Brass from the past

Brass made, used and traded from prehistoric times to 1800

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Brass candlestick inlaid with gold, silver and a black substance, 1340s. The side shown is thought to depict Tashi Khatun, Mongolian regent and mother of Sheik Abu Ishak of Shiraz. She is being offered fruit and a book. Inv. 47632. © Museum of Islamic Art, Doha, Qatar

Detail of brass candlestick inlaid with gold, silver and a black substance, 1340s. The side shown is thought to depict Tashi Khatun, Mongolian regent and mother of Sheik Abu Ishak of Shiraz. She is being offered fruit and a book. Inv. 47632. © Museum of Islamic Art, Doha, Qatar

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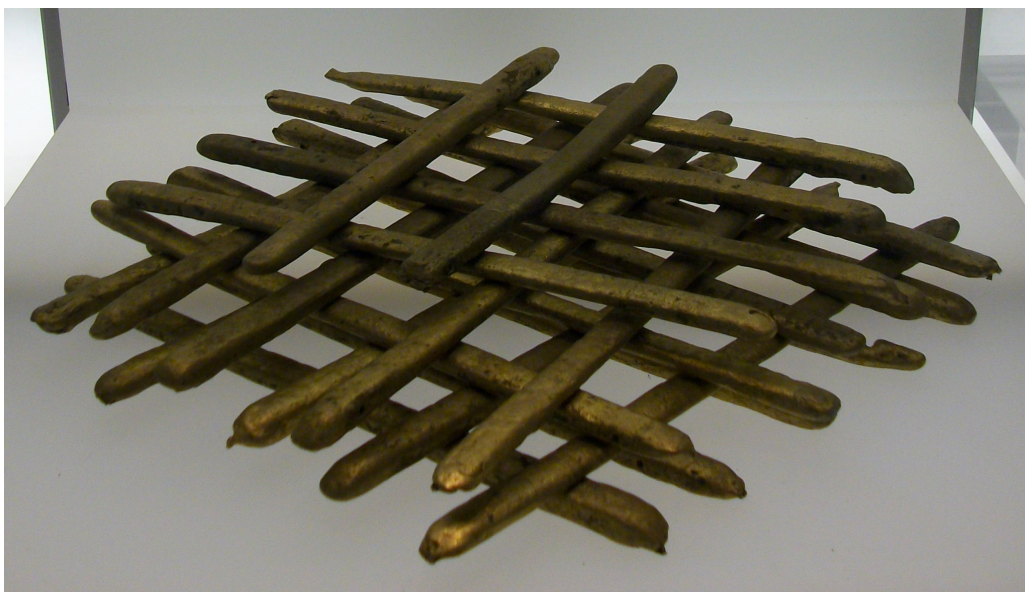

Brass currency bars from Hedeby, northernmost port of the Carolingian empire, freshly cast from metal ores mined in the Balkans. 16-25cm long. *Top*, photo © Wikinger Museum, Haithabu, Schleswig; *Bottom*, photo © author, by courtesy of the Viking Museum, Haithabu, Schleswig

Chapter 1

Experiment and emergence

From prehistory to the Roman Empire – *c.*2500 BC-AD 500

Brass, a gold-coloured, metal alloy, shows an engaging aptitude to follow the same course of history as its human makers. The glint of flames on brass ornaments on the shelves of elderly relatives may evoke memories, but brass, in the past, was for more than just trinkets. It is an exciting glistening alloy with a turbulent history, ranging from the exotic to the sordid, and it was often at the centre of political, social or economic interactions. Brass was long seen as resembling gold, which is a metal that can occur in nature, whereas brass, like bronze, must be alloyed. Brass-making, however, was more difficult than normal metal-alloying, caused pollution, and used up valuable fuel resources – yet new brass-alloying processes and decorative techniques were steadily developed over time, to meet increasing demand, so what did people make from it, how, and why? Since it was a somewhat difficult alloy to make, why take the trouble to make it at all? Why would people want brass, and who were they?

Brass, being an alloy, is a mixture of metals that have been selected and modified, and it is alloyed from copper and zinc whereas bronze is alloyed from copper and tin, so why might brass sometimes be chosen in preference to bronze? They had some differences, brass (8% zinc) has a desirable rich yellow-golden colour much like that of gold and it was tougher, harder and stronger than bronze. Brass is also more malleable (easier to hammer) than bronze and more ductile (it could be drawn out into fine wire). This was because the crystal structure of brass consists of positively-charged atoms[1] of copper and zinc that are virtually equal in size, allowing them to form a tightly-packed solid cubic crystal lattice of metal atoms with a cloud of negatively-charged electrons moving freely throughout the lattice. This arrangement allows the smooth surfaces of layers within this lattice to slide against each other when hammered, so the alloy is hard and holds together well under stress. Another useful property of brass is its low friction, making it useful for moving parts like locks and hinges. This contrasts with bronze, in which the atoms of copper and tin forming its crystal lattice are very different in size, so the surfaces of the layers are more corrugated, meaning that hammering or stretching forces its atoms out of position more readily. These dislocations distort the bronze crystal lattice sooner, producing a more brittle metal that is prone to cracking.

Another great advantage of brass over bronze is that not only are zinc sources far more widespread than the tin sources needed for bronze-making, but zinc ores often

[1] strictly-speaking, ions

occur in the same region as copper ores. Early on in the prehistoric period, pure or 'native' copper ore often lay near the surface, and native copper, a malleable, easily hammered material, was among Neolithic exchange goods handled before 8000 BC at Hallan Çenü and at Çayönü settlements in eastern Anatolia,[2] where small artefacts made from locally-sourced native copper date from 7400 BC onwards. In Anatolia, at Catal Höyük (double mound), native copper beads accompanied female burials dated to *c.*5900 BC.[3] In China, copper artefacts have also been found, dating back to at least the 4th millennium BC[4]. The extensive Kargaly copper mines in today's northern Kazakh steppes, date from the late 4th to the early 3rd millennium BC.[5] Copper is also thought to have been worked from the 4th millennium BC in Nubia, south of Egypt, and around 1200 BC at three sites with furnaces at Agadès, south-east of Azelick, Niger.[6] An important late Egyptian and Roman copper source was in Cyprus (source of the Latin term *cuprum* – copper), where copper was locally exploited from 3500 BC, intensifying from 2500 BC upon cultural contact with Anatolia.[7]

In Europe, the copper-exploiting, or Chalcolithic, Age started at different times depending on the area. Nearer to the Carpathian Mountains, the Vinča culture (*c.*5700-4500 BC), embracing most of the Balkan states, produced a copper axe dating to 5500 BC. Later Vinča-culture burial mounds, or 'cities of the dead', near Pločnik in today's Bulgaria, have revealed copper tools, weapons and personal adornment such as armbands[8] and, by about 4800 BC, nearby sites produced needles, awls, beads and earrings.[9] The Bulgarian Varna culture (*c.*4400-4000 BC) used copper axe-heads, spearheads and chisels. The Copper Age started about 4200 BC in Austria and Bavaria, and about 3300 BC (the date of the copper axe of Ötzi, the ice-man) in the rest of southern Europe.[10]

Smelting, using heat to release metals from their ores, made it possible to alloy one metal with another. Lead is simple to smelt from ore, so its onset is hard to trace, but evidence exists from the 6th millennium BC.[11] Copper was probably smelted in the late 6th to early 5th millennium BC, in the Balkans and perhaps Iran,[12] by which time metal workers could experiment with alloying copper with other, different, metals, wondering what each new alloy had to offer. Knowledge of the history of these ancient alloys is growing all the time thanks to the expertise and technology of

[2] Özdoğan 1999: 54; Sharp-Jonkowsky 2002: 88
[3] Mellaart 1967: 22, 52, Radivojević et al 2017: 108-9
[4] Reade 1991:34
[5] O'Brien 2015: 187-8
[6] Herbert 1984: 7, 16-17
[7] Steel 2004: 3, 83, 121-1266, 114, 143-144
[8] Jovandovič 1990: 55-56
[9] Gale *et al* 2003: 124-125
[10] Heyd 2008: 24
[11] Craddock 1995, 125, 205
[12] Radivojevic et al 2017, 121

archaeo-metallurgists, those scientists who analyse and study archaeological metal objects. The deliberate alloying of copper and tin to make bronze signalled the start of what we call the Bronze Age. The origin of most early copper alloys is not known, but in north Georgia in the Caucasus region (between the Black Sea and the Caspian Sea), copper was first alloyed with locally available arsenic in the 5th millennium BC,[13] and arsenic, antimony, nickel and lead ores were subsequently all alloyed with copper there[14]. A few bronze examples date to about 4300 BC from Aphrodisias, western Anatolia[15] and a bronze spiral ring containing 11% tin, from Talin, Armenia, dates to around 3500-3300 BC.[16]

The origins of brass making are hard to clarify, but small-scale developments evidently occurred earlier than previously thought. For example, in the eastern Black Sea region of the south Caucasus (now western Georgia), small outcrops of polymetallic ores containing copper, zinc and iron[17] are very common.[18] People of the agricultural Kura-Araxes culture (about 3500 to 2500 BC) alloyed and worked metals in Armenia, the south Caucasus, north-west Iran and eastern Anatolia. From the early 3rd millennium BC, rare small copper-alloy artefacts, particularly beads, occur in this area, containing up to five to six per cent of zinc, as well as arsenic and tin.[19] The contemporary northern-Caucasus Maikop culture used these alloys in high-status burial goods, one of which was made of zinc metal.[20] In Armenia, a few early brass objects were made from the late 3rd millennium BC,[21] and were widespread in South Georgia and East Anatolia during the 2nd millennium BC.[22]

China, too, had zinc-rich copper ores from which early brass was perhaps sometimes accidentally produced,[23] under the right conditions, enough to make a few objects. Its zinc ores stretched from the T'ai-Hang Mountains of Shaanxi province in the north,[24] through the central provinces,[25] and southwards to Guangdong and to Pa Niu (now just inside Thailand).[26] Rare, scattered reports of fortuitous Chinese brass include a hairpin from Shaanxi province claimed to date to about 3000 BC, and an awl from

