

MINING AND METALLURGY

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India's phenomenal contribution in the field of religion, spirituality, language, literature, philosophy, grammar, arts, architecture etc. is well-known. In the scientific field, her contribution to mathematics, astronomy, medicine, and other allied branches of studies has also been recognized by scholars from many parts of this globe. There are thousands of texts available in Sanskrit on different branches of science which are yet to be published, and even among the texts which are available in print, analytical study from scientific perspective has not been done on most of the texts.

Ancient Sanskrit texts are the prime sources from which one can understand the depth of knowledge the ancient Indians had in theoretical and applied sciences. There are many scientific concepts which have been passed on continuously from one generation to the other for hundreds of years. For example, the metallurgical skill of the ancient Indians can be established from the thousands of metal and alloy samples collected from excavations done by the archaeologists in different parts of our country. This discovery presupposes that the ancients had a deep knowledge of geology, minerals and ores, chemistry of minerals and metals, the physics of high temperature processing, the technology of the kiln and furnace making, knowledge of handling the molten metals, alloy making, making of different ornaments, weapons etc. with metals, for which casting and moulding have to be done with precision and other such details. A survey of Sanskrit literature would bring out the fact that the mining and metallurgical sciences were part of the social life in ancient India.

VEDIC PERIOD

Metals and gems like gold, silver and iron are mentioned in Vedic texts. Since the *Sgveda* is the oldest available literature in this world, we shall start with *Sgveda*. In the *Sgveda*, for example, earring,¹ necklace made of gold and also with jewels² are mentioned.

1 *Sgveda* – I .122.14 – hira'yakar'am ma'igravam.

2 *Ibid.* (1.33.8) hiramyaena ma'inç...

The *¹ukla Yajurveda, (M̄dhyandina Samhit̄)* enumerates the list of metals like gold, iron, lead, tin, and copper:

हिरण्यं च मे । अयश्च मे । सीसं च मे । त्रपुश्च मे । श्यामं च मे । लोहं च मे ।³

It is to be noted that to extract these metals from their ores is not easy, unless the Vedic people had sound knowledge of the various processes of matching these metals.

In the *Athava Veda* the cosmic personality is described having different colour making the metals.

श्याममय अस्य माम्सानि, लोहितम् अस्य लोहितं, त्रपु भस्म, हरितं वर्णः, पुष्करम् अस्य गन्धः ।⁴

– *Where his flesh, blood, body and the smell are compared to iron, copper, tin and lead.*

Nail-cutter made of iron is mentioned in the *Chandogya Upanisad*, (VI.1.6), to drive home some philosophical concepts. In the same context, copper (*loha*) is also mentioned. One can infer the depth of knowledge on metals contained in the *Chandogya Upanisad*, where it talks of alloying of the metals. It says :

तद्यथा लवणेन सुवर्णं सन्दध्यात् सुवर्णेन रजतम् . . . ।⁵

— *“Just like a person would join gold with salt (borax), silver into gold, tin with silver, lead with tin, copper with lead, wood with copper and leather”.*

Yet another wonderful example of the Vedic people having the knowledge of iron or steel which was used to make an artificial leg is seen in the *Śgveda*. We find here the story of a queen Vi^opal̄, the consort of Khela, who was involved in a fight with an enemy king. Vi^opal̄, fought with valour, but in the process she lost one leg.

3 *¹ukla Yajurveda (M̄dhyandina) – R – VIII.13*

4 *Athava Veda XI.8.7-8*

5 *Ch.up. (IV.17-7)*

But the valorous lady prayed to the divine physicians A°vini kumaras who performed a surgery and fixed an artificial leg to her made of iron (steel). Later she conquered her enemies.

Sgveda hymn ⁶ reads:

चरित्रं हि वेरिवाच्छेदि पर्णम् आज्ञा खेलस्य परितक्म्यायाम् ।

सद्यो जङ्घाम् आयसीं विश्पलायै धने हिते सतवे प्रति अधत्तम् ॥

ARCHAEOLOGY

Just as the mathematical and astronomical details given in ancient Sanskrit texts are compared with the modern books on these subjects, the knowledge of the ancient Indians on metallurgy and mining can also be substantiated with archaeological evidences available from various sites. One of the findings which exists even now is the standing monument (250 feet) in the **Singbum copper mine** and the 600 feet vertical shaft in **Hutti gold mines**. These two indicate the degree of high technological advancement in the field of mining in ancient India at least during three thousand years ago.⁷

Apart from archeological evidences, we have evidences through epigraphy and numismatics. For example, the Sanskrit inscriptions of Vishnupadagiri by king Chandra of 5th cent. A.D. and the coins of Gupta kingdom throw much light on the development of the metallurgical and mining skill of ancient Indians.⁸

MINING

If the descriptions of various ornaments made of gold, silver, precious gems, weapons like different varieties of arrows, spears, maces and mechanical contrivances of many types found in ancient Sanskrit texts starting from Vedas, down to the texts in mediaeval and later periods of India are to be believed, then we should accept the fact that the ancient Indians did have a sound knowledge of mining and other industries

6 *Sgveda* I.116.15.

