HISTORY OF MINING AND METALLURGY IN ANATOLIA

Ünsal Yalçın & Hadi Özbal

The First Metal: COPPER

The oldest finds so far uncovered have shown that Anatolia is the cradle land where metallurgy first emerged. Despite this fact, Anatolia's leading role has opened avenues of paved the way for discussions, and various circles have recently been endeavoring to interpret the scientific data available in different ways leading to regional discriminations. When the different stages of development in mining and metallurgy are listed chronologically, Anatolia stands out as the forerunner at every step. As a matter of fact, the geological structure of Anatolia and its great wealth in metal beds clearly shows that throughout history the local inhabitants have had easy access to the available metals.

It is not by chance that the oldest signs of metallurgy are found in Anatolia. There is clear indication that the abundance of metals such as copper, iron, arsenic, antimony, lead, silver, gold and zinc played a major role in the cultural, economic, and technological development of almost all the civilizations of Anatolia throughout history. After the end of the last Ice Age, it can be seen that the indigenous Anatolian populations switched from a nomadic lifestyle, settled in villages and in time began to discover mineral sources. They developed the technologies to produce some much demanded metals objects such as weapons, tools, jewelry, symbols, and kitchenware.

Anatolia lies entirely in the eastern Mediterranean part of the Alpine Orogenic belt that passes between Russia and Siberia/Eurasia to the north and Africa to the south. Over time, the deposits of Tethys Ocean were bent and elevated as they were squeezed by the Eurasia to the north and the African-Arabian continents to the south to form present-day Anatolia. This geological process has divided Anatolia into two main sections stretching in east-westerly directions: Anatolia is a plateau formed by the north Anatolian fold in the north, and the Tauruses comprising many arcs in the south, and the ancient intermediary massifs and secondary folds such as Menderes, Kırşehir, Ankara and Bitlis, and the elevated flatlands and intermediary mountain ranges in between. Some parts of the Anatolian plateau are covered with Tertiary-Pleistocene volcanic rocks. Sandwiched in between these two continental plates, the Anatolian plate is caught in the middle of tectonic movements and has therefore always suffered from earthquakes. The formation and diffusion of all sorts of mineral deposits in Anatolia are under the effect of Orogenic phenomena. The collision of the Black Sea oceanic crust with the Anatolian continental crust and its subduction under the Anatolian plate formed the North Anatolian Mountains, where rich mineral deposits formed due to volcanic activities. The massive sulfur deposits that were formed directly by the oceanic crust in the Kastomonu-Kure region in western Anatolia contain copper, cobalt and gold. On the other hand, the eastern Black Sea Çayeli-Murgul-Ortaköy Belt, formed by volcanic activities, includes polymetallic ores such as lead, zinc, silver, copper and gold. Similarly, the porphyritic deposits containing lead, zinc, silver, gold, and copper in the Balya, Gumushavikoy and Gumushane provinces of the Central Black Sea Region are of volcanic origin. The second important mineral belt of Anatolia extends along the Taurus Range. These deposits were

formed by the subduction of the Tethys ocean crust under the Anatolian plate. This belt contains copper mineralization in the south and lead-zinc mineralization in the north. Mineral deposits that contain lead, zinc, silver, gold and copper have formed in the Nigde-Bolkar Mountains, and in the Cukurova and Keban region of Southeastern Anatolia.In addition, native copper can be found at the carstic cavities of various Anatolian Regions as well as in the secondary mineralization at the oxidized deposits of Kiziltarla, Polusagi, and Cafana in Eastern Anatolia, at Yaprakli and Divrigi in Central Anatolia, and in the Bolkar Mountains. Along side the abovementioned polymetallic deposits of copper, lead and zinc, Anatolia can also be considered rich in iron ore. There are also important deposits of crucial metals such as chromium, aluminum and boron, utilized in today's industrialized world. Secondary ores such as malachite, azurite and limonite that occur on or close to the surface attracted the attention of the earliest inhabitants of Anatolia and were collected and used as pigments or for making beads or other small objects.

When studying the history of Anatolian metallurgy, it is necessary to consider the relations between Anatolia and the neighboring regions. The earliest traces of settlements in the archaeological record have so far been observed in Anatolia and in the Near East, known as the "Old World". When these regions are archaeologically considered, different paths of developments can be noticed. Anatolia, located in the north of this wide region is quite rich in copper deposits. As mentioned above, since it is also easily possible to find native copper in these deposits, it is not surprising for the first inhabitants of Anatolia to recognize copper in the form of metal. The same situation is also applies to northwestern Iran. Therefore, it is not surprising that the first copper objects of human history were recovered in Anatolia.

