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THE PRODUCTION OF ZINC AND BRASS IN ANCIENT INDIA

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ABSTRACT

We are able to reconstruct the technology that was utilized in the production of zinc in ancient India thanks to the evidence that has been uncovered by archaeological explorations and excavations at Zawar. Radiocarbon examine of two wood tests, one of them got from a wash and the other from a platform, both found at a profundity of 100 m in the displays of old sphalerite mines at Zawar, has given dates of 2120±60 bp and 1920±50 bp. Creation of zinc presents unique issues on the grounds that the edge of boiling over of the metal is lower than the base temperature needed for extraction of zinc from zinc oxide.

INTRODUCTION

Zinc (Zn) is a non ferrous base metal, which is by and large tracked down in pale blue white, yellow, brown or in dark tone. Sphalerite or zinc blende, smithsonite, calamine, zincite, willemite, and franklinite are its most important minerals. As it bubbles at around 900° C, which is lower than the temperature it very well may be refined at, hence purifying this metal is troublesome. Therefore, zinc technology was developed later than copper and iron technology. As a result, distillation technology was developed for the production of pure zinc, with India being the pioneer in this field. Zinc is used to galvanize iron and steel, make brass, make alloys, and make white pigment for medicines and chemicals. However, its primary use in ancient times was in the production of brass. In fact, brass has been around for a lot longer than zinc has. Smelting zinc-containing copper ores or copper and zinc ore in reduced condition, or combining copper and zinc metals, can produce brass.

Numerous parts of Europe and the Middle East, including Palestine, Switzerland, Greece, and Cyprus, have been claimed to have early zinc evidence. Be that as it may, this large number of cases, with the exception of the proof of the sheet of zinc from the Athenian Public square (300 BC) are dubious (Craddock et al., 1998: IS). Recent research has demonstrated that the accidental use of copper ore associated with zinc or its ore may result in such low zinc concentrations.

China has reported brasses from the fifth and third millennia BC that contained up to 25% zinc. However, it appears that these brasses did not contribute to the development of zinc production technology in the Far East. Most people believe that the Han Dynasty, which flourished in China at the end of the third century BC, was the first time the Chinese used zinc and brass. Craddock and Zhou have recommended that zinc was presented in China through Buddhism about a long time back. Weirong and Xiangxi, on the other hand 16-17) state that Buddhist writings from the Tan dynasty (619-917 AD) contain the earliest reference to brass being referred to as tutty. Brass (thou-shih) was not widely available in China in the early Christian era, at least not until the third century AD. Bowman and others 1989) have investigated 550 coins going from third century BC (Zhao administration) to the late nineteenth 100 years (Ch'ing line). They have found that the level of zinc unexpectedly expanded by 20% or even up to 28% in brasses of the mid seventeenth century Promotion. The well-known textual evidence of T'ien Kung K'ai Wu, written in 1637 (Sung and Sun, 1966), also lends credence to this assertion. It also gives specifics about the alloys that are used in coins, making it the first definite evidence of metallic zinc in China. According to Weirong (1993), who looked at ancient Chinese writings and archaeological evidence, metallic zinc was not used in China before the 16th century AD.

In terms of India, the only location with concrete evidence of zinc smelting is Rajasthan. According to Agrawal and Kharakwal (2003), the Ganeshwar-Jodhpura cultural complex in the north of Rajasthan and the Ahar culture in the south of Rajasthan, mining various types of ores dates back to the Bronze Age (mid-fourth millennium BC). Misra and co. 1995; Shinde and co. 2001-02). According to Hooja and Kumar (1995), these two cultural complexes have produced over 5,000 copper-bronze objects dating from the fourth to the first millennium BC. In addition, a few copper arrowheads were discovered at the Mesolithic site of Bagor in the Bhilwara district (Misra, 1973). In the Aravallis region of Rajasthan, there are numerous ancient copper, iron, and lead working and smelting sites, indicating a long history of metallurgy. From these early settlements, in addition to metal tools, we know about a variety of pottery, semi-precious stone beads, paste, terracotta, and other antiquarian materials. Using pyro technologies, these early farmers were engaging in a variety of trades. According to Kharakwal (2005), the long history of metal technology involving pyro techniques appears to have led to the large-scale production of various metals, such as copper in Singhana, Toda Dariba, Banera, Suras, Bhagal, Kotri, lead-silver in Ajmer, Agucha, and Dariba, zinc in Zawar, and iron in Dokan, Iswal, Karanpur, Loharia, Parsola, Big Like Anatolia, the Aravallis are actually a polymetallic region.