[13] Meliksetian *et al* 2010: 201
[14] Ghambashidze 1919: 42, 47
[15] Sharp-Jonkovsky 2002:143
[16] Sagona 2018: 268-9
[17] Zinc-rich chalchopyrite
[18] Ghambashidze 1919: 42, 47
[19] Abesadze: 1969: 207, 253, 282-283
[20] Chernykh, 1992: 66-67, 74
[21] Meliksetian et al 2011: 205, 209
[22] Iskili and Altunaynak: 2014, 78
[23] Fan Xiaopan, personal communication
[24] Golas 1999: 138, note 375; Song Yingxing 1966, 471
[25] Chen Jianli *et al* 2005: 49; Smith 1918: 68
[26] Needham 1974: volume 5, part 2, 212;

a site in Shandong province claimed to date to the 3 millennium.[27] However, dating and stratification may be a problem for these isolated claims, especially given that the widespread adoption of brass in China did not come until the 15 century AD. Local craftsmen in either the Caucasus or China may have produced low-zinc objects accidentally, rather than intentionally, because in practice their yield would mostly have been copper, with up to about 1% of zinc, most of the zinc having vaporised, and most of the iron having ended up in slag (the waste product of smelting).[28] The main problem was that, despite availability of materials, brass was not straightforward to alloy in the prehistoric era, and the difficulties may have taken a long time to solve.

To alloy copper with zinc, metal workers had to overcome two daunting technological problems. The simplest way to make an alloy is to mix the two metals together, metal with metal, but zinc is more difficult to handle in this way, and this will be discussed below. The other reason is that zinc metal does not occur on its own in nature – it combines too readily with other elements – but it is common as a composite ore, occuring as zinc carbonate or zinc sulphide.[29] Even copper is rarely found as a native metal on its own, so making making brass deliberately by combining copper ore directly, even with zinc carbonate, was not likely in early prehistory.

The next question is: who first made brass intentionally, and where? An alert prehistoric copper craftsman might occasionally have noticed unusual, slightly golden, effects when smelting ores containing copper and zinc, and have repeated the experiment. The earliest evidence for deliberate brass-making seems to emerge in a very few places in the Caucasus, the Middle East and neighbouring areas in the 3 millennium BC. Later on, it is rare for a copper-zinc brass to contain less than about 8% zinc. Therefore, for this account, brass will be assumed to contain at least 8% zinc, by weight, and the objects described in this chapter as brass have all been analysed and found to be copper containing at least 8% zinc, together with only small amounts of other ingredients.

During the prehistoric period, the story relies on scarce archaeological finds of individual brass fragments, but a picture is nevertheless emerging. As farming led towards a settled lifestyle, communities gradually became organised into simple villages. Farming – herding and grain-cultivation – brought the chance to produce more food than was needed for subsistence alone. Surplus grain or meat raised the prosperity and status of the communities, allowing agricultural and herding leaders to emerge. Surpluses allowed these privileged members of family society to profit from the work of those producing the excess food, and perhaps to pay or maintain certain craft specialists like the makers of the special new metal, brass.

[27] Zhou Wenli 2016: 9

[28] Gilmour et al forthcoming and B. Gilmour personal communication

[29] $ZnCO_3$, smithsonite or ZnS, sphalerite

The practice of crafts like making brass would have been determined by the overall customs of the culture, but the golden appearance of the alloy would arrest the attention of ambitious leaders. Over time, stronger leaders and more organised societies emerged, developing from nomadic pastoralism to villages, city-states and kingdoms and finally to empires with fluctuating, fluid boundaries. Shifting boundaries gave excellent opportunities for contact between peoples, and this kind of interaction allowed the diffusion of knowledge needed to identify and find copper or zinc carbonate ores and to learn brass-making technology from practising craftsmen. Archaeological evidence shows that leaders gained prestige and power by circulating rare gifts that carried a magic aura. Early brass came into this category, and those who knew the mysteries of making it would have been worth enticing or capturing. The rare surviving prehistoric brass items suggest that they were intended for handling by those higher up the social ladder. Skilled craftsmen who made brass are likely to have depended on those who could repay them and perhaps lift them from subsistence living and keep them while they worked.

The skill of these very early, possibly itinerant, brass craftsmen is astonishing, because of the complexity of making brass as opposed to bronze (for which copper and tin can simply be melted together). There are two major problems. One, as already mentioned, is that zinc does not occur in nature as a pure metal. It is too volatile and reactive – combines too readily with other elements – and only occurs in compound ores such as zinc sulphide (ZnS) or zinc carbonate ($ZnCO_3$). The other problem is that zinc is so volatile that it vaporises and escapes into the atmosphere when heated above 907ºC, a temperature below the melting-point of copper (1084°C). Therefore, since zinc and copper cannot both be in a molten state at the same time, it was no use trying to melt them together. The answer was to produce zinc oxide, as a first step, because zinc oxide is more stable (less volatile) than zinc on its own. To produce it, zinc carbonate ore ($ZnCO_3$) was crushed, layered with powdered charcoal (which is carbon, a reducing agent) and left to roast at about 700°C in a partially enclosed space. Carbon (C) combines with oxygen (O_2) and escapes as carbon dioxide gas (CO_2), leaving behind zinc oxide (ZnO).[30]

The most practical zinc ore for the cementation brass-making process was zinc carbonate ore, commonly called calamine. However, in many mountainous areas, zinc sulphide ores predominated, so before reaching the zinc oxide stage, unwanted sulphur had first to be partly purged from the ore by slow roasting with charcoal until sulphurous gases escaped. Upland metal-workers in the Middle East discovered that they could produce zinc oxide by heating powdered zinc sulphide ore (ZnS) over a fire until it vaporised, combining with oxygen in the air to form white clouds of zinc-oxide vapour. This method eliminated most of the unwanted sulphur, and white powdery zinc-oxide encrustations could be collected on cold metal or clay bars above the open

[30] $ZnCO_3 \rightarrow ZnO+CO_2$

fire, as the vapour cooled.[31] Flakes of the zinc oxide could then be scraped off and collected either for making brass or for medicinal eye-ointments. An Indian medical treatise dating to about 500 BC mentions the product of this process, and its use for treating sore eyes and open wounds.[32] The zinc oxide flakes could be used for brass-making by the cementation process to be described below, during which, as the brass began to form, the temperature could be lowered and a bit more zinc oxide powder quickly sprinkled onto the surface.[33]

In order to actually make brass, prehistoric metal-workers would have needed (besides copper and zinc oxide) wood for making charcoal – which provided both heat and a reducing atmosphere – the heat of a fire, and some small containers to act as crucibles to hold the molten metal. Pottery was already culturally important, and fire- and heat-proof ceramic vessels were a natural choice as containers for molten or liquid material because they were already used at early copper-working sites for heating ore to extract copper metal.[34]

The cementation method mainly used by prehistoric brass-makers involved placing powdered zinc oxide and crushed charcoal (carbon) together inside a vessel (crucible), together with finely divided copper fragments. Zinc oxide reacted with carbon inside the crucible to produce zinc vapour plus, mainly, carbon dioxide.[35] A tightly-fitting crucible lid could prevent zinc vapour from escaping into the atmosphere. Once the zinc vapour started diffusing in through the surfaces of the warm but still-solid copper fragments, brass began to form. The temperature always had to be kept just below the melting-point of copper (1084ºC) to make sure the small, hot copper pieces remained solid, because if copper melts it will sink into a pool at the bottom of the crucible and present too little surface area to absorb enough zinc vapour to form brass. Experiments suggest that 950-1000°C is the temperature for maximum uptake of zinc vapour by copper,[36] but the optimum temperature varies as the process proceeds.

During the brass-making process, as copper absorbs zinc, the temperature will drop as the solid alloy becomes fully liquid (the *liquidus* phase). Once 20% zinc has been absorbed, for example, this liquid phase will have lowered from 1084°C, to 1000°C. Once nearly 30% zinc is absorbed, the alloy will become liquid at only 919ºC. Since this is barely above the temperature at which zinc vaporises enough to diffuse into the copper, the reaction soon halts. This explains why early cementation brass did not normally contain more than just under about 30% zinc[37]. Ideally, therefore, the

[31] Allan 1979: 38-9; Reade 1991: 34
[32] Craddock, Freestone *et al* 2000: 29
[33] Craddock and Cowell 2000: 123-124
[34] Jovandovic 1990: 55-56
[35] $2\ ZnO + C = 2\ Zn + CO_2$
[36] Bourgarit and Bauchau 2010: 51; Newbury *et al* 2005: 75
[37] Rehren and Martinón-Torres 2008: 168

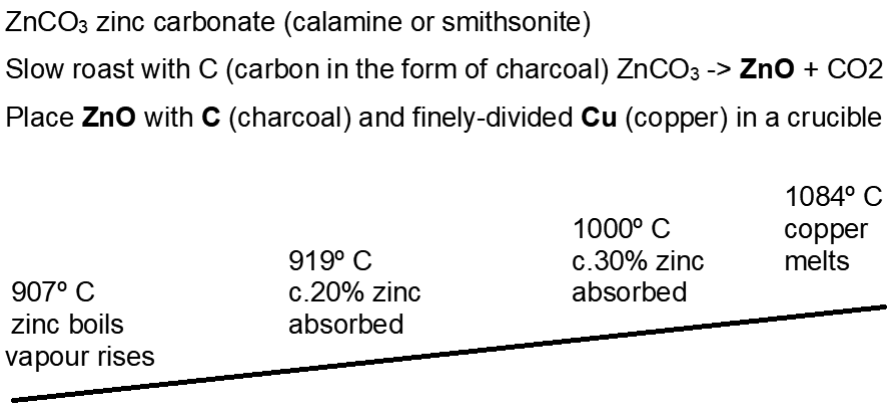

Figure 1. Diagram of temperatures during cementation

crucible temperature should be controlled to start at around 1000-1100°C and be gradually lowered to nearer 907°C (the boiling point of zinc),[38] not easy to regulate without thermometers, and perhaps seldom achieved. Once alloyed, the brass could be heated slightly further, to make sure it was evenly mixed, after which it could be cast – poured out into a mould.

