, which filled the cracks in the rocks, giving rise to veins. This is a geological process called magmatism, followed by hydrothermalism, through which the magmatic fluids interacted with the surface meteoric ones, disseminating the minerals in the pores or fissures of the rocks, with the generation of stock-type ores.

During the following geological eras, the gold veins were exposed to the weather, and the gold was detached and transported by water, forming alluvial deposits, while the lighter quartz was carried further. Such alluvial gold deposits are found in the Ural Mountains of Russia, northern Spain, Sri Lanka, northern India, Senegal, Germany, the west coast of Africa, the shores of the Arabian Sea and in the area of the second cataract of the Nile.

Gold does not easily form chemical compounds and as such appears in nature almost pure, in the form of dust, flakes, nuggets and often branched crystalline formations, similar to ferns. The ancient peoples who found gold crystals in the form of ferns believed that it grew as a plant in the rock and therefore it should not be extracted completely, leaving some "seed" there [1].



Fig.1. Samples of native gold from the museums of Denver (USA) and Brad (Romania)

2. Gold and the first civilizations

It appears that gold was first used as a medium of exchange in Mesopotamia, a region between the Tigris and the Euphrates ("*Land of the Rivers*"), considered to be the cradle of human civilization.

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Civilization began with the appearance of agricultural settlements, when the need for a constant supply of food also appeared. Because food could not be transported long distances without spoiling, gold was used as an acceptable means of exchange. The ancient Mesopotamians invented cuneiforms, the first writing system in the world, and they also created the *Epic of Gilgamesh*, the oldest literary creation of mankind. The Assyrians also lived on these places, who founded a vast empire that included almost the entire Middle East, with the city-states of Assur, Nineveh and Nimrud.

Although no gold deposits or traces of its exploitation have been discovered on the current territory where ancient Mesopotamia existed, impressive amounts of archaeological gold have been found instead. Historians believe that all this gold came from trade with the peoples of the Arabian Peninsula, west of present-day Bahrain, north of Yemen and near Aden. Other known sources of ancient gold near Mesopotamia were the regions of Aqaba in present-day Jordan and Alaca Hüyük in present-day Turkey. In 1936, a previously unknown royal necropolis was discovered in Alaca, dated around 2,500 BC, with fabulous amounts of gold worked into objects and fine ornaments, from this period of the Bronze Age. The city was at the intersection of three trade routes leading to Mesopotamia, the Black Sea and the Aegean Sea.

Things were different in ancient Egypt, which explored and intensively exploited the gold between the Nile and the Red Sea. The first written account of gold mines in Egypt belongs to the Greek historian and geographer Agatharchides (c. 208 BC – after 145 BC), who visited Egypt in 145 BC, when Ptolemy VIII purified Alexandria of the intellectuals who had supported her rivals to the throne. In fact, he died in Alexandria shortly thereafter. On this occasion, he wrote the book *On the Eritrean Sea*, a passage from the book being copied by the Greek-born Roman historian Diodorus of Sicily. Diodorus states that he devoted 30 years to writing his book *The Historical Library*, during which he undertook a series of dangerous journeys in Asia and Europe, during which he also visited the gold mines of Egypt. In fact, Strabo, Pliny the Elder, Claudiu Aelian, Joseph Flavius and Plotinus also profited copiously from those written by Agatharchides. Diodorus of Sicily describes in detail the exploitation and processing of gold from the mines of ancient Egypt, in Book III, chapters XII-XIV of *The Historical Library* [1, 2].



Fig. 2. Bas-relief attesting the processing of Egyptian gold around 2,000 BC

Those written by Diodorus are confirmed by a bas-relief found in an Egyptian tomb in Beni Hasan, dating from around 2,000 BC (Fig. 2). On the left, gold ore is washed; in the centre, a gravitational concentration is applied, by washing with water on an inclined plane, while on the right, the gold concentrate is melted, in the presence of some fondants.