The goal of this paper is to provide an overview of the archeometallurgical studies of zinc as well as the significance of zinc and brass in the context of Indian archaeology.

Zawar: Zawar, the oldest center of zinc production (24°21'N; 73°43'E) is in the Aravalli hills of Rajasthan and can be found on the riverbank 38 km south of Udaipur town (Fig. 1). According to Craddock et al., it is the only known ancient zinc smelting site in India. 1985). Indicating a long history of zinc smelting at Zawar, enormous piles of slag and retorts line the entire Tiri valley at

Zawar. On some slag-hills are found remaining parts of houses made of utilized counters (Fig.) and stones, possibly those of the smelters and smiths.

Although archeometallurgical activity at Zawar was casually documented by several Indian and British scholars between the 17th and 20th centuries, Crookshank (1947), Carsus (1960), Morgan (1976), and Strackzeck et al. are credited with highlighting the significance of the ancient remains. 1967), and Werner (see Gurjar et al., 1976). 2001). P.T. Craddock of the British Museum and K.T.M. Hegde of the M.S. University of Baroda started archeometallurgical research at Zawar in 1983 with the help of Hindustan Zinc Limited, Udaipur (Craddock et al., 1983, 1985; Gurjar and other, 2001; Hegde, 1989; Paliwal and team, 1986; 1984 Willies). This group did broad examinations both for old mining as well as refining of zinc at Zawar. From the Zawar dam fill, they also found primitive smelting retorts and incredible evidence for mining and furnaces used for zinc smelting.

In addition to Zawar, ancient mine workings and a small retort heap 2 kilometers south-east of the village Kaya provide evidence of early zinc mining and smelting. It is the northwestern continuation of Zawar mineralization. These remaining parts have not been concentrated on exhaustively yet taking into account the state of counters it tends to be securely reasoned that they are of a similar period. Kaya is found 6 km north of Zawar, and around 15 km south of Udaipur town.

Mining zinc ores can be found all over the country, but the Aravallis contain the largest deposits. Even though the well-known ancient lead-zinc workings are located in the Zawar area of the Udaipur district, one of the largest lead-zinc deposits has recently been discovered at Agucha in the Bhilwara district (Tewari and Kavadia, 1984). Zinc (Zn) is for the most part tracked down in veins in relationship with galena, chalcopyrite, ironpyrite, silver and cadmium and other sulfide minerals (Raghunandan et al., 1981). Pre-Cambrian metamorphic rocks make up the rugged and stunning Aravalli range in southern Rajasthan, which has narrow valleys. Sphalerite veins containing zinc ore, galena, and copper-bearing deposits are abundant in these rocks. The mineral-rich Zawar belt covers approximately 25 kilometers. Sheeted zones, veins, stringers, and lenticular bodies have been identified as the primary mineralization of sphalerite and galena with varying amounts of pyrite (Raghunandan et al., 1981). Because these minerals are very different from one another, it was possible to manually separate them, which is why zinc mining and smelting only developed at Zawar.

There are broad remaining parts of old functions in Zawarmala, Mochia Magra, Balaria, and at Hiran Magra in Zawar region as profound channels, shafts, open stopes, long serpentine exhibitions and grades. These mines are narrow and range in length from 10 to 300 meters. Underground mining is also evident in large quantities (Fig. 3). The enormous pile of slag and smelting scraps suggests that this mining went on for several hundred years.

Fig. 1: The ancient mine in Zawar

When the metal was situated on ground, in view of the presence of gossan or mineralized veins, the excavators followed the down ward expansion along plunge and pitch of the metal shoot and created colossal slanted stopes and loads underground. These stopes and spread chambers were upheld by finger like actually leans further down. Curve formed points of support (around 4XSm) were passed on to help the rooftop while growing such stopes and loads (Gurjar et al., 2001). The galleries and stope chambers' rounded profiles, supporting pillars, smooth rock faces covered in sooty deposits, and floors covered in charcoal, ashes, and calcined rocks all indicate that mining was carried out by fire (HindZinc Tech 1989). The rocks were broken with chisels, pick axes, hoes, and other iron tools after the fire was put out. Mochia mines have yielded a few of these items (Craddock et al., 1989: 62, p13). Broad utilization of wood as stepping stools, rooftop support, haulage platform (14C date: 2350±120 BP) have been tracked down in the mines.