Brass can contain varying amounts of zinc. To find out whether an early copper alloy metal object is made of brass, it is necessary to know the ratio, by weight, of copper to zinc and to any other elements present. As already mentioned in this account, only copper alloys containing at least eight per cent zinc (by weight) will here be counted as brass. For the alloy to be a true brass, other elements such as iron, lead or tin should only be present in much lower percentages than zinc – generally up to two or three per cent, but this was almost certainly uncontrollable in prehistoric times. Lead, tin or iron lower the melting point, reducing the amount of zinc that copper can absorb, so that when the molten brass temperature drops to 907ºC it will contain less zinc than with a purer mix. Too high a percentage of the elements arsenic and antimony makes brass brittle to work.

Although there is very little evidence for brass-making in the early Bronze Age – the early to mid 3rd millennium BC – what does survive gives an idea of which levels of society saw the fascination of brass and could afford it. At Thermi on the island of Lesbos, just across the water from ancient Troy, the few excavated brass objects include a knife, pin, ornament and pierced disc,[39] dating probably to the mid to late 3rd millennium BC. These were luxury items in use during the first and second phases of Troy, where a powerful leader, with his family, retinue and servants, ruled from a citadel, surrounded by farming families, perhaps dependent on him for protection. Thermi, on Lesbos, which had an organised layout of long rectangular buildings, had

[38] Rehren 1999: 1083-1085

[39] Begemann *et al* 1992: 224; Thornton and Ehlers 2003: 4

the same stratified society as Troy itself, so it is not hard to guess to which social level the users of the four golden-looking brass objects belonged.

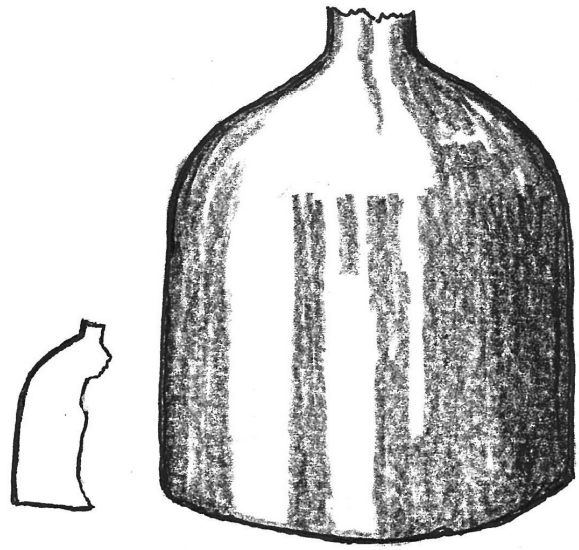

Figure 2. Miniature brass helmet from a royal grave at Ur

More evidence for Middle Eastern brass in the mid to late 3rd millennium BC comes from a high-status grave at the cemetery at Ur, which contained part of a miniature 9 cm-high brass helmet,[40] too small to have been worn into battle but a clear statement of power and influence. Ur was the world's largest city of its day, and capital of the great and progressive Sumerian Empire (southern Iraq). It imported luxury goods from Afghanistan, India and Asia Minor, and was the leading port on the Persian Gulf, which then extended further north. Brass grave-goods at Ur, including the helmet, a dagger, spear-tip (10.7 cm long)[41] and bowls, imply the presence there of a wealthy elite, and were perhaps originally used as revered objects for gift exchange, or produced solely to accompany important burials. Another Sumerian city, Kish (Kiš) on the Euphrates, covering several square kilometres of land about 80 km south of today's Baghdad, had forty tells (habitation mounds) and a simple palace – a sure sign of a stratified society. A brass bowl and a toilet knife found at Kish seem to have been intended for elite users.[42] Also dating to the early Bronze Age (the mid 3rd millennium BC) they too suggest which levels of society desired brass – and could afford it.

In the late 3rd millennium BC, the evidence suggests that brass was exploited by powerful members of society to achieve their own ends. On the steppes of Kalmykia (now western Kazakhstan), the elaborate catacomb graves of the settled farming community at Ergeni (Ergeninski) north of the Caspian Sea contained a brass knife and hook.[43] Other excavated material from this site shows that the pastoral horse-riding nomads of Kalmykia dressed in multi-coloured clothing adorned with long strings of bronze and paste-glass beads. In many prehistoric contexts, exotic materials possessed by powerful leaders reinforced their status, and unusual objects gained in

[40] Hauptmann and Pernicka 2004: 82, and figure 127
[41] Hauptmann and Pernicka 2004: figure 103
[42] Hauptmann and Pernicka 2004: 27 and figure 35
[43] Thornton 2007: 126

prestige as they passed around the exchange networks, imparting their value to the giver and receiver. A leader who participated in the exchange system stood far higher on the social ranking ladder than the craftsman who made and worked the brass.[44] At Ergeni in Kalmykia, and contemporary sites, objects made of unusual metals were used in complex burial ceremonies and as symbolic talismans for reinforcing territorial control. Around 2500-2200 BC, shortly before the Kalmykia steppes dried up for a millennium,[45] brass and locally-mined copper were cast in moulds. Casting brass in a mould was less straightforward than casting bronze but solutions were available and experiments would have shown craftsmen how to cast brass successfully. The rare brass items excavated from such sites must represent a small minority of what originally existed, many more having been lost or looted, so never available for analysis. At two sites in today's Georgia, besides third-millennium copper-working evidence, copper tools and weapons, two objects, a dagger blade from Nuli in today's northern Georgia and a disc-shaped pin from Telebi (Telavi), east Georgia, each contained five to six per cent of zinc, which might (for this early date) be called a low-zinc brass.[46]

Societies were starting to urbanise, but the few surviving brass objects from millennia ago may represent the way in which many more were used and valued. From the late 3rd millennium BC, excavated material from two Middle Eastern urban settlements includes three different kinds of brass artefact. Two of them, a needle and seal of pure brass were excavated at Namazga (in today's southern Turkmenistan), a 60-hectare nascent urban community on a strip of land where rivers descend to the plain from the dramatic eastern Iranian slopes.[47] The third artefact, a dagger, also of pure brass[48] was excavated at Umm-an-Nar,[49] a different contemporary urban settlement on an island next to Abu Dhabi on the Persian Gulf (now United Arab Emirates).[50] It has been calculated that circulated prestige goods, like the brass objects described, must have facilitated the creation of political and economic hierarchies by imparting authority to them – an effect that radiated from the impressive rarity of the brass objects, their symbolism, possible invested spirituality and the elevated strata of society within which they circulated.[51] With urbanisation, however, brass making would gradually begin to lose its aura of mystery and become more utilitarian.

The stone buildings of the Umm-an-Nar culture, which lasted from 2600-2000 BC, included one extra-large house with many rooms for the dominant leader, and beehive-shaped burial cairns constructed of carefully fitted stone. Copper-working

[44] Frachetti, 2006: 27
[45] Anthony 2009: 48
[46] Kavtaradze 1999: 73, 91, 95
[47] 37°37 N 59°55 E
[48] 90% copper, 10% zinc
[49] artefact 1011, A1, Grave II
[50] Frifelt 1991: 98, 100-101
[51] Weeks 2003: 189

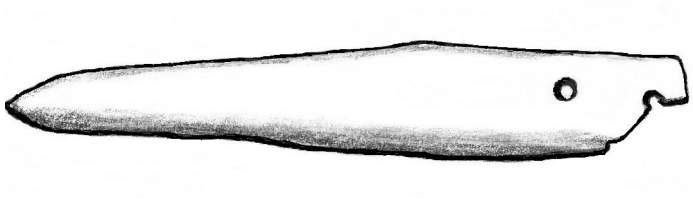

Figure 3. Dagger from Umm-an-Nar

took place at this site,[52] whose inhabitants drew their prosperity from fishing and maritime contacts, and from trading their local copper to Mesopotamia (Iraq). It is possible that the brass dagger found there was made in Mesopotamia as an object for exchange connected with the copper trade. It was found in a stone-built grave, twelve metres in diameter, furnished with picture-stones, one bearing the image of a camel in low relief. At Nuzi, in Akkadia, east of the River Tigris in northern Mesopotamia (north-eastern Iraq), two excavated brass rings date from the late 3rd millennium BC.[53] Nuzi was a provincial town full of Hurrian people who originated from Anatolia where zinc ores occur,[54] so they may have arrived already knowing how to alloy brass.

This was becoming more than just a period of emerging city-states; it merged into a time of ruthless rulers pressing into new territories, forming empires whose boundaries surged back and forth with the winners and losers. Contact across shifting boundaries diffused technical knowledge. As one powerful state or empire shrank towards oblivion, crafts such as brass-making would remain or travel with expert craftsmen, to be taken up and exploited by a newly emerging power. The development of better agriculture and herding meant that cattle- or grain-owning communities were prospering, to the envy of their neighbours. Dating from shortly after 2000 BC, at Dalversin, an influential state in the fertile, prosperous Amu Darya (Oxus) valley (in today's southern Uzbekistan) a brass ring and pin were excavated,[55] suggesting interaction with neighbouring states.

Within the boundaries of the new emerging states, more complex hierarchical societies were developing. In the early 2nd millennium BC, at Tepe Yahya, in the Soghun valley, in Kerman province (in today's southern Iran, 1,200 metres above sea level and several days' walk east of the Persian Gulf) three fragments of brass, and part of a bracelet dating to the early 2nd millennium BC were excavated.[56] A '*tepe*' was a group of *tells* or great mounds created by generations of inhabitants building their homes upon those that had been there before. This early town had defensive walls and buttresses,[57] and the rooms containing the bracelet and other finds show that its houses and other buildings belonged to a ranked society, and the bracelet found there was probably worn by a well-to-do woman.