The earliest metal utilized by human beings was copper. The inhabitants of Asikli Hoyuk near Aksaray and Cayonu near Diyarbakir, who lived 10,000 years before present, collected native copper occurring naturally in their environment and worked it by simple methods to produce small tools like piercers or ornaments like beads. They achieved this feat much before the invention of pottery, making metallurgy one of the most basic achievements of human history.

Copper artifacts dated to the Pre-Pottery phase of the Neolithic Period were also uncovered in northern parts of what are today Syria and Iraq, and in the western parts of Iran. At settlements such as Tell Ramad, Tell Maghzaliyeh, Tell Sotto and Yarım Tepe, dating to the end of the 8^{th} millennium BC and to the beginning of the 7^{th} millennium BC, small objects made out of native copper were recovered prior to the production of clay pottery.

On the other hand, no metal objects dating to this period have been recovered from research conducted in Jordan, Israel or southern Syria (known as the Levant) along the coasts of eastern Mediterranean. The rich copper deposits like Fenan and Timna in the region, actually, do not have any native copper. Yet, attractively colored minerals like turquoise and copper containing malachite minerals, were collected and used as pigments or as raw materials for making ornaments. The best examples of these were uncovered at settlements such as Jericho, Yiphtael or Ain Ghasal. Artifacts recovered in these sites show that metallurgy started in this region towards the end of the 5^{th} millennium BC when the people developed the technology to obtain copper directly from the ore by smelting.

The Emergence and Developmental Phases of Metallurgy

Besides the fact that the earliest traces of metal use were uncovered in Anatolia, it is worth noting that metalworking spread to other regions from Anatolia as well. Increasing multidisciplinary and especially archaeometallurgic research during recent years solved many of the mysteries of ancient metallurgy. Thus, it is now possible to chronologically categorize and study the emergence and development of Anatolian metallurgy. The stages of Anatolian Metallurgy are divided as follows: Preliminary Stage (Nonmetallic Period) before 8200 BCE; Beginning Stage (Monometallic Period) after 8200 BCE; Development Stage (Onset of Extractive Metallurgy) after 5000 BCE; Organization/Experimentation Stage (Advanced Metallurgy) ca. after 4000 BCE; and Industrial Stage (Bronze and Iron Ages) ca. after 2800 BCE.

Preliminary Stage: Nonmetallic Period (before ca. 8200 BCE)

As previously mentioned, even before getting acquainted with metals, early man collected attractive and vividly colored minerals and ores and used them to obtain pigments. The earliest evidence of minerals used as pigments have been uncovered in carstic cavities and caves, which were used as settlements during the Paleolithic and Mesolithic Periods. The earliest ore (malachite) examples were uncovered at the open-air settlements of Southeast Anatolia such as Hallan Çemi and Çayönü. Malachite, worked as beads, was recovered from the later occupation levels of Cayonu. Such data indicate that malachite was not worked around 10,000 BC during the beginning stage. Utilization of malachite in production of small objects began later, by about 9000 BC.

Beginning Stage: Monometallic Period (after ca. 8200 BCE)

Mankind got acquainted with copper at the end of the 9th millennium BC. Humankind was able to produce small implement from native copper that they recognized from its color even before the production of pottery from clay. Occupants of settlements in Southeastern Anatolia and the Cappadocia region of Central Anatolia brought colored minerals and stones, such as flint and obsidian, into their settlements and shaped them into useful tools. Using their previous experience of shaping stones, it did not take long for them to recognize that native copper could also be shaped by hammering into useful shapes. They also observed that when copper was cold worked, it cracked and crumbled but when heated its plasticity was increased and it could be re-worked again easily. The metallurgical study of the earliest metal objects, such as pins and beads, showed that the early metal smiths were shaping native copper into sheets by hammering and repeated annealing, that is re-heating to avoid cracking. Thus, mankind discovered a new raw material and made use of heat for the first time to work it. Before this time, fire had been used for only cooking, warmth or protection from wild animals, but now fire was utilized for technological purpose. This innovative technology that laid the foundation for metallurgy is considered to be one of the main achievements in the development of human societies. It is clear that pyrotechnology was used in metal working much before its application for the production of pottery from clay. The 113 artifacts of small tools and beads from Diyarbakır-Çayönü and the 45 beads from Aksaray-Asıklı Höyük represent the application of pyrotechnology. Thus, objects made from copper are first encountered in the Pre-Pottery Neolithic Period at Çayönü (8200-7500 BCE) and at Aşıklı Höyük (7800-7600 BCE). A copper bead dated to the same period was also uncovered at Urfa-Nevali Çori. The copper finds from Asıklı and Çayönü are not only the earliest metal

finds of Anatolia but represent the oldest known metals objects in human history. Thus, the claim that metal was worked first in Anatolia is well substantiated.

