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SOURCES OF GOLD IN INDIA AS DESCRIBED BY ṬHAKKURA PHERŪ — AN ASSESSMENT

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Ṭhakkura Pherū, in his book *Dhātūtpatti*, states that mountains and rivers are the two important source areas of gold in India. Mountain rocks are the source of load or vein type gold deposit, while the sands, soils and gravels of rivers are of alluvial type gold deposit. The paper scientifically analyses these two types of gold deposits. It has been discussed as to how gold particles present in mountain rocks are transferred into rivers, and are ultimately deposited in the sands and gravels of rivers. The description made by Ṭhakkura Pherū has been compared with the literary description written by earlier authors and the findings from the archeological study of old Indian gold mines. The antiquity of the gold deposit in India has been traced, and it has been shown that both alluvial placer and vein or lode gold deposits were exploited in India through ages from ancient to medieval times.

Key words: Antiquity of Gold, Alluvial Placer Type Gold, Load or Vein Types Gold Deposit, Sources of Gold

INTRODUCTION

Ṭhakkura Pherū was a Royal Treasury Officer of Allauddin Khilaji. After the death of Khilaji, he was appointed the Governor of Royal Mint by his successor Sultan Kutubddin of Bandichoda Birudawale in 1316 AD. The date of birth of Ṭhakkura Pherū is considered to be in the later part of the thirteenth century AD. He has authored several books on subjects as varied as Mathematics, Astrology, Gemology, Metallurgy, Vāstuśāstra, and Geology. *Dhātūtpatti*, consisting of 57 *gāthās*, is an important little book written by Ṭhakkura Pherū in Prākṛta language. It gives important information on Indian

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Metallurgy. This book was composed in the early part of the fourteenth century AD.

The present paper discusses the sources of gold in India as stated by Ṭhakkura Pherū, and a scientific explanation for the formation of these gold deposits has been given. It has been shown with the help of examples from earlier Indian texts and the archaeological findings from the old Indian mines that the types of gold deposit referred to by Ṭhakkura Pherū were also known and exploited in Indian antiquity.

Sources of Gold

Ṭhakkura Pherū in the very first *gāthā* of his book *Dhātūtpatti* has stated that gold is found in the sands of rivers, and in mountain rocks:

ruppaṃ ca maṭṭiyāo nai-pavvayareṇayāu kaṇao ya |
dhāuvvāo ya puṇo havanti dunni vi mahā dhāū ||

Eng. tr: "Silver is found in soils (i.e. ground mountain rocks). Gold is found in the sands/soils of rivers and mountain rocks. These (deposits) are purified/refined by metallurgical processing. As a result, these two get converted into eminent/distinguished metals (i.e. gold and silver)".

Gold occurs mainly in native state. It is usually alloyed with silver and less frequently with copper. Gold is also a common micro-constituent in a large number of sulphides and sulphides-arsenides, being concentrated mainly in the silver and antimony species, and in pyrite and arsenopyrite. In these minerals, gold occurs native and also as a lattice constituent.

Mountain rocks are the source of lode or vein type gold deposits, while the sands and soils of rivers are of alluvial placer type gold deposits. The formation of these types of gold deposits is discussed below.

Lode or Vein Type Gold Deposit

Lode or vein deposits are formed, when hydrothermal solution flows through an open fissure, and deposits its dissolved lode. Such types of deposits are found in cracks and veins in rocks. Most of the gold vein deposits are gold bearing quartz veins deposited from hydrothermal fluids at medium (mesothermal) or shallow (epithermal) depths in the crust. Precipitation is usually caused by cooling of the hydrothermal solution, by boiling, or by chemical reaction between the solution and rocks lining the fissure. Veins may also contain carbonate, pyrite, pyrrohite, arsenopyrite, albite and chlorite. Stibnite or scheelite are significant in some deposits.

The vein deposits of gold situated at depth in mountain rocks get exposed as outcrops over geological time due to tectonic upheavals. In ancient times, the near surface parts of friable (oxidized) veins were first mined. Subsequently, deep mining of gold was practiced. As described above, mountain rocks were the important source of lode or vein deposits. The auriferous rocks were broken, usually by “fire setting” process. These auriferous rocks were crushed, ground in stone mortars, and finally panned for the recovery of gold particles from the gangue. Alternatively, gold was also recovered from the ground rocks by amalgamation process. The relatively bigger gold particles were hand picked in the initial stages of recovery.

Alluvial Placer Type Gold Deposit

Alluvial placer gold refers to gold found in river beds, stream beds, and flood planes. Gold has been found in the sand and gravels of rivers and streams throughout the world. An interesting question, which may be asked as to how gold comes into rivers and streams. In the subsequent paragraphs, it has been shown as to how alluvial placer gold deposits are formed from the vein deposits.