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[52] Frifelt 1991: 188. Oriental Department, Moesgard Museum, Jutland
[53] Website: news.harvard.edu/gazette/1998/05.14/Fragments.of.a.Forgotten.Past
[54] Website 2003: bu.edu/phpbin/researchbriefs/display.php?id=121
[55] Thornton 2007: 126
[56] Thornton 2007: 126; Thornton and Ehlers 2003: 4-5
[57] Lamberg-Karlovsky and Magee 2001: 128, 180, 302-322

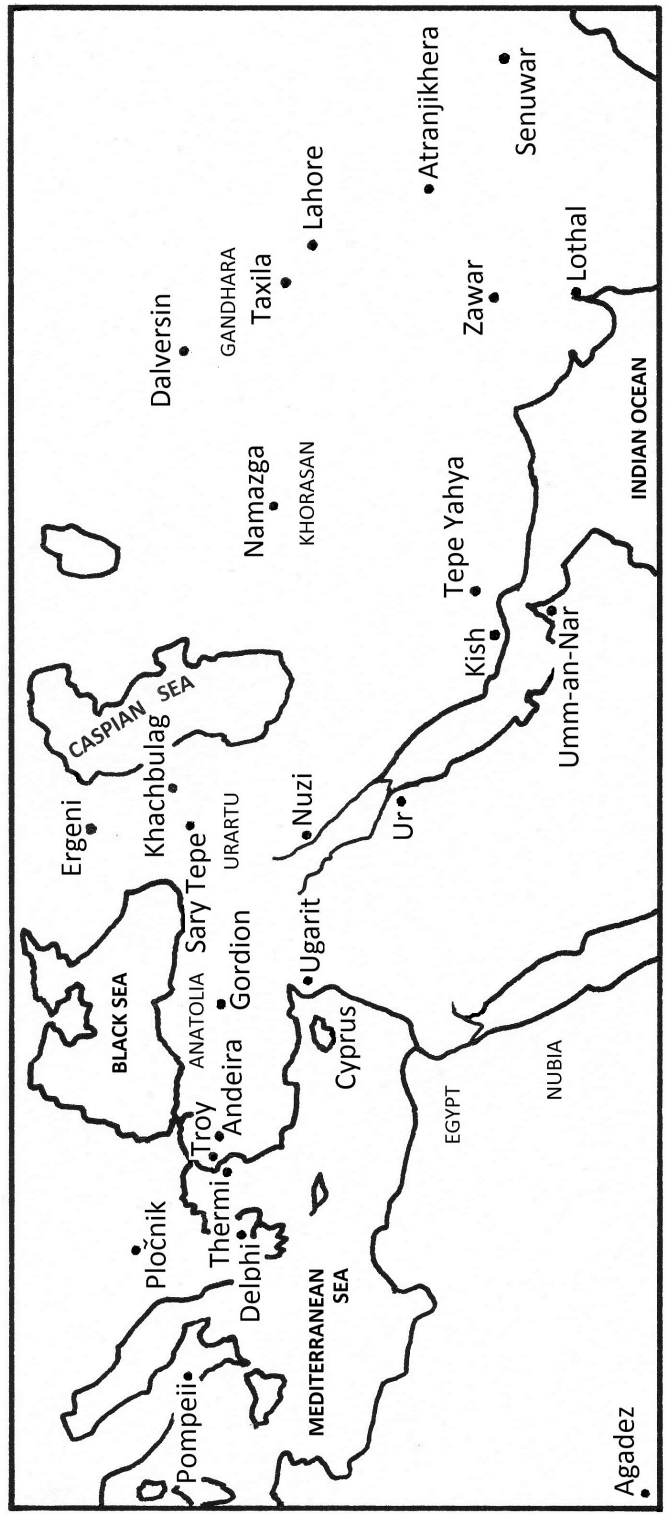

Figure 4. The Middle East to India, map showing some sites mentioned in the text

During this city-state period, when trade contact was widening, the metal contents, and therefore qualities, of brass varied. Metal finds from middle or late Bronze Age sites in the Caucasus, for example, tended to be less pure than in the 3 millennium BC, being mostly of mixed copper alloy with varying amounts of zinc, tin and lead and sometimes arsenic or antimony. Ugarit, a Mediterranean headland port (now in Syria) stood on the south-north route from Egypt to Anatolia – a rich source of zinc carbonate ore.[58] Pottery and metal finds show that Ugarit had strong links with contemporary Egypt and with Cyprus, one source of the copper needed for making brass. A brass statuette and brass ring from Ugarit, dating to around 1400-1300 BC had a lower zinc content but higher lead content than earlier objects, which suggests a change in the way the metal was being used.

By the later 2nd millennium BC, Middle-Eastern brass contained greater amounts of metals like lead and tin, perhaps due, in part, to casting rather than hammering the alloy. Casting brass in a mould would prove less straightforward than casting bronze, but a deliberately-added extra two per cent of lead lowers the melting point of the copper and so makes a more fluid alloy – allowing the molten metal to be poured easily and flow into all the corners of a casting-mould. On the other hand, the increased lead may have resulted from the use of locally available lead-rich copper ores, whilst increased tin could have resulted from recycling old bronze and brass objects together to make new ones.

Rising prosperity in the emerging empires and city-states is revealed by archaeological evidence for brass items possessed mainly by the elite of the Elamite, Sumerian, Babylonian, Assyrian and neighbouring territories, wealthy enough to pay for their production. Such leaders would have valued brass objects, possibly already charged with superstition and mystical religious belief, and used them as talismans to protect their households or to present as charmed gifts to leaders of other city-states. Not only could brass look rather like gold, but it may have had a cachet of its own due to the little-understood processes required to make it. The Azerbaijan coastline, along the east side of the Caspian Sea, brought the region into frequent contact with other cultures and made it a popular target for expansionist empire-builders.[59]

During the earlier 1 millennium BC the Assyrians were being forced out of the region between the Black Sea and Caspian Sea by a rival dynasty, the Urartians, whose domains covered today's eastern Turkey, western Azerbaijan and Iran. In 764-735 BC, Sarduri II of Urartu (a state at the time called Biainili) built Sary Tepe, an elite settlement. Strung along a rocky ridge, the site (in today's Armenia, north-east of today's Dilijan), it still shows clear traces of buildings, from which a brass bracelet and an arrowhead of almost pure brass were excavated. Brass would have made an effective sharp tip to

[58] Website: metmuseum.org/toah/ugar/hd_ugar.htm

[59] Babaev *et al* 2007: 31-32

an arrowhead, but no other brass arrowheads have been analysed from Sary Tepe (just one bronze one), so it may have been created as a rare prestige item rather than for normal use. Also from a Urartian settlement is a figurine of a small horse, with a loop perhaps intended for hanging it from a necklet as a talisman – an early example of 'gunmetal', a term meaning copper containing similar amounts of zinc and tin.[60] Another luxury item of dress-adornment was an 11th- to 12th-century BC brass bracelet fragment excavated from Khachbulag[61], lying between the south-east corner of the Black Sea and the Caspian Sea in western Azerbaijan (south-west of today's Mingecevir).

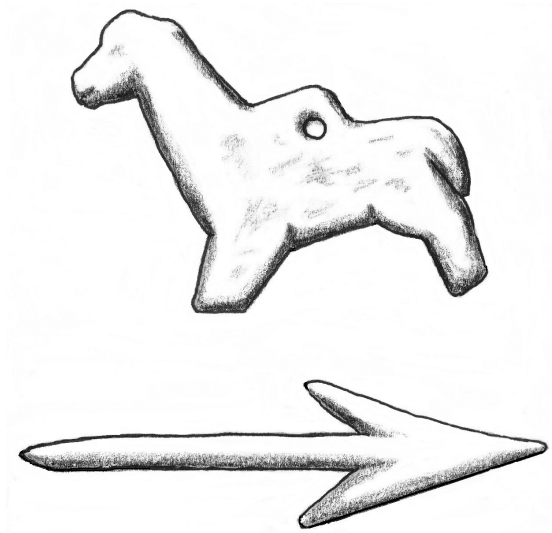

Figure 5. *above*, horse figurine, Kachbulag; *below*, brass arrowhead, Sary Tepe

Although recorded sporadically up to this point, brass became more widespread from the 8 century BC, when brass objects are known from Urartu, Phrygia and Assyria.[62] The metal craftsmen of Urartu used hammering, casting, embossing and engraving techniques. Mineral-rich Anatolia (in today's north-east Turkey, just south of the eastern Black Sea) steps into the picture in the 8 century BC as a source of calamine and a centre of brass-making. A brass bracelet dating to that period was excavated from Cavustepe, south-east of Lake Van in north-east Anatolia.[63] In central Anatolia, by the 8 century BC, Gordion, part of Phrygia, the state ruled by the powerful Midas, had fortification walls and formally planned buildings along a broad main street.[64] Farm produce was abundant around Gordion, and its people were in close contact with eastern Mediterranean trade. Besides metal-working, its farmers and craftsmen practised textile-weaving and pottery.[65] A brass bowl was found there, as well as four early brooches made of bronze, but each containing a little zinc – the copper alloy now termed gunmetal. Brass craftsmen are likely to have worked among agricultural communities where iron and bronze tools were made. Some may have moved to gain the support and protection of a wealthy patron, perhaps transferring from one to another, allowing technical knowledge of brass-making to diffuse over time.