For a long time, even after the onset of Pottery Neolithic Period, native copper remained the only metal known by humankind. Traces of copper were uncovered at another Neolithic site, Konya-Çatalhöyük, and slightly later at Burdur-Hacılar, Kırklareli-Asagıpınar. The macehead with a shaft-hole that was uncovered at Karaman-Can Hasan, dated to Early Chalcolithic Period levels (6,000 BC), was also among the most important examples of copper objects made out of native copper in Anatolia. This find is the oldest and the only example of its period in the Near East. In the 7,000's BC at Çatalhoyuk, galena (PbS), along with brightly colored copper minerals such as malachite and azurite and iron mineral pyrite, was used for the first time to make beads.

Development Stage: Onset of Extractive Metallurgy (after ca. 5000 BCE)

Towards the end of 5,000s BCE, humankind began to smelt copper ores like malachite and azurite in crucibles to yield almost pure copper. The metalworkers of this period collected ores like malachite that they found nearby, brought them to their settlements, and smelted them to produce tools suitable for their needs. Apparently, the masters of this period were more in command of pyrotechnology and employed various techniques to produce copper objects from the metal they obtained by smelting. Copper prills were obtained in small clay crucibles. These prills were re-melted to remove impurities like charcoal, unsmelted ore remains, and crucible particles. The refined copper was then poured into open molds to roughly shape a desired object. After the metal solidified, the final desired shape was produced by forging. With the commencement of extractive metallurgy, that is, with the ability to smelt copper from ores, the path to obtain all the needed metals was opened. Thus, copper was used to produce the first examples of tools, such as axes or chisels, by casting. Similarly, in this period about 5000 BCE, spiral headed pins were also produced by forging. Examples of such objects have been uncovered at settlements like Samsun-Ikiztepe in the Central Black Sea Region, at Çorum-Alacahöyük and Büyük Güllücek in Central Anatolia, at Yumuktepe in Çukurova (Cilician plains), and at Kuruçay, Beycesultan and Orman Fidanlıgı in the interior of Western Anatolia. Moreover, traces of metallurgical activities have been found at settlements in Southeastern Anatolia. For instance, at Tepecik and Tülintepe in Elazıg smelting wastes have been recovered, and two copper ingot pieces have been brought to light at Malatya-Degirmentepe.

Organization/Experimentation Stage: Advanced Metallurgy (after ca. 4000 BCE)

By the second half of the 3rd millennium BCE, metallurgical activities in Anatolia increased both in quantity and quality. In every settlement surveyed, workshops for smelting and metalworking have been found. Not only in Anatolia, but also in the Near East as a whole, metallurgists generally smelted the copper ores near the mines and then transported the ingots to their settlements to produced the needed implements and tools. However, at times, evidence of in settlement smelting of copper ores was also observed. The miners of this period not only collected ores on the surface but also dug galleries deep into the ore deposits and obtained polymetallic ores with complex compositions. They realized that such ores had different properties and attempted to smelt them as well. Among the polymetallic ores, their

attention was especially attracted by arsenic containing copper ores. Experimentation with such ores unintentionally yielded arsenical copper, from which they eventually learned to produce objects of higher quality. It was noticed that a small amount of arsenic affected both the color and the quality of copper, and depending on the amount of arsenic, improved the casting features of the copper. The first copper alloys that contain arsenic must have been produced unintentionally by the smelting of arsenic-containing copper ores such as tenantite ($Cu_{12}As_4S_{13}$) and enargite (Cu_3AsS_4). During the smelting process, arsenic is also reduced, together with copper, to form an alloy with copper before being oxidized. When such fahlerz type minerals in the uppermost layers of copper mineralization were consumed, arsenical copper alloys were procured by co-smelting of copper ores together with arsenic ores such as arsenopyrite, orpiment or realgar.

It was recognized from the earliest examples uncovered in the Late Chalcolithic Periods that copper was also the first metal used for casting in Anatolia. These earliest examples were shaped in open molds. These first castings, which must have been used as flat axes or chisels, have been uncovered at Çorum-Büyük Güllücek, Mersin-Yumuktepe and Burdur-Kuruçay.