Rocks at or near the earth’s crust are subjected to both physical and chemical changes due to contact with the prevailing atmospheric conditions brought about by natural agencies such as air, water, frost, etc. As a result, the rocks are broken down or undergo chemical changes leading to their decomposition. This process is called “weathering”. Weathering is of two types – physical or mechanical, and chemical. Physical or mechanical weathering involves the breakdown or disintegration of rocks without a marked change in the chemical composition. The main types of physical weathering are: freeze-thaw, insolation, hydration and dehydration, and stress release. On the other hand, chemical weathering involves chemical changes in the rocks, which are brought about by atmospheric, hydrospheric and biologic agencies. Some of the mineral constituents of the rocks are attacked by water, oxygen and carbon dioxide, and are removed in to solution. In nature only a few minerals are dissolved in pure water. However, carbon dioxide dissolved in water can dissolve several minerals, notably carbonates. This is due to the fact that when carbon dioxide is absorbed by water, solutions of weak carbonic acid are formed which react with minerals more strongly than pure water. The rain-water absorbs carbon dioxide from the atmosphere. The soil-water absorbs carbon dioxide released by the growth of the plants and the metabolic processes of microorganisms in the soil. Minerals vary in their dissolution behaviour. Some minerals are insoluble, some gelatinize with acids, and some partially dissolve. The commonest insoluble or difficulty soluble minerals are: quartz, zircon, tourmaline, ilmenite, sillimanite and gold. The residue left after chemical weathering recrystallizes to form new mineral phases, the nature of which is determined by the chemical composition of the residue. It is apparent from the above discussion that physical or mechanical weathering assists chemical weathering, because it results in rock disintegration, leading to enhanced chemical attack.

The products of weathering of rocks are subject, from the moment they are formed, to dispersal by various agents, such as moving water, air or ice. Running water is the most common agent for the transport of the weathered product. Depending upon the topography, the transported weathered material get collected near the base of the mountain hills. Such deposits are called colluvial placers. Alternatively, the deposit collected at the base of mountain slope can further be transported down by water stream. Several streams may join together progressively at lower levels. In the case of chemical weathering, as discussed above, most of the solution drains slowly under the influence of gravity through pores and fisures in the rocks resulting in the leaching of dissolved material from the weathering site. The dissolved species in the solution may enter exchange reactions with other minerals. At some stage of its travel, the solution intermingles with the surface drainage water.

Channels get enlarged and the total quantity of sediment in the transport increases. As the stream reaches lower level, gradient becomes flattened, and rivers are formed. This also results in additional freedom for lateral movement of the stream. As explained later, water not only transports the material, but also helps in sorting the sediment. The debris of weathered product would move in different fashion, depending upon the size and the gradient.

The load carried by a stream consists of three types of load: bed load, suspended load and solution load. The coarse materials like pebbles, which are unable to remain in suspension, settle down at the bottom. Such a load is known as bed load. The bed load transport may occur in different ways. When the descending grain reaches the bed, either they bounce back into the water stream, dislodge the stationary grains on the bed and help to initiate their motion, or simply have their kinetic energy dispersed into the bed. The jumping and bouncing motion of grains close to the bed during vigorous bed load transport is known as "saltation". When a grain reaching the bed does not bounce, its kinetic energy may be dispersed amongst several grains resting on the bed. As a result, some of the grains on the bed may be pushed a short distance down the current and the phenomenon is known as "creep". "Rolling" occurs when rather large rock fragments are set in motion. This occurs particularly when a large size grain is moving over a relatively flat surface of smaller grains.

The particles, which have settling rate lower than the vertical components of velocity opposing their deposition, remain in the suspension. Such particles constitute the suspended load. The sediment moves while remaining under suspension in the water stream. The flow velocity needed to start a particle in motion is called critical flow velocity. Its value increased with the size of particle for a given mineral. As the intensity of turbulence increases, the suspended mass carrying capacity of the flow, and the maximum potentially transportable grain size of the sediment in the flow increase.

It must be noted that grains of a variety of minerals would be flowing together in streams. A concept of "transport equivalence" has been introduced, which describes the behaviour of mineral grains that, despite difference in their physical properties, have the same net average velocity (Fletcher and Loh, 1996). Grains of same transport equivalence have the same average transport velocities and are transported and deposited together.