At Rajpura Dariba, extensive open pit mining was followed by underground mining. An opencast mine of lead-zinc (300 m long and 100 m wide) created over east jackpot at Dariba, (Raghunandan et al. 1981 : 86-87) is remarkable proof that ancient mining techniques were used in southern Rajasthan. Uncovering did by Hindustan Zinc Restricted in 1986 has drawn out the presence of gigantic lumber revetment in the draping mass of the open pit. This consists of three or possibly four 4m-tall benches that are held back by three pairs of horizontal timbers and are pinned by long timbers to support the weak hanging wall.

Here, in one of the underground mines of the East Burden the diggers arrived at up to a profundity of 263 m, in the third fourth century BC (Craddock et al. 1989:59; Willies and other 1984). Such mines are seldom known in the antiquated world. Deep underground mining had begun in the second half of the second millennium BC, according to a Dariba 14C date. Additionally, extensive evidence of rich galena pocket mining from the Mauryan era has been found at Agucha (Tiwari and Kavdia, 1984: 84-85). The smelting debris and mining clearly indicate that lead and silver were the primary targets.

Launders made of hollowed timber that were three meters long and twenty centimeters wide were used to dewater mines and date back to the second century BC (Bhatnagar and Gurjar, 1989: 6). It's possible that buckets of some kind were also used to extract water from such deep mines. It is impossible to rule out the possibility of water collection from shallow depressions in the mines' slanting wall at specific intervals.

A couple of shallow cone shaped and U formed pits have been accounted for in hard shakes at Baroi and Dariba. In order to separate and beneficiate the ore prior to smelting, they may have been utilized for the crushing and breaking of rock fragments. At Dariba such pits having a measurement of 27-30 cm and 60-70 cm profound were found near a huge opencast in calc-silicate rock. These were discovered on the surface next to ancient mine operations at Baroi in Zawar. They had a diameter of 8 to 12 centimeters and a depth of 10 to 18 centimeters.

It is fascinating to take note of that mining of such non-ferrous metals was additionally kept in the contemporary writing like Kautilya's Arthasastra (2.12.23, 2.17.14 and 4.1.35), which specifies that there was a director of mines in the Mauryan Realm (Kangle, 1972). He was responsible for finding metals and setting up factories. While depicting silver minerals the text plainly makes reference to that it happens with pester (lead) and anjan (zinc). It is highly likely that Kautilya was aware of the lead, zinc, and silver mining and smelting that took place at Zawar, Dariba, and Aguchha in Rajasthan. According to Harry (1991), the imperial Maurya series of silver coins, which contain one fourth copper, strongly suggests that silver and zinc were mined from southern Rajasthan. By the middle of the first millennium BC, if not earlier, such ores had already been mined in Rajasthan.

In the Samoli inscription (Halder, 1929–30), some scholars have argued that Zawar should be identified as Aranyakupgiri, a figure from the seventh century AD. The word Aranyakupgiri of the engraving maybe represents profound well like mines. Naturally, such mines existed in Zawar at the time, but the inscription may be referring to Basantgarh mines in the vicinity of Samoli in the Sirohi district rather than Zawar.

It's possible that the underground mining of ores at Agucha, Dariba, and Zawar are the result of a gradual development of mining technology in Southern Rajasthan that began in the middle of the fourth millennium BC, when Bronze Age cultures had just emerged in the area.

The fact that no evidence of zinc smelting has been found prior to the 9th century BC is interesting. Craddock and co have pointed out that zinc ore was definitely mined in Zawarmala in the third or fourth century BC. The massive dumping of retorts, smelting debris, and temple complexes may have obscured the evidence of smelting from the 4th century BC to the 9th century. The same is supported by the discovery of Early Historic pottery shapes and a large stone structure near the Jain temple in old Zawar.

According to Craddock et al., these radiocarbon dates clearly indicate that mining was carried out during the Early Historic period and the Middle Ages. 1989:48).

Traditionally, it is believed that these mines were reopened by Maharana Lakha or Laksha Singh (14th century), who reigned for the final quarter of the 14th century. Instead of reopening the old mines, he might have opened several new ones. In addition, new mines at Zawar are also credited to Maharana Pratap (16th century). He is named after one of the major mines at Zawarmala. During the late medieval period, it appears that large-scale zinc production continued despite political instability in southern Rajasthan.