The first examples of other metals in relatively pure state have also been uncovered in the Late Chalcolithic Period. Mankind first began to use lead and silver, and then gradually gold. The earliest examples of silver in Anatolia were found at settlements like Elazığ-Korucutepe and Denizli-Beycesultan.

Industrial Stage: Bronze and Iron Ages (after ca. 2800 BCE)

As of 2800 BCE, i.e. during Early Bronze Age II, the finds uncovered indicate that in Anatolia rapid and important developments in metallurgy took place. In this period, the mines were exploited at industrial levels and underground galleries were dug to remove the ore. Large slag heaps near the ore sources indicate that smelting was also carried out near the source. Increase in metal production made the transportation of relatively heavy ores to the far away settlements unattractive. The metal smelted near the mines was transported as ingots to the settlements or traded. The production of metal objects from the ingots took place in workshops set in the settlements. Thus, metallurgy was fully organized, from the mining right through to the final workshop production.

The major increase in the number of arsenical copper objects in the Late Chalcolithic period is noteworthy. The early metal masters could not produce copper that contained arsenic, even though they knew arsenic minerals. Initially, they probably attempted to separately co-smelt arsenic and copper ores to produce arsenical copper. Although arsenic is easily reduced under normal smelting conditions in the smelting furnace, due to its low volatility, it is quickly oxidized and most of it is lost from the furnace. Copper with arsenic content of about 3-5 % is much harder than pure copper. Besides, casting becomes easier as it melts at a lower temperature; in addition, forging and rusting features also improve.

Major achievements in arsenical copper production technology took place during this period. Arsenical copper alloys can also be produced by the cementation technique, which involves adding arsenic ore mixed with coal powder onto the molten copper in the crucible. The

arsenic is reduced quickly in the crucible and rapidly dissolves in liquid copper to form the desired alloy before it is oxidized. The masters, noticing this feature, produced the works of art we know from many Anatolian settlements such as Beycesultan, İkiztepe, Alişar, Alacahöyük, Yumuktepe, Pulur, Arslantepe, Tülintepe and Hassek Höyük. When the arsenic content of copper reaches 8-10%, the alloy becomes silvery in color. The ceremonial spearhead with relief decoration and the quadruple spiral pendant uncovered at Samsun-Ikiztepe were produced from such a high arsenic content alloy.

By the middle of the Early Bronze Age, the first objects of bronze – an alloy of copper and tin – appeared in Anatolia; however, the widespread use of arsenical copper continued in use until the beginning of the Late Bronze Age. Especially when the tin necessary for making bronze was scarce, the Anatolian masters met the demand for metal objects by using arsenical copper instead.

The increase in the variety of metal artifacts and the fine quality of workmanship of the objects uncovered during Early Bronze Age II is an indication of the use of new casting techniques. The recent discovery of very rich arsenic ores in Sinop-Duragan revealed that arsenic was mined extensively in the area in order to prepare intentional arsenical copper. Ikiztepe is located in very close proximity to both copper and arsenic ore sources. Numerous artifacts of arsenical copper were uncovered at this site. The Ikiztepe metal workers can be considered as the forerunners of this important technology. Using arsenic copper alloys, Ikiztepe metal smiths produced high quality artifacts with higher strength and finer shapes . After the initial exploitation of the Duragan arsenic mines by the Ikiztepe miners and other contemporary Anatolian metal producing centers, the continued utilization of this mine is documented by the writings of geographer Strabon. Strabon informs us that these deposits were found in Mount Sandarakurgion, which literally meant “red arsenic”.

During Early Bronze Age II, the metal objects were produced not only in open molds but also in closed molds. The lost-wax technique must have been employed because the shapes of most artifacts dating from the period indicate that hard stone molds were not used. With the new technique, the desired object was first shaped either with clay or wax. The clay or wax object was then either covered with a second clay layer or immersed into sand to produce the clay or sand mold of the object. The molten metal was then poured into the cavity in a clay or sand mold to obtain the desired metal object. In addition, stone master models are known to have been used, especially for the mass production of high quality large size objects. The final shape of the cast objects was attained by hot or cold forging, then finished by polishing the surface with abrasive stones. The fact that the artifacts produced do not resemble each other, neither in size nor in form, indicates the use of this technique in Early Bronze Age II.