The special qualities of gold were appreciated by the ancient Egyptians since the time of the first dynasties. Craftsmen then appeared who created true works of art, using beaten gold threads or sheets to make jewelry or to plate wooden objects. The peak of the craft was reached in the period 1500–1300 BC. The funerary mask of the child pharaoh Tutankhamun, who died at only 19 years old, in 1323 BC, impresses with the sophistication with which it was executed. Made of two plates of gold alloy with silver and copper, joined by soldering and decorated with semi-precious stones, it weighs 10.32 kilograms. A special impression is created by the combination of gold and lapis lazuli, an ultramarine blue mineral. The forehead is adorned with two emblems: one is the goddess Nekhbet, the protector of Upper Egypt. The burial chamber, discovered in 1922 by the



Fig. 3. Tutankhamun's funerary mask

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British Howard Carter, had 5,000 objects, many of them made of gold. The pharaoh's mummy was housed in a golden sarcophagus that weighed 110 kilograms, inserted into two other wooden sarcophagi plated with gold leaves (Fig. 3).

Another ancient country where gold was mined and used was Lydia, an Iron Age kingdom in western Asia Minor. The Kingdom of Lydia existed between 1,200 and 546 BC, then becoming a province of the Persian Empire. The first official gold coins were minted here, during the time of King Croesus (c.561–546 BC). Both gold and silver coins were minted, each weighing 10.76 grams. On the obverse of the coins there is a lion roaring at a bull, symbolizing the sun and the moon, and on the reverse a bas-relief framed in two interlocking squares. These are the world's first official coins, issued by a government authority, with exchange value markings [1].



Fig. 4. Gold and silver coins of 10.76 grams issued in Lydia in 560-546 BC

In ancient China, gold was not as important as jade, which was considered a symbol of wealth and imperial rank. As a result, gold is mentioned rather vaguely in ancient Chinese writings, only under the name of *yellow metal*. The first mention of the use of gold dates back to the Shang Dynasty (1600–1046 BC), when



Fig. 5. Gold coins of the State of Chu

the gold leaf was used to plate decorative objects. At first, gold was extracted from alluvial deposits, but starting from the 2^{nd} century B.C. it was also mined underground, in the Shandong Peninsula.

As for the coins, they appeared only after 770 BC, being made by casting from ordinary metals. Indeed, about three centuries before, small gold squares were used as means of exchange, but only in certain areas. The only exception is the 3–5 mm thick sheet gold coins of various sizes from the Chu State of the Yangtze River Valley (770 – 221 BC), with square or round inscriptions, in which one or

two characters. For the Chinese, jade and bronze remained the main ornamental materials in the following centuries, gold being used less. Even the official coins were cast from bronze and brass or even from iron.



Fig. 6. Statue of the goddess Athena Parthenos

The ancient Greeks not only knew and appreciated gold, but also exploited it, first from alluvial deposits and outcrops, and then from underground. Gold is present throughout Greek mythology, whether it is *the golden fleece* of Colchis or *the golden apples* in the garden of the Hesperidia, or the request of the reckless Phrygian king Midas to the god Dionysus that everything he touches will turn to gold. His wish was fulfilled, but when he wanted to feast he could not put anything in his mouth, because as soon as he touched them, the pieces and the drink turned to gold. Thirsty and hungry, Midas asked the god to rid him of this burdensome gift. Dionysus advised him to bathe in the waters of the river Pactolus, which the king did. Instead, the river's waters remained golden. The myth became so deeply rooted in the consciousness of the Greeks that when the Lydians minted the first gold and silver coins, many Hellenes believed that the noble metals had been extracted by them from the river Pactolus.

Homer makes numerous references to gold in *The Iliad* and *The Odyssey*, without specifying its origin, but there is evidence that at the beginning of the century VIII BC, in Greece there were several centres of exploitation of alluvial or outcrop gold: Pangaion, Rhodope, Thasos, Lavrion, Kythnos, Serifos and Sifnos. The influence of gold mining on the development of ancient Greece was overwhelming. The

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accumulated reserves of gold and silver allowed Pericles (495–429 BC) to erect the great constructions of Athens, including the Parthenon on the Acropolis, dedicated to the goddess Athena Parthenos, built between 447 and 432 BC. The statue of the goddess, 11.5 m high and made by the sculptor Phidias, was assembled on a wooden support covered with bronze plates, plated with 1,130 kg of gold, except for the face and arms, carved from ivory, being erected in the honour of victory against the Persians. According to Pausanias and Plutarch, artisans of various trades participated in the making of the statue, being closely supervised by Phidias. Today she no longer exists, disappearing under unexplained circumstances, probably for the purpose of robbery (Fig. 6).