As noted earlier, the deposition of suspended particles takes place in streams, wherever the velocity of flow falls below the critical flow velocity. The concept of "hydraulic equivalence" (Rubey, 1933) of the grains in water stream explains the fact as to why smaller grains of heavier minerals, such as gold, deposit together with the bigger grains of lighter minerals such as quartz. The basic principle is that the hydraulically equivalent particles settle at the same velocity in water. From the Stoke's law of settling (Collinson and Thomson, 1982), the hydraulically equivalent diameters of minerals such as ilmenite (ρ = 4.79 g/cc), magnetite (ρ = 5.2 g/cc), cassiterite (ρ = 7.0 g/cc) and gold (ρ = 16.9 g/cc) with reference to quartz (ρ = 2.65 g/cc) can be calculated, and the values are 0.66, 0.62, 0.52 and 0.32 times diameter of quartz respectively. In the above calculation, it has been assumed that the particles are spherical. The deposition of gold particles takes place in gulches, creeks, rivers, flood plains and deltas.

Thus if the moutain rock contains gold veins, the weathered product would contain gold particles. Subsequently, the weathered product forms the load of rivers and streams. The deposition of gold occurs at suitable places along the river and stream flow as discussed earlier.

ANTIQUTIY OF GOLD DEPOSITS IN INDIA

As discussed earlier, Ṭhakkura Pherū stated that mountain rocks and rivers were the sources of gold. It is interesting to note that these sources were stated in many ancient Sanskrit texts as well. The results of archaeological findings from old working sites also suggest that vein or lode deposits of gold present in mountains were mined in India in ancient times. It is not the intention of reviewing all these references. However, a brief description of the antiquity of gold deposits in India is presented to show the continuity of these deposits through ages.

In the *Atharvaveda*, it has been said that the chest of the earth contains gold:

viśvaṃbharā vasudhāni pratiṣṭḥā hirṇyavakṣā jagato niveśani |
vaiśvānaraṃ bibhrati bhumiragnimindaṛṣbhā draviṇe no dadhātu ||

(*Atharvaveda*, 12.1.6)

It clearly indicates that the earth has mines of gold. The word '*bhūmi*' used in the above hymn does not denote merely the surface of the plain land, but it also includes banks and bed of rivers, hills of mountains, together with the interior of the earth and mountains. Thus this reference embraces both vein and alluvial placer deposits.

The ancient Sanskrit literature contains several references of mountains, which contained gold. The *Rāmāyaṇa* mentions various mountains, which contained gold. The *Rāmāyaṇa* mentions various mountains, which contained gold. These were: Udai and Soumanasa mountains in the eastern; Soma, Pariyātra and Varāha mountains in the western; and Kāla mountain in the northern directions of India (*Rāmāyaṇa*, 4.41.15-30; 4.43.15-16). It has also stated that the Ṛṣạbha mountain contains gold (*Rāmāyaṇa*, 6.74.61). The *Vāyu Purāṇa* states that the following mountains contain gold - Nīlagirī (34.20), Niṣadha (41.49), Suvarṇa (47.4), Sūryaprabha (47.10), Aruṇa (47.17), Hema (49.49), Udai (49.78), Hemakū ṭa (34.15), etc. All these mountains were situated in the Himalayas and beyond. The most important mountain as a source of gold, which has been referred to in several Sanskrit texts, is the Meru or Sumeru mountain. In many such texts, it has been referred to as 'Kanaka' mountain (*Mahābhā rata*, Vana Parva, 104.2; *Mahābhārata*, Bhīsṃa Parva, 6.10; *Vāyu Purāṇa*, 35.10; *Varāha Purāṇa*, 75.39, 77.5; *Mārkaṇḍeya Purāna*, 51.14). *Kanaka* is a Sanskrit word for gold.

Archaeological evidence collected from the old gold mining sites also supports the mining of lode gold deposits in ancient India. Foote reported old gold workings including pits and small shafts and passages choked with debris at Belli-Betta (Silver Hill) situated 20 miles NW of Seringapatam, and Sonnahalli situated 18 miles SW of Mysore (Foote, 1888). Bosworth Smith has reported a large number of old gold workings NW of Halebid and at Woolagiri, situated 20 miles SW of Mysore (Bosworth Smith, 1913). Several old gold workings have been reported in the Dharwar area of South India. Important old gold workings were found between the town of Gadag and the river Tungabhadra by several workers. Maclaren has mentioned two dozen pits of 18-25 ft in depth on the top of Jalgaragudd Hill (Goldwasher's Hill) (Maclaren, 1906). Foote reported the details of various old workings and mines lying between Hutti and Maski in the Raichur district of the present time Karnataka state, which are perhaps the most remarkable and interesting group of old gold workings (Foote, 1889). Numerous old shafts were 50 ft in depth. At the Hutti mines, old gold workings were encountered at depths of up to 640 feet during the mining operation in 1902. Similarly at Maski, about 15 miles from Hutti, 13 old gold working sites were encountered; of which one mine extended up to a depth of 117 feet (Munn, 1934). In 1955 AD, C-14 analysis of two specimens of timber found at a depth of about 250 feet in the old workings at Oakleys shaft of Hutti mine were carried out in New Zealand (Allchin, 1962). The results were as follows: Sample No. 1: -1890±70 years B.P, and Sample No. 2: -1810±70 years B.P. It suggested that the gold mines were being worked at depths of 250 feet during the 1st century of the Christian era. It must be noted that the gold mining near the surface must have began long time before this period, which must have constituted a separate phase. Tools available were too limited for any deep mining in this phase. The deep mining as reported above, would have started with the arrival of tools made of carburised steel. Allchin has stated that small scale and local extraction of gold was taking place in the Neolithic period in the Wandalli and Hutti zones (Allchin, 1962), which in the Deccan area is now established at between the end of the 3rd millennium BC and the first half of the 1st millennium BC.