Towards the end of this period, the most important achievement in Anatolian metallurgy was the use of bronze (an alloy of tin and copper) for the production metal artifacts. However, the use of bronze was still limited during this initial period, and examples have been uncovered in sites located in a narrow band stretching from Northern Mesopotamia to Troia through central Anatolia. Outside this region, arsenical copper was still used for the production of metal objects. For instance, bronze was used alongside arsenical copper at Çanakkale-Troia, Balıkesir-Yortan, Afyon-Kusura, Yozgat-Alişar Höyük, Çorum-Alacahöyük, Tokat-Kayapınar, Amasya-Mahmatlar, Tokat-Horoztepe, Tarsus-Gözlükule and Mersin-Yumuktepe

while arsenical copper was the only metal alloy used at Samsun-İkiztepe and Malatya-Arslantepe.

The use of bronze brought with it new changes. Masters now had the opportunity to start mass production. Thus, techniques such as casting, tempering, welding, and gilding reached their peaks. Bronze was used extensively in Mesopotamia, even though there were no local mineral deposits. This means that the metals used in Mesopotamia must have been imported. The same point is valid for tin as well. The tin required for bronze production was initially brought in, probably from Anatolia, but with the increase in demand other sources like Afghanistan were also utilized.

Surprisingly enough, when one considers the sites where the copper and tin alloy was first used to obtain bronze – one of the most important inventions in the history of mankind – it is seen that no tin deposits are found in close proximity to these sites. Recently discovered tin mines at Nigde-Kestel were in production from the second to the last quarter of the 3rd millennium BC. With its strategic location at the center of the bronze producing 3rd millennium BC Anatolian sites, Nigde-Kestel mines would have been an important tin source. Apart from Kestel, the tin deposits closest to Anatolia and the Near East are found in central Asian countries like Tajikistan, Uzbekistan and Afghanistan. Written sources dating to the beginning of the 2nd millennium BCE that were uncovered at Kayseri-Kültepe/Kanesh inform us that tin was brought to Anatolia by the Assyrians. Possibly the Assyrian merchants obtained the tin from distant lands, such as Afghanistan, and brought it to Anatolia. It is known that tin was produced in Tajikistan and Uzbekistan during this later period.

By the first half of the 2nd millennium BCE during the Late Bronze Age, the lack of tin was felt not only in Anatolia but also at other Mediterranean and Middle Eastern sites. Excavations of late Bronze Age shipwrecks in the Aegean and the Mediterranean have yielded many ox-hide, rectangular and bun shaped tin ingots as well as many copper ingots, indicating that tin trading was carried out by sea during this period.

Anatolia had the geological features for the formation of tin deposits, and since the earliest known examples of bronze objects appeared in Anatolia, it is clear that tin was produced in Anatolia during the Early Bronze Age.

Adding 7-10% tin to copper to create the alloy bronze can be considered one of the most important human achievements. The Bronze Age comprises two millennia of human history, and the first bronze works were produced in Anatolia and Mesopotamia towards the end of 3rd millennia BC. Both bronze and arsenical copper were used together during the Early and Middle Bronze Ages. However, by the end of the Middle Bronze Age, tin replaced arsenic in copper alloys. Unlike arsenical copper alloys, the creation of bronze cannot be a chance occurrence because copper and tin ores do not occur together. Bronze production probably began only after tin was independently discovered. Cassiterite, the most important tin ore, has a relatively high specific gravity. Just like gold, crystalline Cassiterite particles accumulate in river sediments.

The earliest gold objects began to appear in Anatolia at the beginning of the 3rd millennium BC, and the source of the gold was most likely alluvial gold recovered from river sediments by panning. It is most likely that the heavy, black or ruby colored cassiterite crystals were

first recognized by ancient miners while panning for gold. With their advanced smelting technologies, it must have been quite simple for the metallurgists of the time to smelt cassiterite to obtain tin. It is actually very easy to obtain metallic tin by smelting the enriched cassiterite ore together with charcoal in simple furnaces. It must have taken a very short time for ancient metallurgists to discover that the addition of this silvery metal to copper would produce bronze.

As far as the mechanical properties of copper alloys are concerned, using tin as an alloying element instead of arsenic has no advantage. Since both arsenic and tin lower the melting point of copper, casting becomes easier. The main reason why tin replaced arsenic was probably due to the fact that the exact percentage of tin in copper can be determined since it is added to copper in the metallic state. However, since arsenic cannot be obtained in the metallic state, it is not possible to pre-determine the arsenic content of arsenical copper. The amount of arsenic absorbed by copper during co-smelting depends on the type and quality of the ore used, as well as on the smelting parameters. At times, both arsenic and tin were used as alloying element in the same copper object. This combination occurred because of the remelting of copper objects that contained both arsenic and tin.