[60] Kashkai and Selimkanov 1973: 222, plate 20, figures 46 and 45
[61] Kashkai and Selimkanov 1973: 221, plate 199, figure 37
[62] Kroll *et al* 2010: 36
[63] Kroll *et al* 2010: 17
[64] Thornton, 2007: 127; Young 1981: 287
[65] Kealhofer 2005: 1 and 31

The excavated and analysed brass samples so far described as brass in this chapter contain an average of 14.4% zinc, and most of them come from sites representing social hierarchies where a more powerful leader could provide a livelihood for skilled craftsmen such as brass-workers but brass was not yet an everyday utilitarian metal. Many excavated copper-alloy items contain too little zinc or too much lead or tin to count as the copper/zinc alloy defined here as brass, so early brass-making was far from a standardised process. Metal ores in some areas contained widely varying amounts of different metals, for instance zinc or copper ores from the Indian sub-continent commonly included iron and more than three per cent of lead. The pure metal known as 'native copper' (Cu), still occurs in the Deccan region of India – the triangular raised plateau spanning central and southern India.[66] At the far north-western corner of the Deccan, an early second-millennium BC site at Prakash produced a brass object found to contain over 25% zinc,[67] a fairly high percentage for the time.

About six leaded copper-alloy fragments containing up to 6% zinc, dating to around 1500 BC, were excavated from Lothal beside the Indian Ocean (in today's Gujarat).[68] This organised port had a well-built dock, ruler's residence, merchant houses and customs house. Lothal had been settled by Harappan people from the developed Indus Valley civilisation further north, near sources of zinc-bearing copper ore.[69] The civilisation stretched from the Himalayas down to Gujarat, and its merchants traded to Mesopotamia and up and down the east African coast.[70]

Copper alloys of the Indus Valley, though they may have contained zinc, also held a considerable percentage of lead and tin – so they were quaternary alloys – combinations of four metals – with a variable balance of copper, zinc, lead and tin. They were therefore not brass by the definition used here, but may represent an increasing use of leaded gunmetal.[71] The Indus Valley civilisation ended by about 1500 BC. By the 6th century BC, the Ganga (Ganges) plain was becoming urbanised. Increasingly high percentages (by weight) of zinc began to be included in early Indian leaded copper alloys. At Atranjikhera, Uttar Pradesh, a settlement on the Kali Nadi river, a tributary of the River Ganges (Ganga), two pin fragments dating to around 600-500 BC were found, made from leaded gunmetal.[72]

The clouds of change hung over the Indus Valley region. The powerful Persian leader Darius (521-486 BC) advanced, conquered and added the north-western Indian states to

[66] Chakrabati and Nayanjot 1996: 18
[67] Kharakwal 2012, http//infinityfoundation.com/mandala/t_pr_khara_zinc.htm, 4
[68] Lothal analysis, number 4169
[69] Kharakwal and Gurjar 2006: www.ancient-asia-journal.com/rt/printerFriendly/aa.06112/23, volume 1, 5
[70] Taxila, 1999: http;//archeology.about.com/od/thers/g/taxila.htm
[71] Kharakwal 2012: http//infinityfoundation.com/mandala/t_pr_khara_zinc.htm, 4
[72] Gaur 1983: 231, 233 and figure 69/4; 444 and figure 130/5; Thornton 2007, 127

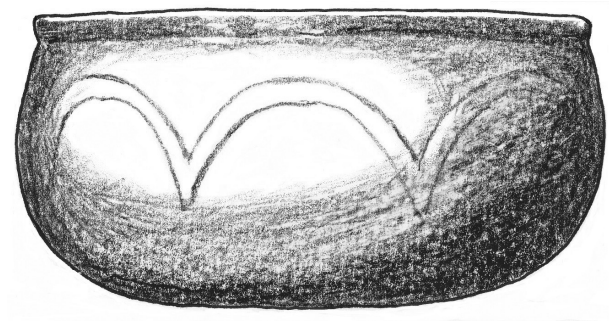

Figure 6. Brass bowl from Taxila

his vast empire, which already included Anatolia and Persia (Iran). His conquests brought these diverse areas into trading contact, and Darius himself was later reported to own an Indian cup which looked like gold but gave off a slightly offensive smell – characteristic of brass.[73] Another powerful and warlike ruler, Alexander the Great of Macedonia (356-323 BC), may have helped to diffuse brass technology,[74] by sweeping in to take much of Egypt, Mesopotamia, the entire Near East and Asia Minor – which fell to him after nearly 200 years of Persian rule. From 332 BC, Alexander the Great also conquered lands bordered by the River Indus and the Arabian Sea, moving north to Taxila beneath the Himalayas. Leaded-brass coins became expressions of power in India, and many were produced there to honour successive rulers, a few in the 4 and 3 centuries BC, but most from the 2 and 1 centuries BC.[75]

Taxila was already a famed Buddhist centre of monasteries and education, at the north end of the Indus Valley (about 32 km north of today's Rawalpindi, Pakistan). One of the most exciting third- to second-century BC finds from Taxila is a high-zinc brass bowl or vase (34.34% zinc), excavated from Bhir mound, a large settlement with many winding streets and closely packed dwellings.[76] Brass containing such a high percentage of zinc implies that it was made by a process different from the cementation process described above. Another high-zinc brass artefact (35.52% zinc) dated to between 700 and 200 BC,[77] was excavated at Senuwar, much further east near the borders of Bihar and Bangladesh.[78]

The existence of this high-zinc Indian brass can be explained. The great Mauryan Buddhist dynasty (321-185 BC) had been taking in territories throughout northern India. Chandragupta, the first Mauryan emperor, had a strong and ruthless advisor named Kautilya, a scholar educated at Taxila. Between 321 and 296 BC, Kautilya wrote of brass-making as part of an organised Indian metal-working industry. He specified that not only should the superintendent of mines understand 'the science of dealing with copper and other minerals', but should also have experience in the 'art of

[73] Hoover and Hoover 1950: 403, translation of Pseudo-Aristotle, *On Marvellous Things Heard* (4-3 century BC)

[74] Craddock and Eckstein 2003: 217

[75] Kharakwal and Gurjar 2006: http//infinityfoundation.com/mandala/t_pr_khara_zinc.htm, 7-8

[76] Marshall 1951, vol. 2: 568, table IV, plate 175, No 284; Marshall 1951, vol. 3: plates 2-7

[77] Kharakhwal and Gurjar, 2006: http//infinityfoundation.com/mandala/t_pr_khara_zinc.htm, 7

[78] *c.*110 km east-south-east of Varanasi, *c.*140 km south-west of Patna

distillation and condensation of mercury' and be responsible for 'the manufacture of brass (*arakuta*)' and for producing commodities from it and from other metals.[79] The art of distillation mentioned by Kautilya brought a key advance in brass making, since distilled zinc metal allowed more precise control of the proportion of zinc to copper and made it possible to include a higher percentage of zinc than was possible with the cementation process.

Clearly, the Senuwar brass artefact and the earlier Taxila bowl both have especially high zinc ratios, and were therefore unlikely to have been produced by the cementation process already discussed. Cementation, which relied on diffusing zinc vapour into copper, and produced brass containing a maximum of *c*.30-31% zinc, was unlikely to have produced objects containing as much as 34.34% and 35.52% zinc. The answer lay with zinc distillation. The Aravalli Hills of Rajasthan, north-west India, which partly consist of good copper ore known as dolomite, are also rich in zinc sulphide, mined there from the late 1st millennium BC onwards.[80] Mining of zinc sulphide ores around Zawar (now Jalore) in the Tiri River valley in the Aravalli Hills was already active during the 4th to 1st centuries BC,[81] and more recent tree-ring dating of timber suggests that it started there by the 9th century BC.[82] Zinc sulphide ores, besides containing sulphur, often held too much iron, which, during the cementation process, would also be reduced to the metallic state and would dissolve into the copper. The alloy produced would thus contain more iron and therefore less zinc, which meant that a different approach had to be taken. Ores were first prepared just as for the cementation process, by crushing and calcining (slow roasting) to produce zinc oxide. Then an extra process was added.

Powdered zinc oxide (ZnO) and charcoal (C) were distilled – heated together in a retort – to remove oxygen, iron and all other impurities, leaving only zinc metal vapour (Zn). As it heated, the vapour rose up the retort and trickled down a cooler tube as molten metallic zinc, which then solidified. The resulting zinc metal could be added directly to molten copper to make brass by mixing them together. The volatile zinc metal was thrown into the molten copper and quickly shoved beneath the surface before it could vaporise – very hot work. Direct mixing of distilled zinc metal now made it possible to produce high-zinc brasses containing more than 32% zinc. The main advantage of mixing distilled zinc directly with copper was that the amount of added metallic zinc could be regulated, so the craftsman could plan the type of brass to be produced. Small amounts of zinc metal could also be added to molten cementation brass, to raise its zinc content and make it purer. Distilled zinc metal must have been involved in producing the two high-zinc brass objects from Taxila and Senuwar.

[79] Ray 1956: 51, translating Kautilya
[80] Craddock and Eckstein 2003: 211
[81] Craddock et al 1990: 38
[82] Kharakhwal and Gurjar, 2006: http//infinityfoundation.com/mandala/t_pr_khara_zinc.htm, 7

Later, the archaeological evidence for brass making was backed up by the written word, bringing it into the historic period. Writing in about 44-33 BC, the Greek writer Strabo quoted a fourth-century historian, Theopompus, who described brass-making, referring back to the mid-7th century BC when Greeks were in the Byzantium (Constantinople) area. He mentioned an ore found in the neighbourhood of Andeira in Anatolia (today's Turkey), which was first 'burned' and then 'when heated in a furnace with a certain earth, distils mock silver; and this, with the addition of copper, makes the so-called 'mixture', which by some is called mountain copper' – *oreichalkon*.[83] Strabo, it has been suggested, might have been referring to Andreida near Balya Maden silver mines, located near Balikesir, south of the Sea of Marmara. In Asia Minor, the Hittites too had a word meaning 'mountain copper',[84] believed to have meant brass. The distilled 'mock silver' may have been droplets of pure zinc, condensed and deposited together with powdered zinc oxide. A seventh-century BC anonymous Greek poem[85] mentions lower-leg armour of shining *oreichalkos* (brass)[86]. The Romans would later adopt, or rather corrupt and adapt, *oreichalkos,* the Greek word for brass, by spelling it *aurichalcum* (golden copper) to mean brass.

