

## Tin Deposits and the Early History of Bronze

by R.J. Cathro

Previous chapters have focused on the mineralogically complex and structurally simple silver-uranium-base metal vein deposits in the Erzgebirge, such as Joachimsthal, which were relatively easy to find and mine. We now turn our attention to the tin mines, which could not be more different. The various deposit types exploited by the medieval Saxon miners illustrate the sophisticated prospecting, mining, and metallurgical skills that they had developed by the sixteenth century.

Today, tin is just another alloy metal, like titanium or beryllium, and many geologists and mining engineers may never see a tin mineral outside a museum. Until the appearance of hard steel during the Industrial Revolution, tin held a similar strategic importance to that held by oil today because it is a vital component of bronze. Bronze was used to manufacture the first hard, corrosion-free metallic tools such as shovels, axes, chisels, and hammers, as well as weapons, jewellery, burial items, and bell metal. It became an indispensable commodity, worth scouring the world for and going to war over, and it occupies a special place in the history of mining, economic geology, agriculture, warfare, art, and human development. Gold and silver could finance a war, but bronze could win it. The metal is even mentioned several times in the Bible; for example, "I will turn my hand upon thee, and purge away thy dross, and take away all thy tin" (Isaiah 1:25).

The significance of metals has been well stated by Muhly (1988). "Turning a hard rock into a softer and more useful metal was a unique step in human development." To appreciate the historic importance of Erzgebirge tin, we must quickly review the early history of copper and bronze production and the first sources of tin. Because the production of copper and bronze predate written records by many millennia, deciphering the historical record by determining the source and age of metallic artifacts has been the work of archaeologists. They have shown that the first use of metals began in the part of the Middle East that lies between the eastern end of the Mediterranean Sea, the Persian Gulf, and the Black and Caspian seas, and forms the boundary between Europe and Asia. It encompasses the mountainous parts of Turkey and Iran and extends south into northern Iraq and northeast through Armenia, Georgia, and Azerbaijan to the Caucasus Mountains. It is a mineral province that contains abundant copper, silver, iron, and other base metals, but only moderate amounts of gold and little tin. For additional geological background and a review of metallurgical history, see Cathro (2000) and Knauth (1974), respectively.



Archaeometric dating has shown that the first metalsmiths began working with native copper about 9500 BC. After the native metal became scarce, they discovered that copper could be produced from the associated gossans by heating copper oxide, carbonate, and silicate minerals at a high temperature in the presence of carbon. Further progress depended on finding ways to produce higher furnace temperatures. The early smiths soon discovered that the melting temperature of copper ore was lowered and the metal became harder when the ore contained impurities, a lucky advantage since they had no way to predict what contaminants were present in the weathered ores. By about 6000 BC, they were able to smelt copper from gossans formed from oxidized complex ores, and by about 4000 BC, they had learned to smelt silver-lead oxides. Bronze was produced by about 3500 BC and poor quality iron by about 2700 BC. About 2500 BC, the bronze technology began to spread northward into central and western Europe and eastward to the Indus Valley civilization. It reached China about 1500 BC.

Through trial and error, the smiths gradually learned how to choose the right mixture of ores to avoid undesirable results. For example, minute amounts of bismuth make copper brittle, whereas large amounts of lead make it soft. Pure copper does not cast well because it develops bubbles that weaken it. The addition of zinc produces brass. The early smiths must have been astounded to find that combining a bit of tin, which has a hardness of 5 on the Vickers scale, with copper (50) would produce a superior alloy with enhanced workability, durability, and appearance, and a hardness of about 90. It was named bronze. With annealing, copper could be raised to a hardness of 125, whereas bronze could be raised to 228 with hammering. For comparison, wrought iron has a hardness of 80 and rusts easily, and mild steel is only 140.

What is commonly referred to today as bronze is actually tin-bronze. However, archaeologists have shown that the first bronze produced in virtually all of Europe and the Middle East was an alloy of copper and arsenic. It is logical that an accidental arsenic-bronze would be produced first because arsenic minerals are much more abundant than tin minerals. Furthermore, arsenic and copper minerals commonly occur together in sulphide deposits, and both weather to form greenish oxide and carbonate minerals that can be difficult for the untrained eye to distinguish. Arsenic-bronze proved to be the best early copper alloy because it is hard and cuts the absorption of

gases that make copper castings porous. A similar trend developed independently in Peru, where arsenic-bronze was discovered about 200 AD to 600 AD, and remained the alloy of choice until tin-bronze became the official standard after the formation of the Inca state about 1474 (Lechtman, 1980; Cathro, 2000). Modern tests have shown that it is more ductile than tin-bronze, which made it important in the manufacture of metal sheet for armour plate or decorative items in Latin America (Lechtman, 1996).