During this period, metallurgists developed new casting methods to supplement the earlier casting methods previously developed by trial and error. One of the new applications was the production of daggers in which the haft and the blade were cast separately and then joined together to form the weapon. Another innovation is the application of a second casting onto objects to produce decorative reliefs. A final noteworthy application is the production of axes with shaft holes. This last application arrived in Anatolia from her neighbors to the south as understood from earlier examples uncovered in those regions. The production of axes with shaft holes in Anatolia started about the same time as the use of tin as an alloying metal.

In the Middle Bronze Age, the art of casting continued uninterrupted, building on the experience accumulated in the preceding periods.

At its peak, the technology was traded between Anatolia and Northern Syria/Mesopotamia through a highly organized system, the world's oldest documented commercial network.

In this period, tin had already replaced arsenic as an alloying element. After the establishment of interregional trade with the south, tin became widely available to the Anatolian metal masters. As a result, the quality of Anatolian castings increased. The tin content of bronze objects from this period is around 10 percent. In contrast to the previous period, the utilization of tin in the production of bronze spread to all regions of Anatolia.

As understood from the quality and quantity of artifacts uncovered, in the Late Bronze Age, Anatolia and other Near Eastern countries were at an advanced level in casting. The most noteworthy distinction in casting during this period was the advancement in statuette production. The limbs of the first large-size example, ca. 0.50 meter tall, representing a king, were cast separately and then welded onto the body, which had a lead core. Later examples of this technique were to be produced in the Hellenic and the Roman Periods; however, since the first example is from the Hittite Period, it illustrates the high art which Anatolian casting had reached within the Near East and Aegean worlds.

Another feature worth noting in Late Bronze Age Anatolian casting is the limited use of brass, an alloy of copper and zinc.

The Anatolian art of casting slipped into a decline in the 300 years following the Late Bronze Age owing to political developments in the Aegean and the Near Eastern worlds. Since excavations have yielded cast artifacts as well as forged ones from the $9^{th}/8^{th}$ centuries BCE, it is understood that metallurgy – and thus casting – had started to revive at this time. Improvements in metallurgy in the region have continued successfully up to the present. The fluctuating development of the art of Anatolian casting was greatly affected by political developments in the region. The art of casting reached its peak in Anatolia especially during the Ionic/Hellenic and ensuing Hellenistic and Roman Periods. Extraordinary developments in marble sculpture reflected itself in the art of casting as well. However, metals and their alloys and techniques in use since the Bronze and Iron Ages improved somewhat and were applied more practically.

Anatolian metallurgy and the art of casting must have originated and developed in the regions near the ore deposits, which are abundant in Anatolia. Copper is still produced in most of these regions today. Diyarbakır-Ergani where the earliest copper objects from the Neolithic Period were uncovered, is still the major copper production center in Turkey. Apart from Ergani, other known important copper mines that were exploited following the Neolithic Period are found in the Elazığ-Malatya region in Southeastern Anatolia. The Murgul and Küre copper mines in the Black Sea Region and those in Merzifon-Tavşan Mountain and Kozlu mines in Northern Anatolia were also exploited in antiquity. Other significant deposits, known to have been worked at least as long ago as the Iron Ages, are found at Çankırı-Yapraklı in Central Anatolia and at Siirt-Madenköy and Artvin-Kağızman in Eastern Anatolia. These rich copper deposits of Anatolia continued to be exploited in the following centuries, i.e. Ionic/Hellenic, Roman, Byzantine, Seljuk and Ottoman Periods. Those at Murgul, Ergani and Küre are still worked today.

That these copper mines were extensively exploited in the past is attested by the millions of tons of slag piled up around in the ancient mine workings. The presence of slag indicates that metal ores dug from the galleries were enriched, reduced locally with charcoal, and cast into ingots. The ingots were then taken to the production workshops located in the settlements. The impure copper was melted in crucibles for refining, followed by the addition of the necessary alloying metal before the desired objects was cast. . Such metal workshops dating from the Early Bronze Age are found at Elazığ-Norşuntepe, Tarsus-Gözlükule, Malatya-Değitmentepe and Arslantepe, and Samsun-İkiztepe. One noteworthy metal workshop of the Middle Bronze Age is the one brought to light at Kültepe/Kanesh. Besides these early metal workshops of Anatolia, during the Roman and Byzantium Period, workshops were located in Antakya, during the Late Byzantian Period in Istanbul, and during the Seljuk and Ottoman Periods in almost all of Anatolia.