Brass was therefore known to the Greeks, even though they preferred gold to brass for prestigious objects, so brass artefacts occurred mainly in Anatolia, their Black Sea settlement.[87] Anatolia may have been the source of 47 brass ingots recovered in 1988 by divers, from a ship wrecked in the first half of the 6th century BC near the prosperous Greek city of Gela, southern Sicily. The narrow ingots, two of which were about 40 cm long, one pointed at each end, formed part of a mixed cargo on a Greek vessel trading to Greek Mediterranean ports.[88] A roll of almost pure (therefore distilled) sheet zinc metal was excavated from a second-century-BC level of the Athenian market place (*agora*), so Greek merchants also handled distilled zinc metal, perhaps from Zawar in Rajasthan, northern India.

The Phoenicians were probably key distributors of zinc metal. In the 9 century BC, when the near-eastern Phoenician city of Tyre held power, Phoenician trading networks already included Anatolia, and they traded copper from Cyprus to the Levant and Egypt and probably helped to spread the knowledge of brass-making around the Mediterranean area, so their alliances are relevant. The Phoenicians had set up city-states around the Mediterranean shores for trading items like glass, purple dye and hunting-dogs in exchange for goods like copper, silver and tin. Sicilian historian, Diodorus Siculus, wrote, around 60-30 BC, that Phoenicians had

[83] Jones 1929: 115, translation of Strabo *Geography,* book 13.1, paragraph 56
[84] Craddock and Eckstein 2003: 211
[85] Shield of Herakles: lines 121-2
[86] Craddock 1995: 293-294,
[87] Caley 1963: 68
[88] Sebastiano Tusa, Soprintendenza per i beni culturali e ambientali del mare, Palermo. Inventory Nos. 4239, 4240

traded since time immemorial to Iberia (Spain), where they exploited rich, silver-bearing copper mines from the 8th to the 6th centuries BC.[89] In the 7 century BC, the Assyrians threatened Phoenician territory by raiding nearby northern Mesopotamia. Under threat from Assyrian aggression, the Phoenicians allied themselves with the newly united (North and South) Egypt, helping it to invade Judah and Israel and sack Jerusalem. The Assyrians and Babylonians meanwhile harried the Phoenicians' eastern Mediterranean home ports. When the Babylonians won, the Phoenicians changed allegiance and traded enthusiastically with Babylonian regions. However, when Babylon was captured by the Persians in 539 BC, the Phoenicians were quick to place their fleets at the Persians' disposal, and helped them to invade Greece (485-465 BC).[90] At this period, therefore, Phoenician traders were in a prime position to spread brass, its ingredients and technology around the Mediterranean.

The Phoenicians also traded with the Etruscans, who lived around the copper-rich Tuscan *Colline Metalliferae* in today's northern Italy and were prolific, lively and imaginative creators of tiny high-tin bronze figures.[91] From the 5th century BC, the Etruscans understood how to work calamine and other zinc and copper ores,[92] but the few analysed brass objects thought to date from the 4th to 2nd centuries BC, mainly figurines, appear more Roman in style than Etruscan.[93] During the Greek period, zinc oxide had an alternative ophthalmic use, and zinc oxide pills, thought to be intended for eye treatment, have been found in a tin pill-box from the wrecked second-century BC ship '*Relitto del Pozzino'.* Judging by the cargo, the vessel was travelling from the eastern Mediterranean, and sank near the busy Etruscan east-west trading port of Populonia (today's Piombino), Tuscany.[94] This is probably the earliest physical evidence for zinc oxide used for anything other than making brass. The Romans defeated the Etruscans in the 2nd century BC.

From the 5th century BC, mine workers at Castello di Parre in the Italian alpine foothills east of Bergamo, produced copper alloys with varying percentages of copper, tin, lead and zinc, Their ancestors are understood to have come west from the Balkans and also to have had links with the Etruscans. Nearby Gorno (a bulgar place-name) in the Val del Riso had exceptionally rich and extensive zinc carbonate (calamine) deposits and the region gradually became criss-crossed with mule-tracks to bring down ore from the high valleys to streams where it could be washed.[95] The Romans first gained control of the alpine foothills area and their zinc-mining activities around 222 BC, only to lose it two years later to local tribes who supported Hannibal, but the Romans recovered

[89] Diodorus Siculus 60-30 BC: paragraphs 20 and 35
[90] Markoe 2000: 37-50
[91] Riederer 2002: 132-152
[92] Stos-Gale 1993: 101
[93] Riederer 2000: 147; Craddock, 1986: 237-238
[94] Giachi *et al*, 2013: 1193
[95] Furia 2012: 23-25, 30-31

this mining region between 198 and 191 BC, as Cisalpine Gaul, incorporating it in 42 BC into their Italian empire and subjecting it to Roman law in 16-15 BC. A mule track (the Và di Góren) linked the mineral-rich valleys and others led down to the north Italian plains, but so far the earliest evidence for brass workshops comes from a settlement just outside the Roman city walls of Milan (*Mediolanum*), dating from the 1st century BC to early 2nd century AD.[96] A first-century AD condenser with deeply impregnated evidence for the preparation of zinc oxide for brass cementation was recently found there, by the great canal that carried water into Milan from the River Ticino. The zinc ore is very likely to have come from Gorno.[97]

Brass objects began to be traded further west along the Mediterranean coasts. A fourth- to third-century BC monumental Phoenician tomb excavated near Cadiz in southern Spain, for example, yielded a four-centimetre brass pin with a round head. A votive hoard of the same period, found in a pit at El Amajaro (near Albacete, south-east Spain), included a fragment of brass sheet.[98]

Earlier on, brass had been made in Asia Minor rather than in the Mediterranean area, but after Alexander the Great of Macedonia took his army into Anatolia in 334 BC his troops may have discovered centres of brass-making and spread the knowledge to the eastern Mediterranean, where evidence for the use of brass started to increase. The Greek, Theophrastus of Lesbos (372-287 BC), wrote of brass-making, reporting that one particular ore, mixed with copper, could turn it yellow,[99] and a later Greek physician, Dioscorides (*c*.40-*c*.90 AD), described how powdery white zinc oxide (*pomphylox*) and zinc metal were collected from silver-smelting furnaces. The metal specks (zinc metal), he added, were lighter and brighter than silver, and used by brass-makers to add to their crucibles.[100]

Brass is also mentioned by Plutarch, born in Pontus and later a priest at Delphi. In about 44-33 BC, he wrote, in his life of the fifth-century BC Greek hero Pericles, that a brass wolf stood in the Temple of Apollo at Delphi at the time when Pericles fought to win back possession of the Oracle (from the Laodaemonians). Pericles had his victory inscribed on the brass wolf before returning Delphi to its former owners (the Phocians), thereby gaining himself and his fellow-Athenians priority access to the predictions of the Delphi oracle.[101] Although his account of Pericles' victory in the 5th century BC is a legend, Plutarch himself was evidently familiar with brass.

[96] Grassi 2015: 156-157
[97] Tizzi 1996: 115-119
[98] Montero-Ruis and Pereira 2007: 136-137
[99] Furia 2012: 30, 33
[100] Dioscorides Book V, section 84, in Gunther 1933, 624
[101] Plutarch 75 AD: Dryden online translation: http//classics.mit.edu/plutarch

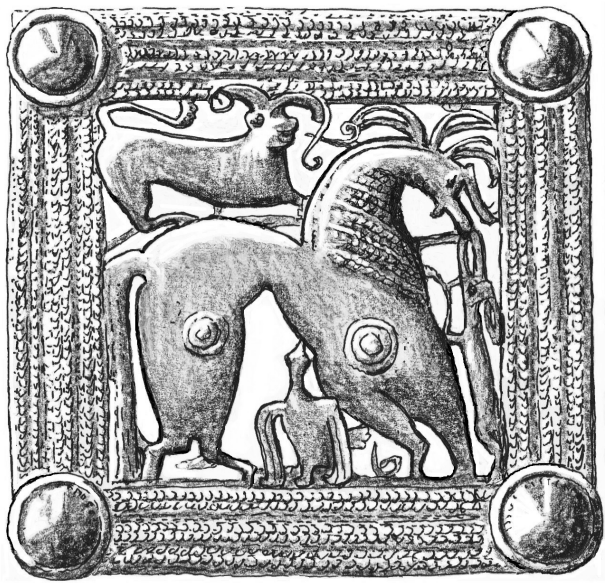

Figure 7. Transcaucasian belt-clasp

During the 7th century BC, the early Greek period, the Iron Age Hallstatt 'Celtic' period had started in Europe. The term 'Celtic' describes a stylistic and linguistic culture enjoyed by peoples living north and south of the Alps, active as far afield as tin-producing Britain and the Mediterranean world.[102] Bronze craftsmanship would reach a peak with the succeeding La Tène culture, with the production of decorative brooches and the widespread use of lost-wax casting (described in the next chapter). In Britain, a second-century BC sword has been found in the River Thames at Isleworth, west London, decorated with La Tène-style maker's brass stamps, hammered to a thin foil. The pure brass stamps (80% copper to 20% zinc) appeared very golden when retrieved, and have a quite similar metal content to contemporary Middle-Eastern brass coins.[103] The absence of lead is significant – lead is not a useful addition in hammered (forged) brass, because the small lead droplets present throughout the solid brass make the alloy more likely to crack under the hammer.[104] Foil is so delicate and fine that no lead should be present in the brass beaten out to produce it. Though the decoration of the foils on the sword was La Tène in style, it is thought that the brass originated from the mines of Andreida, or Andeira, in Anatolia, where relatively high-zinc copper-alloys were produced at that time[105]. A very decorative belt clasp from the Caucasus (Georgia), also of true brass, dates from the 1 or 2 century AD and features curiously-shaped, curvaceous animals.[106]