Certainly, the gold reserves of the Greeks came from their own exploitations, as Herodotus (c.484 - c.425 BC) writes in Histories (Book VI, chapters 46 - 47): "In the next year after this, Darius first sent a message bidding the Thasians, who were falsely reported by their neighbours to be planning rebellion, to destroy their walls and bring their ships to Abdera. Since they had been besieged by Histiaeus of Miletus and had great revenues, the Thasians had used their wealth to build ships of war and surround themselves with stronger walls. Their revenue came from the mainland and from the mines. About eighty talents on average came in from the gold-mines of the "Dug Forest", and less from the mines of Thasos itself, yet so much that the Thasians, paying no tax on their crops, drew yearly revenue from the mainland and the mines of two hundred talents on average, and three hundred when the revenue was greatest.

I myself have seen these mines; by far the most marvellous were those that were found by the Phoenicians who with Thasos colonized this island, which is now called after that Phoenician Thasos. These Phoenician mines are between the place called Aenyra and Coenyra in Thasos, opposite Samothrace; they are in a great hill that has been dug up in the searching. So much for that. The Thasians at the king's command destroyed their walls and brought all their ships to Abdera" [3].

The gold deposits of ancient Greece were more limited than those of silver, so silver became the official means of supporting economic exchanges. Between the 8th and 5th centuries BC, the gold/silver ratio was 1/13, except for the years 407–404, when Athens issued gold coins to support the Peloponnesian War. Only the Macedonian king Philip II (359–336 BC) gave the Greeks their first official gold coin, from the metal extracted from the mines in Thrace, the gold/silver ratio reaching 1/10.

In biblical times, material wealth, as opposed to spiritual wealth, was represented by gold and silver. It is no coincidence that gold is mentioned so many times in the Bible, being used in large quantities to decorate places of worship dedicated to God. After leaving the Egyptian captivity, God commanded the Israelites to build a tabernacle, that is, a portable tent that could be easily transported from one place to another during their journey through the wilderness. Inside the tent the Ark of the Covenant stood, which was a box made of acacia wood plated with gold, measuring 112x67x67 cm, which contained the tablets of the law. Around the tent there was a rectangular enclosure of 45x22.5 m, closed with melted linen cloths, mounted on wooden poles polished with silver. The total amount of precious metals used for all the works of the sanctuary was about 1,000 kg of gold and over 4,300 kg of silver, coming from the gifts made by the Egyptians to the Israelites, to see them go as quickly as possible in the exodus. The number of Jewish donors was 603,550 people over the age of 20 (Exodus 38:24–32). It is not known exactly what happened to the Ark of the Covenant. A rabbinical writing from the end of the second century AD says that he was taken to Babylon in 587 BC, after the conquest of Jerusalem. The Bible says that the prophet Jeremiah took the ark before the Babylonian invasion and hid it in a cave on Mount Nebo, from where Moses looked at the Promised Land, before he died (2 Maccabees 2:4–10).



Fig.7. The tabernacle (reconstruction)



Fig. 8. The Ark (reconstruction)

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About two and a half centuries have passed. Solomon (970 - 930 BC), the tenth son of David and the second son of Bathsheba, ascended the throne of Israel, which had reached the greatest extent in its history. The time has come for the Israelis to build the temple to God that they have dreamed of for so many generations. Solomon reigned for 40 years – like his predecessors Samuel and David – in one of the most prosperous periods in the history of the country, commonly called *The Golden Age of Israel*. Controlling the trade routes that came from Edom, Arabia, India or Africa and building a profitable network of alliances, cemented by a large number of wives and concubines, Solomon accumulated large quantities of gold and silver, with which, in the fourth year of the reign, the construction of the temple began. The works lasted seven years, creating a true architectural wonder. On the basis of what is recorded in the Bible, historians have calculated that for the construction of the temple there were expenses equivalent to 3,000 tons of precious metals, a good part of which was inherited from his father David.

King Solomon was famous not only for his great wisdom but also for his wealth. His many building projects included the building of the temple. In the Bible it is written that much of Solomon's gold came from Ophir, without specifying its geographical location. There were also many legends about *Solomon's gold mines*, about which books were written and films were made. Only in the last century, American and Saudi geologists discovered between Mecca and Medina, in the town of Mahd adh Dhahab, huge amounts of waste from ancient gold mining, about one million tons, with an average concentration of two grams of gold per ton, which confirms the existence of a very rich deposit. The excavations led to the discovery of tools used by ancient miners to extract and process gold ore, archaeologists claiming that the ancient Ofir would have been located here. The gold was transported by ships on the Red Sea, to the port of Aqaba, and from there, to Jerusalem, by caravans.