As of the Ionic/Hellenic Period, along with permanent and temporary metal workshops, itinerant workshops also existed. There are written sources informing us about the production of life-size or monumental statues that were cast locally by itinerant masters, especially at newly developing centers. On the other hand, the hollow casting technique was employed to produce statues and vases for the purpose of decreasing the amount of metal used, or for producing objects with less weight. .

Itinerant metal workshops were also known during the Ottoman Period. Miniature paintings depict mobile workshops pulled by horses so that the itinerant masters could produce the requested object on the spot.

Examples uncovered indicate that adornments or religious objects were forged or sometimes cast from lead, silver, and gold, metals already known in Early Bronze Age Anatolia alongside copper. In the beginning, gold and silver artifacts were produced from native metals. However, in the following periods, with the invention of the cupellation method, the production of silverwork increased significantly. Sometimes gold was used together with silver. Silver was also used as a secondary metal for inlayed decoration on copper/bronze artifacts, the best examples of which are found in the middle of the Early Bronze Age and later during the Seljuk and Ottoman Periods.

The first examples of extensive use of these metals in casting date from the Assyrian Trade Colonies Period (first quarter of the 2nd millennium BCE). More advanced workshop using the casting technique were brought to light at Manisa-Sardis, the capital of the Lydian Kingdom, dated to the middle of the Iron Age. These workshops extensively produced objects of gold, silver and electrum, an alloy of gold and silver.

The first traces of silver production using the cupellation method have been found at Fatmalı-Kalecik in eastern Anatolia. Study of the crucible fragments, which were encrusted with lead oxide, revealed the presence of tiny silver particles, a residue showing that cupellation was employed. Besides Fatmalı-Kalecik, silver finds have been uncovered at Değirmentepe, Arslantepe and Tülintepe. It is reasonable that the silver ingots produced by cupellation uncovered at Aksaray-Acemhöyük of the Assyrian Trade Colonies Period were for commercial purposes.

Anatolia has quite rich silver deposits. The silver produced from these mines has been alluded to by early travelers and geographers. Besides supplying the local demand, the production from Anatolian silver mines was also exported to Iran, Iraq and Syria. Written sources provide us with a wealth of information about silver production. The biggest silver production mines were those in the Uşak-Güre and Kütahya area in western Anatolia, at Ankara-Işıkdağ in central Anatolia, Amasya-Gümüşhacıköy in the central Black Sea region, at Bayburt, İspir and Gümüşhane in the eastern Black Sea region, at Malatya and Elazığ in the Middle Euphrates region, and at Lülüve near Ulukışla in the central Tauruses.

As attested from finds uncovered, in the Middle Bronze Age and especially during the Assyrian Trade Colonies Period, artifacts were also cast from lead. Lead, which has a very low melting point, was previously used for casting simple ornaments but then became popular for mass production in open molds of religious objects such as deities, holy couple or family with children compositions,.

As of the last quarter of the 8th century BCE, owing to unfavorable political developments, the Urartian Kingdom had to turn to ore deposits in the north in order to continue to exist. As of this date, the Urartians paid more attention to the Erzincan-Erzurum-Gümüşhane-Artvin-Kağızman regions and founded new fortresses for economic and administrative purposes in order to keep the production at the mines under control. These regions held the second richest deposits of silver, lead, copper and iron in eastern Anatolia. These rich deposits were exploited greatly, not only in antiquity but also in the Middle Ages and the Ottoman Period. This region, known as Diauehi by the Urartians, was so important for their mining industry that King Menua launched military campaigns there. Cuneiform Urartian sources say that King Menua took tributes of gold and silver of unknown quantity from Utupurshi, the ruler of the Diauehi Kingdom. King Argishti I (786-64 BCE), son of Menua, received a tribute of 20.5 kg of gold, 18.5 kg of silver and a total of 5 tons of copper during his military campaign into the Diauehi Region in the second year of his kingship. In addition, Argishti I demanded a tribute of gold, silver and copper of unknown quantities from the Lusha Land, thought to have been located somewhat northeast of Diauehi. After this reference, no further mention of

Diauehi has come to light in the cuneiform documents relating the deeds of the Urartian kings. It is inferred that Argishti I annexed the Diauehi region entirely into his kingdom and appointed governors from his capital. The cuneiform documents also say that King Sarduri II received a total tribute of 2114 javelins, 13112 bows, 47970 bronze arrowheads, and 3.5 tons of bronze from the "Arabalar Land", the modern Kağızman-Çoruh Valley, over a period of 336 months. Besides, King Sarduri II received a tribute of 126 tons of bronze from the same region during his 28-year reign. These references show how rich in copper deposits this region was and how big its production had become.