Tin-bronze usually contains from 3 to 15 per cent tin, although 10 per cent is enough to produce an alloy that will take and keep a sharp edge. It also produces an attractive colour, which made it valuable as a decorative item as well as a tool or weapon. Bell metal contains as much as 25 per cent tin. Tin had two practical advantages over arsenic in the production of bronze. First, by eliminating the highly toxic fumes produced when arsenic is roasted, it reduced the mortality of metal-smiths, who were vital members of society. The second advantage was that tin provided more predictable results because it commonly occurs as the oxide mineral cassiterite, which typically contains about 78 per cent tin. Without any knowledge of chemistry, the smiths found it much simpler to estimate the quantity of cassiterite to add to the copper charge than to judge the arsenic content of a mixed oxide or sulphide ore.

However, replacing an arsenical ore with cassiterite was a mixed blessing. On the one hand, cassiterite is easy to find because, like gold, it is durable, dense (specific gravity of 6.8 to 7.1), and hard (6 to 7 on Moh's hardness scale). As a result, it concentrates in stream channels as alluvial (placer) deposits that can be found with a gold pan. On the other hand, cassiterite is scarce in the birthplace of metallurgy and the few placer deposits found there were small, quickly exhausted, and soon forgotten. In the words of Hoover and Hoover (1912, p. 412), "...we see no reason why alluvial tin may not have existed within easy reach and have become exhausted. How quickly such a source of metal supply can be forgotten and no evidence remain, is indicated by the seldom remembered alluvial gold supply from (Wicklow) Ireland." As the demand for bronze grew in Mesopotamia (Iraq) and the early Mediterranean cultures (Egypt, Greece, and Rome), the search expanded to the far corners of the known world.

Numerous ancient sources of tin have been identified in Europe and the Middle East but these were too small or too distant to account for the amount of bronze produced. Relying on Greek and Roman historians, Rickard (1932, p. 347-349) and others have documented that placer cassiterite was transported to the eastern Mediterranean from the Erzgebirge, Tuscany, Spain, Portugal, and Crete. Other confirmed sources of tin are Uganda (Dayton, 2002) and Sardinia (Penhallurick, 1998), and there is speculation that it was also brought overland from India and Asia. Judging by how much effort went into finding it, the price of tin must have been extremely high.

The significant tin deposits in central and western Europe are associated with biotite or two-mica or, in some areas, lithium-mica granite stocks. Most of these are within the cusps or apices of larger plutons beneath shallow cover rocks. They were intruded during the Hercynian Orogeny in the Carboniferous and Permian (360 Ma to 245 Ma). The four main areas (in order of ancient economic importance) are Cornwall and Devon (England), the Erzgebirge, the American Massif in Brittany (France), and the Iberian Massif in

Spain and Portugal (&Mac249;Stemprok, 1980; Penhallurick, 1998). Archaeological evidence indicates that prospectors had found all these belts by about 2000 BC. However, determining when tin was mined in each area, and if and when bronze was produced nearby, is more difficult. The first bronze that appeared in each district was likely imported. Most of the early mining activity was directed towards gold and copper until an overland trading relationship was developed for tin with the more advanced cultures in the eastern Mediterranean. This is a field of intensive, current archaeological research using dating and trace element analysis of artifacts because there are no written records.

Among the earliest of the European metalworkers were the Bell-Beaker people, so called for the distinctive bell-shaped clay cups buried with their dead. They were merchants and traders, possibly from Spain, who roamed Europe beginning around 2500 BC. They were also excellent potters and smiths who knew how to smelt and cast copper, but didn't use bronze. They traveled widely, from Poland in the east to the United Kingdom and Ireland in the west, and from the Baltic Sea to the Alps. Sometime around 2300 BC to 1800 BC, they became assimilated with another group from the east, possibly Russia, known as the Battle-Axe people, and formed a new culture known as the Uneticians. They are named after a small smelting site beside the village of Ún&Mac249;etice (now called Aunjetitz), which was not discovered until 1879. It is situated on the northern outskirts of Prague, about 80 kilometres from the Erzgebirge. Accomplished in the production and use of bronze, these people spread throughout the valleys of Germany and the adjoining lands to the east. Their bronze ware has been found in graves as far away as England and Sweden. Although there is no proof that the Unetician bronze was produced with tin from the Erzgebirge (Niederschlag et al., 2003), that seems like a reasonable conclusion if one accepts the idea that ancient placer mines could have been obliterated by subsequent mining.

By 1500 BC, the Uneticians had become rich and were the dominant people of central and western Europe (Knauth, 1974, p. 58-64). The next part of this history will deal with the vital role played by Cornwall-Devon as a source of tin for the Mediterranean cultures and how that district was later supplanted by the Erzgebirge as the principal source after the Dark Ages.

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