In 1596, Abul Fazl recorded the zinc mines of Zawar for the first time in his well-known Ain-i-Akbari (Blochmann, 1989: 41-43). Not only were the mining and smelting operations documented in contemporary local records and literature (such as Nainsi ri Khyat in 1657; Bakshikhana Bahi 91, records of Udaipur and Bikaner in the Rajasthan State Archives, and others), but also in the writings of a number of scholars from the 19th and 20th centuries, primarily British (Anon, 1872; 1850 Brooke; 1960, Carsus; 1908 Erskine; Shyamal Das, 1986 I, first released in 1886: 305; Tod, 1950: 221-222).

Iron, copper, and lead were among the ores that were mined in Rajasthan as late as the 19th century. Contrary to Chinese traditional zinc smelting, the Zawar zinc operation ended in regret around 1812 AD. In the middle and late nineteenth century, with the financial support of Maharana Sarup Singh (1842-1861), Shambhu Singh (1861-1874 AD), and Sajjan Singh (1874-1884 AD), a few British officers attempted to restart these mines, but they were unsuccessful. These mines are thought to have been abandoned in the 18th century as a result of political instability in Mewar, frequent attacks by the Mughals, Pindaris, and Marathas, and recurrent famines.

Smelting and Production The entire Tiri Valley in Zawar is littered with massive dumps of slag and earthen retorts, pointing to the long history of commercial zinc production. This activity is also supported by a number of radiocarbon dates (see table 1) bracketed between the 12th and 18th centuries. Gurjar and others 2001: 633 states, "The carbon date of 840-110 AD for one of the heaps of white ash removed from zinc smelting furnace is the earliest evidence of zinc smelting on an industrial scale." The piece of moderately little, crude answers and punctured plates found in the earth fill of dam across the Tidi (Tiri) stream might have a place with the period or they should basically originate before the actual dam. It would appear that around the 11th or 12th century, Zawar marked the beginning of the industrial phase of the production of zinc.

A bank of seven distillation furnaces at Zawarmala (Fig. Craddock et al. discovered 4), which were roughly square on plan (66x69 cm). A thick clay plate with perforations separated the upper and lower chambers of each furnace. The excavators believe that the furnaces may have resembled truncated pyramids and stood about 60 centimeters tall. In the upper chamber, charge-filled brinjal-shaped earthen retorts were positioned inverted on the perforated plate. Upwards of 36 answers were set in every heater for purifying and they were warmed for three to five hours. After filling the charge, the retorts were made in two parts and luted together. The ore was crushed and ground along with some organic material and cow dung to prepare the charge! rolled into small balls and dried in the sun. After drying, these balls were placed in retorts. When the retort was initially inverted in the furnace, a thin wooden stick was inserted into the narrow opening. This might have prevented the charge from falling into the lower chamber before heating, and it might also have made it easier for the zinc vapour that was produced during heating to escape. The metallurgists at Zawar created these unique retorts, which have a diameter of 8 to 12 centimeters and a length of 20 to 35 centimeters, for the purpose of zinc distillation. As the evidence of a larger furnace (base 110 cm square) from old Zawar would also indicate, the identification of retorts of varying sizes is a sure sign of different furnace shapes and sizes at Zawar. Zinc vapor was condensed in small earthen pots in the lower chamber following heating. The Zawar metallurgists surely devised a clever method for the downward distillation of zinc vapour. As a result, Zawar was the first location in the world to commercially produce pure zinc through distillation. Gangopadhyay et al. (1984), as well as Freestone et al. 1985) have conducted technical research on retorts and ore. In 1995, Craddock 309-321) contrasts these furnaces with koshthi-type furnaces depicted in the 13th-century alchemical text Rasaratnasamuchchaya and other earlier works on the same topic. We are grateful to the Hindustan Zinc, British Museum, and M.S. University Baroda for working together to make this wonderful discovery, which may be the ancestor of all high temperature pyrotechnic industries worldwide.

It has been assessed that each counter might have been loaded up with one kilogram of charge out of which 400 gram of zinc might have been created. As a result, during a single smelting operation, each furnace produced between 25 and 30 kg of zinc. It has been assessed that 600,000 tons of refining garbage at Zawar, delivered around 32,000 tons of metallic zinc in 400 years (somewhere in the range of 1400 and 1800 Promotion). The amount of metal produced between the 12th and 18th centuries would almost certainly exceed 50,000 tonnes, according to estimates. According to Colonel Tod's well-known book Annals and Antiquities of Rajasthan, the mines of Mewar were very productive in the eighteenth century, earning Rs. 1759 alone. 2,22,000 (Tod, 1950: 222, 399). Tod composes that about haifa century prior these mines were acquiring Rs. three lakhs per year. The Dariba mines produced Rs. 80,000. He has identified these mines as Zawar's tin mines. His tin mines must be nothing more than Zawar zinc mines because we do not have any evidence of ancient tin mining in the Mewar region. Additionally, the Rajputana Provincial Series of the Imperial Gazetteer of India (1908: 52) obviously notice that these mines were renowned for silver and zinc and were dealt with a huge scope until 1812-13 when the most terrible starvation occurred (Kachhawaha, 1992: 26-27; Malu, 1987; Singh, 1947).