In the Byzantine Period, the gold, silver, copper, lead and iron mines in Anatolia and the Balkans from the Roman Period continued to be exploited. The metals produced were important, especially for coin minting and arms manufacture; therefore, they never lost their importance. The information on the metallurgical activities of this period comes mostly from Muslim geographers and travelers. In 951 CE, Arab geographer Al Ishtahri mentions gold, silver, copper and iron mines around Taron (modern Muş), while another Arab geographer, Al Muqaddasi, tells about copper mines in eastern Anatolia. An anonymous Iranian geography manuscript titled *Hudud al Alem* from 982-983 describes a copper mine in the northeastern Black Sea region. Although all this information is not very detailed, it is noteworthy for it shows that mines in northeastern Anatolia were being utilized at the time. As Seljuk Turks settled down in the region, Muslim travelers wrote about the mines in the area. For example, geographer Yakut mentions copper mines in the Ahlat region of eastern Anatolia , and Abul Feda mentions the silver mines in Amasya. Renowned traveler Ibn Battuta writes that he visited the silver mines in Gümüşhane, where he met many merchants from Syria and Iraq, there to buy silver.

In Byzantium, brass – copper alloyed with zinc – was used alongside bronze - copper alloyed with tin. The fact that brass replaced bronze in the 6th century was due to the destruction of trade with England and Spain, where tin deposits were found. However, it is also known that tin and silver deposits in the Tauruses passed into Byzantine hands in 877.

Zinc, which is necessary for brass production, is widely available in Anatolia. As tin is scarce and expensive, the production of brass artifacts became widespread. In addition, the glimmer and grandeur of brass is comparatively greater than bronze, and so there was an increased demand for brass works of art.

Rich zinc deposits exploited in Anatolia was located to the south of Lake Van and especially in the eastern Black Sea region. The oldest examples of copper and zinc alloys are found in the Urartian Period. Ceremonial spearheads uncovered at Van-Ayanis are among the important finds of the period.

Brass was alloyed from metallic copper and zinc ore (calamine) in the Near East until the 16th century. In Islamic art, brass, alongside bronze, was widely used to produce works of art, especially by forging, until the third quarter of the 12th century.

The decrees found in Codex Theodosianus reveal the difficulties in metallurgy faced by the State. The first decree sent to Probus says as follows: "His Majesty Valens decrees that gold prospectors all over the Orient must keep off private premises . It is decreed to all the provinces in Illyria and Macedonia that no one shall settle any Thracian in his territory. Those who dwell here shall return to their lands of birth. Otherwise, those who continue to dwell here shall be punished." In 386, a second decree by Emperors Gratian, Valentianus and Theodosius issued to Eusignius mentions the turmoil in the Balkans caused by the Goth occupation, which gave a blow to the mining industry but did not stop it entirely. Following the retreat of the Goths, a decree was issued in 424 prohibiting miners from migrating to

other regions. All these show that lack of manpower in the Balkans caused a bigger problem for mining than the Goth occupation.

In the Seljuk and especially in the Ottoman Periods, tin was used for plating copper kitchenware in order to avoid poisoning, a practice still observed today. In this period, tin was unavailable in Anatolia, in the Middle Eastern, and in the Mediterranean countries, so it was imported. Therefore, the trading of tin was an important commercial activity, as it had been in Antiquity. In the Middle Ages, tin was procured from England, Spain and especially Malaysia, all of which have the richest tin deposits in the world. According to Roman and Byzantine sources, tin was brought from England to the Mediterranean countries and Anatolia until the end of the 9th century. From the end of the 9th century through the mid 13th century, the tin demand of Anatolia and the Islamic world was supplied from Malaysia. Islamic authors provide us with detailed information on the tin trade from Malaysia. However, due to rising Mongolian power in the Far East, this trade declined. Islamic authors say that the tin demand of the Mediterranean countries was supplied again from England as of the first quarter of the 13th century. This tin trade was conducted by the Venetians and the Genoese and continued until 1571.