According to the Bible, the temple was not only a religious centre, but also a gathering place for the Israelites. The building was 30 meters long, 12 meters wide and 18 meters high, being made up of three units: the porch, the sanctuary and the Holy of Holies. In the inner courtyard there was an altar that was reached by stairs, as well as a huge cup with a diameter of 4.4 meters and a depth of 2.2 meters, intended for the ritual washing of priests, considered a special technical achievement of the craftsmen of the time. The brazen sea, as it is called in the Bible, rested on 12 bronze oxen, with their faces facing the four cardinal points, probably having a water drainage pipe underneath [1].



Fig. 9. Solomon's Temple and the Copper Sea (reconstruction)

3. The exploitation of gold by the Romanians

The Romans exploited all the metals known in their time, such as iron, copper, gold, silver, tin and lead, giving them their names (*ferrum, aurum, argentum, stannum, plumbum*). The current knowledge about the gold mining of the Romans comes from both literary sources and archaeological discoveries. In the first case, the information regarding the location of the gold mines is quite vague, the authors especially insisting on the extraction technologies. Corroborating what was written by Pliny the Elder (23–79 AD) in *Natural History* and Vitruvius (81–15 BC) with the archaeological research done on the ground, we know that the most important gold mines of the Romans were at Las Médulas, in Hispania and at Dolaucothi, in Britannia.

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The Romans had bought gold, but also copper and silver from Phoenician and Carthaginian merchants who, in turn, procured these metals from Tartessos, a port city on the southern coast of the Iberian Peninsula, founded around 1,000 BC. The prosperous population of Rome, lazy and extravagant, spent their time in expensive activities. Every wealthy citizen tried to impress his peers by spending huge sums of money. Moreover, this way of life ultimately led to the fall of the empire. In order to get money, Rome burdened the occupied territories with taxes that were difficult for the subjugated population to bear, which led to numerous revolts. As a result, the existence of gold mines in Hispania and Britannia, known to the Romans, led to the conquest of these territories and the development of a revolutionary mining.

First, the future emperor Octavian Augustus conquered the province of Hispania Tarraconensis in 27 BC, a territory that included the Mediterranean coast of present-day Spain, along with the country's central plateau and northern Portugal, where the famed gold mines of Las Médulas. The province was part of the Roman Empire until 459, providing Rome with impressive amounts of gold. The Las Médulas archaeological area, which covers 2,000 hectares, is today a UNESCO World Heritage Site and includes the mines themselves and large areas occupied by the tailings resulting from the extraction process. The authenticity of the site is absolute as traces of Roman technology have persisted since the beginning of the 3rd century AD until today, even if later small agricultural communities lived in the area.

In AD 43, the Roman emperor Claudius (41–54) formed an invasion force of four legions, conquering Britannia, after several years of fighting that lasted from the days of the Republic and the early Empire. The commander of one of the legions – the II Augusta Legion – was the future emperor Vespasian. One of the main reasons for the conquest of Britain was the gold from Dolaucothi, in Wales. Gold mining at Dolaucothi began in AD 70, and in AD 125. the works were abandoned. It is estimated that during this period the Romans extracted between 50 and 200 tons of gold from here. After the Romans left the British Isles, the mine at Dolaucothi remained unexploited for almost 1,700 years, until 1797, when a local noble family made several failed attempts to extract gold. In the last century, around the 1930^s, the miners who worked here discovered tools and the remains of a wheel for the evacuation of waters, from the time of the Romans. Dolaucothi is the only recognized Roman gold mine in Britain.

After conquering these territories, the Romans simply revolutionized the technology of gold mining and metallurgy, which remained unchanged for 1,500 years. It was described by the Roman historian and naturalist Pliny the Elder, appointed by the Roman Senate governor of Hispania, in the year 74. During his stay in Hispania, he became familiar with the gold mines in the northwest of the province, which he also visited and described them in detail. He called the resulting spectacular landscape *ruina montium* (demolition of mountains). The Romanians extracted 1,200–1,500 tons of gold from Las Médulas, resulting in an average of 5 tons of gold/year, permanently employing 15,000 – 20,000 miners [1].