7 For further descriptions, see the *Indian Journal of History of Science*, 27 (pt.4), 1992.

8 See Prof. Balasubramanian "Metallurgical Marvels of Ancient India – Delhi Iron Pillar". Indian Institute of Science Heritage, Trivandrum, (year not given).

allied to it. As a sample, we can take some ideas from the *Artha^ocstra* of Kau^oilya of the 4th cent.B.C.

Kau^oilya gives much importance to mining, as it was a source of considerable income for the treasury. He says:⁹

आकरप्रभवः कोशः कोशात् देण्डः प्रजायते ।
पृथ्वीकोशदण्डाभ्यां प्राप्यते कोशभूषणा ॥

which means that the treasury depends on mines, the army/protection is sustained by the treasury and the earth is conquered by both treasury and the army.

According to Kau^oilya, starting of new mines and the renewal of old and discarded ones, being an important function of the state, this responsibility was vested with ‘director of mining’ (*j krc̣cdhyak^{3/4}a^a*), who should be an expert in geology (*oocstra*) and metallurgy (*dhctu^ocstra*).¹⁰ He has to make a survey of all the regions where mineral deposits are likely to be found and start new ones or renovate old ones.

The most important metals to be looked for are gold and silver, according to Kau^oilya. He also describes characters of gold and silver ores of different types, the process of refining gold and silver and also other metals to be procured from mines such as copper, lead, tin, iron and precious stones like diamond and rubies. Kau^oilya also refers to salt mines, under the control of a separate authority – *lava^oc̣cdhyak^{3/4}a*.¹¹

While the ancient teachers preferred small mines which yield products of high values such as diamond, Kau^oilya expresses the opposite view. He says that large mines, even if they yield products of smaller value may be preferred, for they ensure a continuous sale, while articles of high value would attract only few purchasers.¹² It is also interesting to note that though Kau^oilya gives importance to mining as an important industry, he does not lay emphasis on coal, iron and steel, which are generally regarded as important heavy industries. We know that it was during this

9 *Artha^ocstra* II.12.37

10 *Artha^ocstra* II.12.1

11 *ibid.* 12th section of second chapter.

12 *Ibid.* VII. 12-14-16

time that Greeks, after the invasion of emperor Alexander, showed much interest in importing steel and iron from India for making swords of good quality. Perhaps to keep the mining activities of steel and iron secret, Kau°ilya deliberately avoided any description on this subject. Another noteworthy aspect of Kau°ilya's description on mining is that he explains the nature of ores, areas where they can be found, extraction of metals, the various kinds of income derived through mining industry and so on.¹³

It is to be added here that the studies conducted (C14 carbon studies) by the metallurgists have shown that there were many ancient mines from which silver, copper, tin, zinc and lead were produced.

Some of the sites are:

Rajapura, Dariba, Udaipur in Rajasthan – 1300 B.C.

Hatti in Karnataka– 1000 B.C.

Zawarmala and Ambamata in Rajasthan – 500 B.C.

Some Iron mines are :

Komaranahalli and Tadanahalli in Karnataka – 1300 B.C.

Pandu Rajar Dhibi in Bengal – 1300 B.C.

Alamgipur in Rajasthan - 1000 B.C.

Varanasi - 1000 B.C.

Suffice is it to say that mining was well known to the ancient Indians.

METALS AND ALLOYS

Each metal has some specific colour, texture and nature. The purity of the metal should be judged properly. The definition of a pure metal, according to *Ras°r°ava* of Govindabha°a (9-11 cent.A.D.) is : pure metal is that, which when melted in crucible does not give sparks, nor bubbles, nor spurts does not emit any

¹³ *ibid.* ch.7 and 2. In fact Kau°ilya describes many varieties of gold, silver, copper, tin and iron ores in the second chapter.

sound, does not show any line on the surface, but is tranquil like a gem and this pure metal flows out from the furnace.¹⁴

न विस्फुलिङ्गा न च बुद्धदाश्च यदा न रेखापटलं न शब्दः ।

मूषागतम् रत्नसमं स्थिरम् च तदा विशुद्धम् प्रवदन्ति लोहम् ॥

Here the word *mūṣā* refers to the furnace or kiln. It is derived from the root *mūṣ* and is defined as, “*mūṣāṅti doṣān*” i.e. the vessel which removes or destroys the impurities.¹⁵

In order to remove the impurities which are firmly attached with the ore which contain smell etc., these furnaces were used. The impurities are burnt, being mixed with other things. Modern metallurgical science says that the organic matter present in the ores is burnt and inorganic impurities are converted into slag and removed from molten metal. In the second chapter of *Arthaśāstra*, detailed description of the silver, iron, copper ores are given.

FLUX:

Since metals and impurities are difficult to be melted directly, a foreign material, known as ‘flux’ is to be added to remove the impurities as slag. This process was also known long ago, as we can see this technique being described in some texts. A variety of fluxes have been used to convert impurities into slag. Archeological excavation from many sites, like that of Rajghat copper mines reveal that production of pure metals was invogue during ancient times¹⁶

CORROSION OF METALS

Degradation of metals, due to various factors like their contact with air/oxygen, moisture, acidic or alkaline materials is common phenomenon. Ancient Indians had

14 *Rasarāśtri* 4.52. This definition of metal seems to be correct, as all the above qualities are possible only when the impurities are removed in the molten metal at a high temperature.