According to the local records of AD 1634-35 and AD 1657, Zawar's annual revenue was Rs. 2,50,000 and Rs. 1,75,002, respectively. This suggests that Maharana Jagat Singh and Maharana Raj Singh had very high levels of zinc production. The record also makes it abundantly clear that these mines earned Rs. 700; this gauge was affirmed by Muhnot Nainsi in his well-known work Nainsi ri Khyat (1657) (Ranawat, 1987). According to another document from Maharana Raj Singh's time, the annual revenue from Zawar was Rs. 17,96,944 (Bhati, 1995: 1, 2, 11, 12, 14). Gurjar and others 2001: 634) have looked at a record of the same king from 1655 AD that is in the State Archives of Udaipur and says he made Rs. 1,70,967 in a solitary month from Zawar! We are in any case, not certain if this pay was gotten exclusively from mining and refining. As the whole area of Zawar is ravishing and agribusiness might not have been sufficient to create income, consequently almost certainly, the whole income was acquired from mining and creation of zinc. Erskine (1908) also mentions that these mines provided the Maharana's treasury with more than two lakh rupees annually from the fourteenth to the early nineteenth centuries, at least until 1766. As a result, Zawar produced a lot of zinc on a large scale, which may have made it one of the main sources of state revenue and a significant trading center between the 12th and early 19th centuries AD. The annual income from Zawar was therefore quite substantial. L.K. Gurjar's discovery in 1984 of an earthen pot containing a 16th-century coin hoard (Gurjar et al.) 2001) at old Zawar also indicates that this area was a significant commercial hub. There are stays of not many designs on top of a hillock at Zawar, which, as per proficient residents, have a place with Vela Vania (a broker known as Vela). It's possible that Vela Vania traded zinc.

The majority of Mewar's forts, massive water reservoirs, temple complexes, water structures, and other monuments were constructed between the 10th and 18th centuries AD, which is important to note here. Almost certainly, the income acquired because of lively exchange of zinc at Zawar was used for development of these huge landmarks.

Zinc and Metal in Archeological Point of view

A couple of Harappan bronzes have yielded a little level of zinc. For instance, Lothal, one of the Harappan sites in Gujarat (2200-1500 BC) (Rao, 1985), has produced approximately a dozen copper-based objects containing zinc ranging in percentage from 0.15 to 6.04 percent (Nautiyal et al., 2001). 1981). One of the items (vestige No. 4189), however not distinguished, contains 70.7% of copper, 6.04 % of zinc and 0.9% Fe, which could be named as the earliest proof of metal in India. A long spearhead of copper with 3.4% zinc content was discovered from another Harappan site in north Rajasthan, Kalibangan (Lal et al.). 2003: 266). Two examples of brass from Atranjikhera, a Painted Grey Ware culture site in the Ganga doab, date to the early Iron Age and provide some evidence. One of the leaded bronzes has 1.68 percent tin, 9.0 percent lead, and 6.28 percent zinc, while the other has 20.72 percent tin and 16.20 percent zinc (Gaur 1983: 483-90). We cannot infer that the Bronze or Early Iron Age cultures were aware of the nature and properties of zinc unless we have additional examples of bronzes that replace tin, arsenic, or other elements with significant amounts of zinc. However, these instances may represent the experimental or early stage of zinc in India. According to the archaeological record, intentional brass use began in the second half of the first millennium BC, when the percentage of zinc began to rise. Such proof has been found from Taxila, Timargarh and Senuwar.

Taxila, which is in Pakistan and is about 30 kilometers north of Rawalpindi, has produced a wide range of metal objects, including copper, bronze, brass, and iron (Marshall, 1951: 567 -69). From the 4th century BC to the 1st century AD, brass objects have been found. One of them was a Bhir mound vase that was found before the Greeks arrived at Taxila (Biswas, 1993). It contained 34.34 percent zinc, 4.25 percent tin, and a small amount of lead (3.0%), iron (1.77%), and nickel (0.4%). From the Northern Black Polished Ware (NBP) levels, another piece of genuine brass was recently discovered at Senuwar in the Ganga Valley (Singh, 2004: 594). It has 35.52 percent zinc and 64.324% copper in it.