Both in Las Médulas and in Dolaucothi, gold had been exploited by the natives long before the arrival of the Romans, especially from alluvial deposits, but perhaps also through small underground works. As Pliny writes, the Romans used three techniques for the exploitation of gold: from alluvial deposits, by hydraulic dislocation and by underground mining works.

Alluvial deposits with heavy minerals have been exploited since ancient times, being a cheap process and available to everyone. The method lasted in Africa until the 19th century, being also presented by Georgius Agricola [4], after 1,500 years, in at least ten variants, in his famous work *De re metallica* (Fig. 10).

The second method used by the Romans was the hydraulic dislocation of alluvium or outcrops on sloping land. Above the deposit, a large amount of water collects in a basin, which is suddenly released, washing the soil and highlighting the outcrops of the veins or separating the gold from the lighter rocks found in alluvium. Water basins and aqueducts for their supply were discovered both in Las Médulas and in Dolaucothi. Pliny wrote about the former, and Sextus Julius Frontinus, a famous Roman architect and builder, former governor of Britannia in 74–78, wrote about those in Britannia. During his tenure, Frontinus established the main fort of the Roman army at



Fig. 10. Alluvial gold mining (after Agricola) [4]

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Pumsaint, in west Wales, to be as close as possible to the goldfields at Dolaucothi. Later, he rebuilt the water networks of Rome and wrote a treatise on the Roman aqueducts of the 1st century AD, also describing those in Wales.

When gold veins appeared, they were exploited through longitudinal trenches, as far as possible. If the vein was rich, exploitation continued underground, this being the third method described by Pliny. For underground mining, the opening of the mines was done through wells or coastal galleries, dug from the surface. In the area of the deposit, the works were continued either with directional galleries, dug in the direction of the vein, or with transverse galleries. The wells of Hispania and Britannia had square shapes and sections of 1-2 m², being reinforced with wood for stability and provided with stairs for the movement of personnel. The directional galleries had somewhat higher heights, depending on the size of the vein, and the transverse ones, heights of 1-1.5 meters and widths of 0.6-0.65 meters. At Rio Tinto, in Hispania, where the Romans mined gold, silver and copper, and in Dolaucothi, some galleries with somewhat wider widths towards the roof were also discovered, probably to allow the passage of baskets with ore, supported on the shoulders. If the rocks were stable, the galleries were not reinforced, but had a vaulted ceiling, for a better distribution of the pressure on the side walls, and if the walls were not strong enough, they were reinforced with wooden frames lined with planks.

The digging of the galleries was done with iron tools like those discovered in an ancient mine in the province of Hispania Baetica, the birthplace of the emperors Trajan and Hadrian. The sharp tools were used to produce cracks or holes in which to drive steel wedges, to dislodge the rock. One could also use wooden wedges on which water was poured to increase their volume and produce other cracks. The method of fire and water or vinegar was also used, but only in the case of very hard and compact rocks, due to the



Fig. 11. Ancient tools for digging galleries

discomfort caused by the presence of smoke that was evacuated with great difficulty from the galleries. The ore dislodged with so much effort was loaded into baskets and evacuated through the narrow galleries with the back, and onto the shaft with the help of ropes.

From what Pliny writes that he saw in the gold mines of Hispania, it follows that the mining method used would have been that of surping, which consists of advancing in the direction of the veins through overlapping galleries, separated vertically by safety boards. The subsequent collapse of these floors would have produced the deafening roar and

blast that Pliny speaks of. He also speaks of a hydraulic exploitation involving the undermining of a mountain with large amounts of water (XXXIII, 74–75): "Another equally laborious task involving even greater expense is the incidental operation of previously bringing streams along mountain-heights frequently a distance of 100 miles for the purpose of washing away the debris of this collapse; the channels made for this purpose are called corrugi, a term derived I believe from coarivatio, a uniting of streams of water. This also involves a thousand tasks; the dip of the fall must be steep, to cause a rush rather than a flow of water, and consequently it is brought from very high altitudes. Gorges and crevasses are bridged by aqueducts carried on masonry; at other places impassable rocks are hewn away and compelled to provide a position for hollowed troughs of timber.