15 *Rasarāśtri* (11-12 cent. A.D.) describes many types of furnaces with different dimensions which were used for extraction of various metals at appropriate temperature. For example, see *Rasarāśtri* x.95

16 For more details, see p.358-59, *Indian Scientific Heritage*, by Dr.N. Gopalakrishnan. Also see pp.172-91 “*Proceedings of the First International Conference*”, Delhi. 1972.

sound knowledge on this subject. The Delhi Iron pillar is the standing testimony for it.¹⁷

Ras̄ara says:¹⁸

सुवर्णम् रजतम् ताम्र तीक्ष्णवङ्ग भुजङ्गमाः ।
लोहकं षड्विधम् तच्च यथापूर्वम् तदक्षयम् ॥

— “Gold, silver, copper, iron, lead and tin are the six types of metals which undergo self corrosion at a slower rate in the reverse order...”¹⁹

Yājñavalkya sm̄iti, which is an ancient text (1-2cent.A.D.) says:²⁰

त्रयु सीसक ताम्राणाम् क्षाराम्लोदक वारिभिः ।
भस्माद्भिः काम्बस्यलोहानां शुद्धिः प्लावो द्रवस्य च ॥

which means, tin, lead and copper may be cleaned with alkali and acids. Iron, bronze and copper alloys are cleaned with ash and water.

ALLOY MAKING

The ancient Indians were well versed with production of alloys. Even today we find in innumerable temples and buildings where idols of gods and goddesses of different metallic alloys have been placed. Popular among them is known as *paṅcaloha* idols, which are well known in South India. According to Caraka,²¹ copper, silver, tin, lead and iron when mixed (in proper proportion) becomes *paṅcaloha*. He adds gold also with this, as the same has been prescribed by Suṅruta. Vṅgbhaṅa, another well known writer on ĩyurveda, slightly differs from him and says that the alloy of five metals of tin, copper, brass, iron and lead is *paṅcaloha*.²²

17 For more details, see R. Balasubramanian *op.cit*.

18 *Ras̄ara* 7.89-90

19 *i.e.* Gold is the least corroding and tin is the fastest corroding of the metals mentioned here.

20 *Yājñavalkya sm̄iti* (I-190)

21 *Caraka Samhita* (s̄trasth̄nam I.70)

22 *Rasaratnasaumcaaya* V. 212

Alloys of various metals, purificatory processes and other details have been discussed in great detail in many Sanskrit texts on ĳyurveda, chemistry, *Artha°astra* (4th cent. B.C.). *B°hadsamhita* of Varĳhamihira

(6th cent.A.D.) and many other texts. Our great epics *Rĳmĳya°a*, *Mahĳ-bhĳrata*, and ancient major Purĳas like *Agni Purĳa* and *Grau°a Purĳa* contain invaluable information on metals, gems and their various usages. Texts like *Ratna parik°*, exclusively deal with gems and precious metals, their nature, their medicinal effects, besides their utility in manufacturing various ornaments, idols, buildings etc. Treatises on war-science like *N°tiprak°ikĳ*, - *°ukran°isĳra* and *Hariharacatura-ga* describe the process of making different kinds of weapons and missiles. It is also interesting to know that Su°ruta describes various medical equipments for performing surgeries, some of which are said to be subtler and thinner than the breadth of a hair ! Texts on architecture and ship-building by the great king Bhoja of Dhĳra, viz, *Samarĳ-ga°as°tradhĳra* and *Yuktikalpataru* also contain breath-taking mechanical contrivances or *yantras*. Some of them are:

- (1) A bed placed on the ground being lifted to each of the five storeys at the end of each watch of the night.
- (2) Some *yantras* which can speak and sing, a dancing bird, dancing elephant , horse , or monkey, an oscillating bird making pleasing sound to reduce the anger of the ladies in conflict ; movements of some *yantras* which are lateral, upward, downward, forward, on both sides, slow, fast and dropping down; some mechanical devices performing the roles of modern robots.²³

CONCLUSION

Well friends, one can go on adding the list of contribution of our ancient Indians in the field of mining and metallurgy.

Mines, minerals, metals, ores etc. are described in detail in Sanskrit literature which are not imaginary, but are supported by the archaeological excavations and

²³ For more such details, see *Bhoja's Contribution to Technical Literature* by Dr. V. Raghavan, Chennai.

architectural marvels available to us even today. An unbiased study of our ancient Sanskrit texts by modern scientists and scholars would reveal more facts in this direction.

Hundreds of such texts have been published so far, but many lie as manuscripts, scattered in different parts of India and abroad. It is a matter of pride for us that such scientific information is available to us. Let our modern scientists look into these texts source books of knowledge and use the same for the welfare of humanity. Let me conclude with these words of wisdom from the *Sgveda*.

आनो भद्राः क्रतवो यन्तु विश्वतः ।²⁴

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24 *Sgveda*I.89.1