Brass coins were minted for Mithradates VI (126-63 BC) of Pontus, northern Anatolia, during the early 1st century BC, and 'Celtic' warriors went to Anatolia in the 3rd and 2nd centuries BC.[107] Tribespeople moving westwards through Galicia from Anatolia are thought to have traded brass items and perhaps introduced brass technology

[102] Cunliffe 1997: 1-3
[103] Craddock *et al* 2004: 340
[104] Dungworth 1997: 902
[105] Craddock and Cowell 2000: 124
[106] Curtis 2002: 50-51, 117, plate 9c, 96, table 2, Alistair Pike analysis 137 of British Museum ANE 1921-6-28,1
[107] Pollard and Heron 2008: 198; Zn 13-26%

from Anatolia to Gaul and to other culturally 'Celtic' areas of Europe.[108] Surprisingly enough, most late Iron Age and early Roman brass artefacts have average zinc contents considerably higher than most of those produced in the later Roman period. Skilfully made late Iron Age decorative brass brooches and horse harness are found at various sites in northern England,[109] the metal alloy perhaps imported through Roman-occupied Gaul.[110] Zinc occurs in the coinage of native British tribes, for example in a coin of the Dobunni tribe and two coins of the Trinovantes.[111] In fact, indigenous brass-makers lived in specific areas of Europe both before and during the early Roman occupation.

Dating to 100-50 BC, three excavated fragments of brass brooches or horse-harness have been found at the Titelberg Iron Age hill-top settlement in Gaul (now in Luxembourg). The archaeologists suggest that they or their technology were introduced from Anatolia by the 2nd century BC,[112] especially since the resident Treveri were a tribe of La Tène Celts whose wider territories extended west to the River Danube trade route to the Black Sea. Brass coins bearing 'Celtic-style' designs dating from the mid-2nd century BC onwards were excavated around huts that served as coin-mints. Among 121 other metal objects excavated from the Titelberg hill fort, dating from about 50 BC to AD 300, 45 were made of brass, including several pins for fastening hair or clothing, a buckle, a tool and 29 brooches (fibulae). The highest zinc contents occur from the years AD 1-70.[113]

In the mid-first century BC, local craftsmen in alpine north-eastern Italy designed and made brass coins and brooches. Their region, lying on trade routes from Italy to the Danube basin and the Balkans, was by this time under Roman control, so most brass fibulae found there followed a northern Italian design intended for Roman soldiers. Hinged brass brooches to fasten Roman military cloaks occur from about 60 BC.[114] Alesia-type brooches dating to around 53-51 BC were found at a hill settlement at Alise in Gaul (50 km north-east of Dijon), thought to have been captured by Julius Caesar in 52 BC, but a site in the Jura has also been suggested. 14 out of 17 analysed Alesia-type brooches were of brass.[115] A sword scabbard with impressive brass fittings has been retrieved from the River Lubljanica in Slovenia,[116] and three fragments of brass brooches, dating to around 50 BC, from the Roman-controlled Zerovnišček Iron-Age hill-fort (Slovenia) located alongside part of the Baltic amber trade route.[117]

[108] Craddock *et al* 2004: 340, 343
[109] averaging around 20% zinc to 76% copper
[110] Dungworth 1996: 414-421
[111] Northover 1992: 264, 292-293, 295
[112] Hamilton 1996: 59
[113] Hamilton 1996: 43
[114] Istenic 2015: 41
[115] Istenič and Šmit 2007: 140-142, 145
[116] Istenič 2015: 40
[117] Laharnar 2009: 103

Roman brass items containing more than twenty per cent zinc began to circulate only during the rise of Rome towards the end of the 1st century BC, when the Romans began to dominate in Europe and beyond. They include a first-century-BC-style statuette of Hermes, from Egypt.[118] Late first-century-BC brass ingots, recovered from a Roman shipwreck off Corsica, were cast by pouring molten brass into an oval hollow in sand. A similar first-century-BC Roman brass ingot was found in the Upper Thames Valley in Britain.[119]

The Romans made brass by the cementation process, using calamine (zinc carbonate ore, $ZnCO_3$ or smithsonite), so they needed calamine sources. Pliny the Elder, in about 77-9 BC, mentioned *auricalcum* (brass) and wrote that calamine (*cadmeum*) was abundant in Asia Minor, had been found in Campania and was now being recovered near Bergamo (Italian Alps). Pliny, writing a century after these alpine valleys had been settled, describes their zinc ore sources as well-known abroad (*celebri trans marea*), so the mining had evidently started there earlier.[120] The source near Bergamo is confirmed by Roman coins dated AD 68-9 found at Gorno, the richest nearby zinc carbonate source then accessible near the surface.

Pliny had also heard reports of calamine being recently found in the province of Germania, presumably Roman *Germania Inferiore* (now Belgium and northern France).[121] In this region the Romans made brass between the Rivers Rhine and Meuse, near the great Vieille Montagne (or Altenberg) calamine source at Moresnet, south-west of Aachen (Aix-la-Chapelle). There is evidence for calamine mining near Stolberg, seven kilometres east of Aachen, even before the Roman occupation.[122] Roman brass-makers formed industrial settlements around Stolberg Roman villa for making brass by the cementation method. Nineteenth-century archaeological finds from the Stolberg area reportedly included figurines and horse harness, though little has survived.[123] Most brass-working sites of this period have been built over, but at Roman Anthée, near Dinant, crucibles, furnaces, and many brooches and other items of jewellery were found before the site disappeared.[124]

Brass was more common and higher in zinc content in the late British Iron Age and early Roman centuries than in subsequent Roman reigns.[125] In the period AD 50-100, forty per cent of 111 analysed enamelled brooches from Roman Germania Inferiore

[118] Craddock 1977: 107-8, discussing British Museum 836
[119] Weisgerber 2007: 148-150, 154
[120] Furia, 2012: 29-30
[121] Pliny, 77-9 BC, 1961 translation: Book 34, Chapter 1, section 2, *Vena que dictum est modo foditur ignique perficitur. fit et e lapide aeroso, quem vocant cadmeum, celebri trans maria et quondam in Campania, nunc et in Bergomatum agro extrema parte Italiae, ferunt nuper etiam in Germania provincia repertum*, 126-127
[122] Gechter 1993: 165
[123] Roderburg 1927: 9
[124] Peltzer 1909: 15-16
[125] Bayley 1984: 42

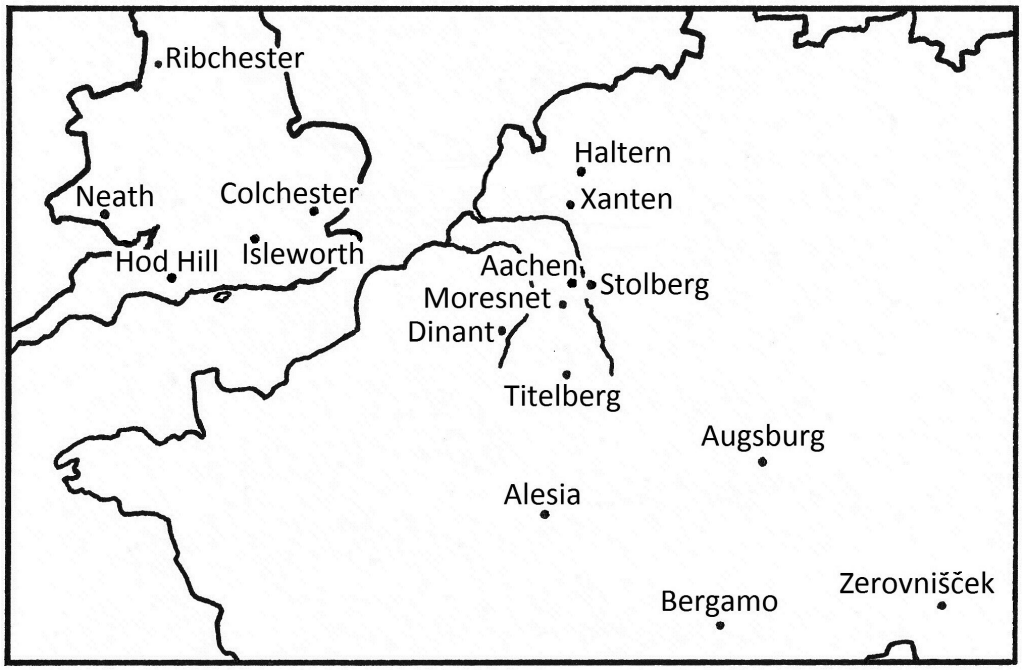

Figure 8. Map, early medieval European sites mentioned in the text

and Gallia Belgica were made of brass, but over the next century it declined to ten per cent. The use of mixed alloys of copper zinc, tin and lead increased proportionally, perhaps due to re-casting or to cost-cutting under financial duress.[126]

Before the Romans invaded, Britain's brass is thought to have been imported from Gaul, including three-quarters of brooches dating to before AD 70 from Hod Hill Iron Age fort (Dorset).[127] In the 1st century AD, thirty-seven per cent of all Romano-British copper-alloy artefacts were brass, compared to only four per cent by the 4 century AD. During recycling by melting down and re-casting, brass loses zinc through evaporation and may be diluted by the addition of bronze objects. In more remote first-century northern Britain, 'Celtic'-style, brass items (mainly horse trappings) contained slightly less zinc than Roman first-century brass made in Gaul, from which it was perhaps re-cycled. However, the brass used for Romano-British rural items normally resembles late Iron Age alloys more than Roman military alloys. For the 1 century AD, more brass brooches are excavated from remote Romano-British farming settlements than from towns.[128]