According to Werner (1970), brasses made through the cementation process typically have a zinc content of less than 28% and rarely exceed 33%. Since Taxila and Senuwar's examples contained more than 33% zinc, these are the earliest definitive examples of genuine brasses. They must have been made by combining copper and metallic zinc. Zinc is difficult to smelt due to its volatile nature and low boiling point (907° C), which is lower than its melting point. In contrast to other metals, it evaporates from the furnace and reoxidizes if it is not condensed. Craddock and co have stated that the mining of zinc ore began in the 5th century BC (PRL 932 430-100 BC; At Zawar, metallic or pure zinc was first produced by distillation for the first time in history (BM 2381, 380-5O BC). At Zawar, the production of metallic zinc can be traced all the way back to the 9th century AD; however, there is a strong possibility that the older evidence is hidden beneath the enormous heaps. Even though Taxila people knew about distillation (Habib, 2000), we can't say that they used it to get zinc because there isn't enough evidence to say for sure. It is possible, but not proven, that metallic zinc was produced at Zawar in the sixth century BC, and that it traveled to Taxila and Senuwar from there. The other chance is that zinc was rejected from the cooler pieces of the heaters at the two locales!

Prakash, on the other hand (Athavale and Thapar, 1967: 132 table IV) and Mahurjhari in Mahararashtra Joshi, 1973:77), Chhotanagpur region Asura sites (Caldwell, 1920: 409-411; Roy, 1920: 404-405) have yielded brasses, which have been dated to the final part of the main thousand years BC. The majority of these brasses contain more than 15% zinc, and some of them have between 22% and 28% zinc. They were produced through the cementation process, as demonstrated by this kind of evidence.

several brass coins with punch marks, some of which are circular or rectangular. mainly from northern India are known to have existed between the 2nd century BC and the 4th century AD (Smith, 1906; see Table 2). Since not even one of them is dissected we couldn't say whether they are genuine brasses (objects containing more 28% zinc are called genuine brasses) or made by cementation process. The fact that the majority of these coins belonged to regional kings is interesting because it indicates that brass was popular in India. This kind of evidence refutes the idea that brass was brought to India by the Greeks. The archaeological evidence clearly demonstrates that the Indians were familiar with brass prior to the Greeks' arrival.

CONCLUSION

Despite the fact that the Athenian Agora and Taxila (dating to the 4th to 2nd centuries BC) contain early traces of metallic zinc, there is no evidence of regular production at these locations. However, the recent discovery of brasses from Senuwar strongly suggests that metallic zinc was unquestionably manufactured in India during the Early Historic Period. One possibility is that zinc was no longer a rare metal. Since the distillation process was used to produce pure zinc in the 9th century AD, Zawar provides the earliest evidence of pure zinc to date. The Bhils of Southern Rajasthan are held to be the natives of this locale (Hooja 1994) and plan liquor by customary down-word refining strategy. Interestingly, the distillation method was also used to produce zinc in Zawar. In addition, according to Brooke (1850), the Bhils of Zawar knew how to distill pure zinc up until 1840. Hence the credit of enhancing exceptional answers and heaters for refining of zinc without a doubt goes to the Bhil clan of Southern Rajasthan. It was doubtlessly this nearby information which they could effectively utilize for refining of zinc. By producing it on a commercial scale, the Zawar metallurgists made a breakthrough in the extraction of non-ferrous metals around the 12th century, if not earlier. In contrast, commercial zinc production began nearly 300 years earlier in China than in India. Apparently metal was presented in China in the early hundreds of years of the Christian Period through Buddhism, however zinc refining cycle might have gone in sixteenth century by means of worldwide exchange to China. In the middle of the 17th century AD, it was shipped from China to Europe under the name "totamu" or "tutenag," which came from "tutthanaga," which means "zinc" in South Indian languages (Bonnin, 1924; 1996, Deshpande). In any case, Indian zinc had previously arrived at Europe before this and had made extraordinary interest in this metal. As a result, the commercial production of zinc at Zawar began nearly 300 years before China, if not earlier. In this manner, Zawar has universally taken the walk by turning into the most established business focus of zinc on the planet. In the 18th century, William Champion's furnace at Bristol was inspired by the Indian downward distillation process, which may have been introduced there by the Portuguese or East India Company or by a European traveler. Thus Zawar, in the expressions of Craddock, is the predecessor of all zinc creation strategies of the world. It was a modern action, which laid the premise of different current compound and extractive ventures.