The workman hewing the rock hangs suspended with ropes, so that spectators viewing the operations from a distance seem to see not so much a swarm of strange animals as a flight of birds. In the majority of cases they hang suspended in this way while taking the levels and marking out the lines for the route, and rivers are led by man's agency to run where there is no place for a man to plant his footsteps. It spoils the operation of washing if the current of the stream carries mud along with it: earthy sediment of this kind is called urium. Consequently they guide the flow over flint stones and pebbles, and avoid urium. At the head of the waterfall on the brow of the mountains reservoirs are excavated measuring 200 feet each way and 10 feet deep. In these there are left five sluices with apertures measuring about three feet each way, in order that when the reservoir is full the stopping-barriers may be struck away and the torrent may burst out with such violence as to sweep forward the broken rock" [5].

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Pliny is right: the spectacular landscape still visible today after the destruction caused to the mountains of Las Médulas could only have been generated by such a destructive process. And at Dolaucothi in Wales, the Romans applied this method to search for gold veins hidden underground, above the present-day town of Pumsaint.



Fig. 12. Hydraulic dislocation of soil for finding gold veins at Dolaucothi [6]

In the mining town of Ogofau in Wales there is still today a trace of the old Roman mining, discovered in the summer of 1970, after a prolonged drought. The Melyn y Milwyr reservoir (Fig. 13), near the road linking Pumsaint and Caio, which was thought to be of more recent date, has dried up, revealing large quantities of Roman pottery, as well as a canal drain to a smaller tank. The analysis of the ceramic fragments showed their age: between the end of the 1st century AD and the beginning of the 4th century. Since the Roman fort at Pumsaint was abandoned by the Romans around the middle of the 2nd century, it follows that gold mining in this area was continued by the natives even after the withdrawal of the Romans. Specialists appreciate that between the two water tanks from Ogofau were placed washing tables covered with soft fabrics which, when a quiet current of water passed, retained the fine particles of gold and discharged the tailings in the form of turbidity. Wasn't it the same with us, later, with the goldsmiths and the old gold stamps?



Fig. 13. Gold washing on cascading tables at Ogofau in Wales [6]

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The exploitation method called by Pliny the Elder *ruina montium*, applied in Hispania, consisted in the surface erosion of the slopes and their undermining from below. The arrow on the right indicates the area where the miners separated the gold from the tailings.



Fig. 14. The montium ruin mining method © 2017 Pierre Thomas/Aula archeològica de Las Médulas

Underground mining has created problems with lighting, ventilation and drainage. The Romans solved them all and solved them so well that they remained unchanged for 1,500 years. Perhaps the most difficult of them was the evacuation of the waters, but its solution came from the applications related to the supply of water to Rome and the cities of the empire, which had been worked on for more than a century. Thus, the renowned Roman architect and engineer Marcus Vitruvius (81–15 BC) in the famous treatise *On Architecture* dedicates an entire chapter to water and related installations. He described in detail the operation of Archimedes' screw and the hydraulic wheel, used in irrigation or thermal baths. A century later, the hydraulic wheel was also used to evacuate water from underground mining operations.

In the 20^s of the last century, in the Rio Tinto copper mine in Spain, eight pairs of hydraulic wheels connected in series were discovered in ancient works from the time of the Romans. Such a wheel with a diameter of 4.65 meters is kept at the British Museum in London, and the series of eight pairs of wheels from Rio Tinto ensured the evacuation of water at a height of almost 30 meters (Fig. 15). A similar discovery was made in 1935 at Dolaucothi, the hydraulic wheel from the old mine workings being exhibited in the Welsh Museum in Cardiff.

Regarding the lighting, Pliny says that it was done with blinds, which also served as a measure of working time, the duration of a shift being 8-10 hours. The ventilation of the workplaces was solved by digging a secondary well with a section of about 1 m^2 , which ensured the evacuation of spoiled air through convection.

The Romanians extracted 6,560 kilograms of gold annually, which means that during the 250 years they exploited the mines of Hispania and Britannia, they obtained over 1,600 tons of gold. Exploitation involved both free workers and slaves from among the subjugated populations. Their thirst for gold was growing, so they turned their eyes to Dacia, possessor of gold-silver deposits at least as rich as those of Hispania and Britannia, taken together. After the conquest of Dacia, the Romans transferred to the Apuseni Mountains the technology that had revolutionized gold mining in the first century of the Christian era. During the 165 years of occupation, they would take over 450 tons of gold and twice as much silver from Dacia [1].



Fig. 15. Evacuation of water with wheels in series at Rio Tinto in Hispania

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