[126] Callewaert, Maxime *et al,* 2013. Elementary analysis of Roman enamelled brooches in Gallia Belgica and Germania, unpublished preliminary dissertation results. Historical Metallurgy Society conference, London, 2013

[127] Bayley and Butcher 1980: 31

[128] Dungworth 1996: 410, and 1997: 907-908

Figure 9. Roman face-mask vizor sports helmet, Ribchester Roman fort

Earlier on in Roman Britain a much greater proportion of objects were of brass (as opposed to bronze) than was the case later. In the early 1st century AD, one third of the Roman brooches found in Britain were made of brass,[129] but from then onwards the average amount of zinc in their brass objects declined. Roman military horse trappings were usually bronze, but a late first- to second-century AD hoard found near Ribchester Roman fort (Ribble Valley, Lancashire) included a fine brass vizor sports-helmet, eye-guards, medals, horse-harness fragments, brooches and brass wire loops linking scale armour.[130] Roman artisans refined their copper by oxidising it, which allowed them to cast such complex objects.[131] At the first-century British Roman forts of both Colchester and Canterbury, brass was made in lidded brass-making crucibles (with zinc residues remaining on their inner surfaces). At Colchester, the inner surfaces of 24 crucible fragments had high levels of zinc (plus some copper, and occasionally lead), suggesting long high-pressure exposure to zinc vapour during cementation. A first-century brass sheet was found at Colchester, and several Roman military sites in Britain have yielded droplets of molten brass, traces of brass on crucibles and part-finished brass artefacts.[132] Nine late first-century brass brooches, found together with crucibles at the pre-Roman and Roman settlement at Baldock, average over twenty per cent zinc.[133]

Many small, capped, brass-alloying crucibles, dating to the start of the 1 century AD, have also been excavated from Xanten Roman military camp in the Rhine-Meuse zone,[134] and much larger ones at Lyon.[135] Military equipment and coins were the most

[129] Bayley and Butcher 2004: 15
[130] Jackson and Craddock 1995: 78-79, 92, 97-98
[131] Peter Northover, personal communication
[132] Bayley 1984: 42; Bayley 1990, 7
[133] Stead 1986: 110, figure 4; 111, figure 42; 114, figure 43
[134] copper age 1999 (a): 1083-1084
[135] Rehren and Martinon-Torres 2008: 170

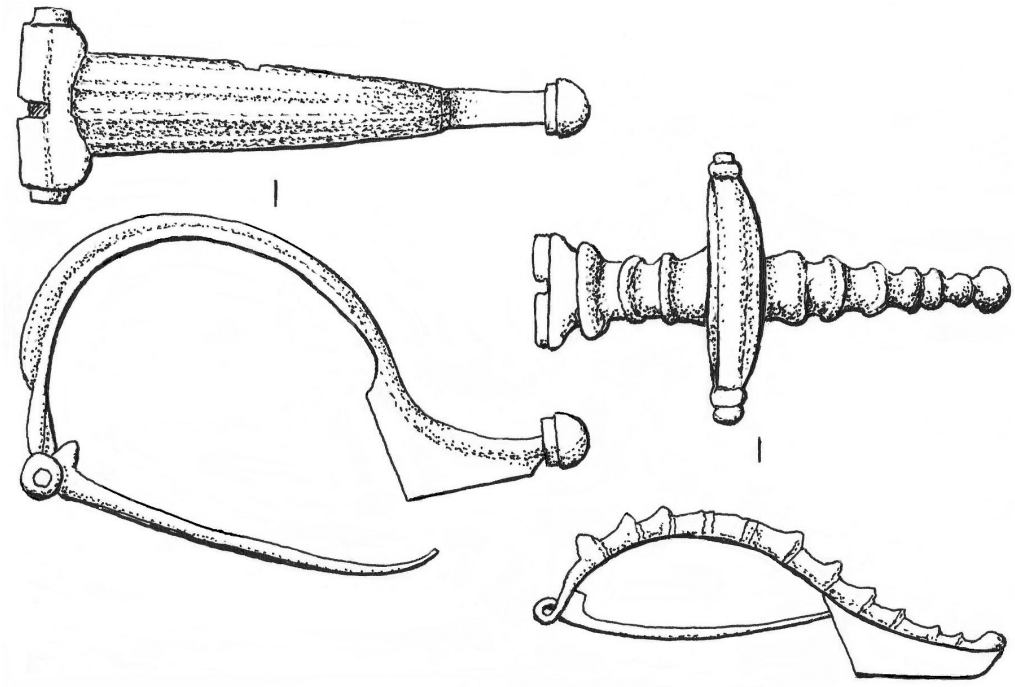

Figure 10. Roman brooches, *left* Aucissa type fibula, c.10 BC-AD 50; *right* Hod Hill type, AD 44-80, Alchester Roman camp

consistently produced early Roman brass items, and Roman coins show the overall pattern of changes in zinc content throughout the period of the Western Roman Empire. Starting from cementation brass using calamine and copper, the content moved to more adulterated alloys. After the relatively high-zinc early Roman coins of Julius Caesar, issued in Macedonia and northern Italy in 44-45 BC, brass coins gradually declined in zinc content.[136] Under the Emperors Augustus, Tiberius and Caligula (27 BC-AD 41), brass coins contained around twenty per cent zinc and a little tin and lead; but under Claudius (AD 41-54) average zinc contents dropped, while lead increased.[137]

Did the composition of Roman brass coins change because lead was added to improve viscosity for fine casting? As already discussed, two per cent of added lead lowers the melting point of copper, rendering the molten brass fluid enough to reach into the extremities of complicated moulds to produce cast metal without the tiny hydrogen-gas bubble-holes released from water-vapour in molten copper.[138] Although extra lead produced a brass that was more fluid for casting and was less liable to shrinkage as it cooled, leaded brass cracked more readily when hammered. Roman Aucissa and Hod Hill type brooches were found at the briefly-occupied Alchester Roman fort (7

[136] Istenič and Smit 2007: 140
[137] Riederer 2001: 220-225
[138] Bayley 2004: 16

km north of Oxford), whose gate-tower corner-posts date to AD 43-44. From after AD 70-80, some Roman brooches cast at sites like Colchester were produced from British-made high-lead bronze (copper, lead and tin), rather than brass.[139]

Metal casting grew more common in Roman Britain from the 1 century onwards, and each time brass was re-melted for casting, more zinc escaped as vapour. Up to about 10% zinc may be lost during re-casting, which helps archaeo-metallurgists to notice where this has happened. Objects recycled from Roman brass artefacts include a Romano-British cast-brass torc (necklet) with 'Celtic' decoration, dating to AD 50-150.[140] A good part of the mid-first-century Welsh hoard found north of Neath, South Wales, consisted of brass military horse trappings carrying traditional Welsh Iron-Age geometric designs, together with the handles of tankards and some foundry evidence for casting. Most of the horse pendants, terrets (rein rings) and strap-ends were of brass, perhaps recycled.[141] Impressive first-century Roman cast objects include helmets with applied brass features, brass fibulae, hinges and horse trappings, many excavated along the Rhine valley where the Roman army was long deployed, for example at Augsburg and Haltern, and by the River Oder (today's German-Polish border).[142] Roman brooches (*Augenfibeln*) found at Augsburg mostly contained 13% to 24% zinc.[143]

After Claudius, the amount of silver in Roman *denarii* was reduced, so the content of brass coins may have been adjusted to correlate their value with the debased silver coins.[144] A *dupondius* brass coin weighed and measured the same as a silver *ass* coin, but was worth twice as much.[145] Under Nero (AD 54-68) little brass was produced, though a sample of nine analysed brass coins and a *dupondius* coin contained almost no impurities, so they were almost pure brass. In Roman provincial Asia Minor, however, brass coins were still made well after Nero's death, their zinc content varying more by where they were made rather than when, suggesting that they were produced in individual local centres independent of Rome. They consistently contained around twenty per cent zinc,[146] some perhaps made from zinc oxide produced by the Middle Eastern mountain tradition (described above) of heating zinc ore to produce thick clouds of zinc vapour in order to collect the resultant zinc oxide flakes on bars over the fires.

[139] Bayley and Butcher 1980: 31
[140] British Museum: P&EE 4-7 1
[141] Davis and Gwilt 2008: 151-153
[142] Riederer 2001: 237-238
[143] Riederer 2002: 118-120
[144] Bayley and Butcher 2004: 49
[145] Furia 2012: 29
[146] Riederer 2001: 211-224

Zinc content in brass is significantly varied by factors like temperature control, the time the process lasts, the mass of the ingredients and the initial ratio of copper to zinc.[147] These factors could not be fully standardised in the Roman Empire, nor could the metal impurities be fully eliminated. Roman horse trappings were nearly all made of brass, but everyday Roman brass objects are rarely found. In fact common utilitarian items from volcano-struck Pompeii (AD 63) included no brass at all.[148] Most Roman statuettes were bronze, but occasional brass examples depict classical subjects like centaurs, gods and goddesses.[149] By this time, villa life had developed in rural areas, and smaller villa workshops may have cast low-zinc or bronze objects rather than attempting to forge higher-zinc sheet brass.

Overall, looking back to the Middle East it can be seen that from the mid-3rd millennium BC through to the later 1st millennium BC, brass-making was a sparsely-scattered, localised activity, with a few craftsmen probably carrying out all the processes. Works in brass may have been very highly valued and therefore mainly exchanged as diplomatic gifts between leaders – prompted by their golden appearance as well as their rarity. Expertise gradually diffused through long-distance cultural contact and later by trade, until Roman brass was used not only for luxury adornments but for military objects ranging from helmets and medals to horse-trappings. Over time, more brass was made, and the way it was viewed and used slowly but constantly changed, and would soon change further, with brass-making becoming more organised and arguably more industrial in approach.

[147] Bourgarit *et al* 2010: 51-52
[148] Riederer 2001: 177-197
[149] Riederer 2001: 160, 165, 173