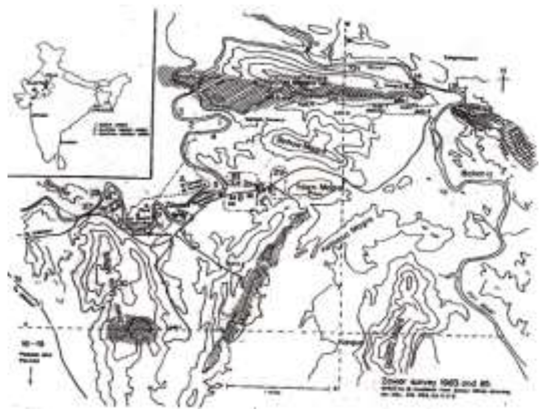

Fig. 2: Map showing location of Zawar (after Craddock et al 1985)

Fig. 3: Residential structures made of discarded retorts

Fig. 4: Zinc smelting furnaces at Zawar

Table 1. Radio Carbon Dates for Zawar Mines (After Gurjar *et al.*, 2001)

BM No.	Context	Material	Date BP	Calibrated dates
BM-2017R	Retort	charcoal	modern	1550 to 1635 AD Modern
BM-2065R	Retort	charcoal	modern	760 to 360 BP
LW/1982/2 BM-2148R		wood	2350±120	285 to 255 BC
BM-2149R	LW/1982/1, Launder in escape route	wood	2140±110	365 BC to 90 AD
BM-2222R	Trench layer 3	charcoal	240±110	1510 to 1690 AD or 1730 to 1810 AD or 1925 AD to modern
BM-2223R	Site 30, N side of furnace	charcoal	530±50	1320 to 1345 AD or 1390 to 1435 AD
BM-2243R	sample 33, site 34	charcoal	350±130	1420 to 1670 AD
BM-2484	site 5, layer 3, slag heap	charcoal	100±45	1695 to 1730 AD or 1815 to 1920 AD
BM-2485	site 14, layer 3	charcoal	1950±60	25 BC to 115 AD
BM-2486	site 29, layer 2, small pit or hearth	charcoal	200±35	1660 to 1675 AD or 1745 to 1800 or 1940 AD to modern
BM-2487	site 2, trench 2, slag heap	charcoal	1930±80	40 BC to 145 AD; 170 to 180 AD
BM-2488	site 7, trench 2, slag heap	charcoal	1370±80	595 to 720 AD or 740 to 765 AD
BM-2638	furnace block	charcoal	modern	
BM-2639	ZWLW/22, Pratap khan	charcoal	2040±70	160 to 135 BC or 125 BC to 25 AD
BM-2481	ZM/LW/85/13 small chamber off main galleries	charcoal	modern	modern
BM-2482	ZM/LW/85/14 short ladder way	wood	2150±110	365 to 100 BC
BM-2483	ZM/LW/85/8, burned layer	wood	2180±35	355 to 290 BC or 250 to 195 BC
BM-2634	ZWLW/87/26, top chamber	charcoal	1340±100	600 to 790 AD
Balaria				
BM-2338	support timber western slope	wood (outer ring)	170±50	1660 to 1695 AD or 1725 to 1820 AD or 1860 to 1865 AD, 1920 to modern
BM-2381	Gallery	wood (outer ring)	2360±60	750 to 720 BC or 525 to 385 BC
BM-2666	ZW/LW/87/32	charcoal	390±50	1440 to 1520 AD or 1590 to 1629 AD

No.	**Period**	**King/Site**	**No.**	**Shape**	**Reference**
1	200 BC	Gomitra	1	Not stated	Smith, 1906: 205
2	200 BC	Mitasa (Gomitra?) or Satasa	1	Not stated	Smith, 1906: 205
3	2nd cent. BC	Unidentified	1	Not stated	Smith, 1906: 194
4	2nd cent. BC	Gomitra (Mathura)	1	Circular	Smith, 1906: 193
5	2nd cent. BC	Uttama Datta (Mathura)	1	Not stated	Smith, 1906: 193
6	2nd cent. BC	Bhavadatta (Mathura)	1	Not stated	Smith, 1906: 193
7	2nd cent. BC	Purushadatta (Mathura)	1	Not stated	Smith, 1906: 192
8	2nd cent. BC	Amoghbhuti (Kuninda king)	6	Circular	Smith, 1906: 168-169
9	2nd cent. BC	Rajanya (Naga or Narwar)	4	Not stated	Smith, 1906: 179-180
10	2nd cent. BC	Asvaghosa (Kosam)	1	Circular	Smith, 1906: 155
11	150 BC - 100 AD	Dhana Deva (Ayodhya)	1	Rectangular	Smith, 1906: 148
12	150 BC - 100 AD	Siva Datta (Ayodhya)	3	Rectangular	Smith, 1906: 149
13	150 BC - 100 AD	Ajaverma (Ayodhya)	1	Circular	Smith, 1906: 150
14	125 - 80 AD	Hagamasha (Satrap of Mathura)	1	Not stated	Smith, 1906: 196
15	100 BC	Audumbara king	1	Circular	Smith, 1906: 166
16	1st cent. BC - AD	Yaudheya kings	3	Not stated	Smith, 1906: 181
17	1st cent. BC - AD	Agnimitra (Panchala and Kaushala)	2	Circular	Smith, 1906: 186-187
18	1st cent. BC - AD	Bhumitra (Panchala and Kaushala)	1	Circular	Smith, 1906: 187
19	1st-1nd cent. AD?	Devasa (Kosam)	8	Circular	Smith, 1906: 207
20	1st-1nd cent. AD	Unidentified	1	Rectangular	Smith, 1906: 201
21	2nd cent. AD	Unidentified	2	Circular	Smith, 1906: 203-204
22	3rd-4th cent. AD	Pasaka (Kushana type)	1	Not stated	Smith, 1906: 89
23	Medieval	Unknown (Jajjapura/i) Sri Siva type	1	Not stated	Smith, 1906: 333
24	3rd-4th cent. AD	Basata (later Kushana)	5	Not stated	Chatterjee, 1957: 103

Table 2: Early brass coins of India (After Smith 1906)

REFERENCES

1. Agrawal, D. P. and J. S. Kharakwal (2003). *Bronze and Iron Ages in South Asia*, Delhi: Aryan Books International.

2. Gurjar, L. K., P. T. Craddock, L. Willies and H. V. Paliwal. (2001). *Zinc in In K. V. Mittal (Ed.) History of Technology in India* vol III, Indian National Science Academy, Delhi. Pp. 621-38.

3. Habib, Irfan (2000). Joseph Needham and the history of Indian technology, *Indian Journal of History of Science* 35 (2): 245-274.

4. Hooja, R. and Vijay Kumar (1995). *Aspects of the Early Copper Age in Rajasthan*. In Raymond and Bridget Allchin (Eds.) South Asian Archaeology (pub. in 1997). Oxford and IBH, New Delhi. Pp. 323-339.

5. Kharakwal, J. S. (2005). *Indus Civilization: an overview*, In Toshiki Osada (Ed.) Occasional Paper 1 Linguistics, Archaeology and the Human Past, Research Institute for Humanity and Nature, Kyoto, Japan, Pp 41-86.

6. Craddock, P.T., Hegde, K.T.M., Gurjar, L.K. and Willies, L., (2017). *Early Indian metallurgy: the production of lead, silver and zinc through three millennia in North West India*. Archetype Publications.

7. Srinivasan, S., (2016). Metallurgy of zinc, high-tin bronze and gold in Indian antiquity: methodological aspects. *Indian Journal of History of Science*, 51(1), pp.22-32.

8. Merkel, S., (2016). Carolingian and ottonian brass production in Westphalia. evidence from the crucibles and slag of Dortmund and Soest. *Metalla*, 22(1), pp.21-39.

9. Ježek, M., (2016). Functional, symbolic or ritual? On several tools from the furnishing of aristocratic burials in eponymous Vendel, Sweden. *Archaeological and Anthropological Sciences*, 8, pp.491-504.

10. Luo, W., Li, D., Mu, D., Bai, J. and Xiao, B., (2016). Preliminary study on zinc smelting relics from the Linjiangerdui site in Zhongxian County, Chongqing City, southwest China. *Microchemical Journal*, 127, pp.133-141.

11. Khan, S., (2016). *A Study on the authenticity of indigenous Art used in brass Antique and Artifacts-A case study of Brass City "Moradabad"* (Doctoral dissertation, Doctoral dissertation, Pondicherry University).