There are several references, which throw light on the alluvial placer gold deposit in ancient India. Only a few of them would be considered here. The *Ṛgveda* (10.75.8) mentions that the river Sindhu (Indus) contains gold, and the word used for it is *hiraṇyayī*:

svaśvā sindhuḥ surathā suvāsā hiraṇyayī sukṛtā vajinīvatī |
urṇāvatī yuvatiḥ sīlamāvatyutādhi vaste subhagā madhuvṛdham ||

Sāyana, the greatest commentator of the *Ṛgvedic* hymns, has given the following commentary on the above hymn:

"This is the river Sindhu which is full of horses, chariots, cotton, gold, grains, and wool (i.e., these materials are either produced or found on the banks or on the nearby area of the river Sindhu). Its banks contain ropelike plants, which are used to tie down ploughs. It bestows fortune on people, and such plants are grown on its banks that help in producing greater amount of honey."

In another reference mentioned in the *Ṛgveda* (8.26.18), it has been stated that the path, i.e. both banks of the river Sindhu contains gold, and the word used for it is "*hirṇyavartani*". Sāyana has translated "*hirṇyavartani*" as "*hirṇmayobhayakūlā*" (i.e., both banks containing gold). The lexicon *Amarakoṣa* of Amarasiṃha (2.1.15) states that "*varatani*" is one of the twelve words used to denote the word 'path'.

In another hymn of the *Ṛgveda* (6.61.7), "*hirṇyavartani*" adjective has also been used for the river Sarasvatī. In another Vedic text *Śatapatha*

Brāhmaṇa, it has been stated that gold is found in water, apparently referring to alluvial placer gold found from rivers. The *Mahābhārata* has clearly stated that the mud, water and sand of the river Jambū is full of gold. It was a pure variety of gold, and was of the colour of *indragopa*. Kālidāsa has said in his *Meghadūta* (Uttarakhaṇḍa, 6) epic that the sand of the river Mandākinī contains gold.

The Classical Greek and Roman historians have also given information on the subject of gold found from Indian rivers, which collaborates the facts given in the Sanskrit texts, as discussed earlier. Herodotus (3.106) has stated that gold is obtained from the rivers in India:

"As I have lately said, India lies at the world's most distant eastern limit; and in India all living creatures four-footed and flying are much bigger than those of other lands, -----; moreover the gold there (India), whether dug from the earth or brought down by rivers or got as I have shown (i.e. ant's gold) is very abundant."

Pliny (33.21.66) has mentioned that gold found in the river Gañgā (Ganges) in India:

"In the world, as known to us, gold is found in three ways, not to mention gold dug up in India by ants, or by gryphons among the Scythians: Firstly in the sands carried down by rivers such as Spanish Tagus, the Italian Padus, the Thracian Hebrus, the Asian Pactolus, and the Indian Ganges. This is the purest of all gold polished finely by the friction of the running water."

On the basis of the statements made by other historians, Strabo (15.1.69) has stated taht gold-dust is brought by rivers in India:

"The following statements are also made by the historians: that the Indian worship Zeus and the Ganges River and the local deities ---- And they (historians) say that some of ants that mine gold have wings; and that gold-dust is brought down by the rivers, as by the rivers in Iberia."

It is interesting to note that the word used for naming some of the Indian rivers were based on the toponyms of gold. This was due to the fact that gold was obtained from these rivers. Only a few examples would be stated here. An alternate name of the river Śoṇa was Hiraṇyabāha or Hiraṇyabāhu. The *Amarakoṣa* of Amarasiṃha (1.10.34) states that - *śono* *hiraṇyabāhuḥ syāta*. Bhānujī Dīkṣita has stated another reading for the word "*hiraṇyabāhuḥ*" as "*hirṇyavāhaḥ*". Arrian has used "Erannoboas" for the river Śona in the *Indica* (10.5), which is the corrupt form of the word *hirṇyavāha*. *Mahā Parinibbāna-Sutta* (5.1) has mentioned the river Hiraṇyavatī. In modern times, there is a river named Svarṇarekhā flowing through the state of Jharkhand.

Concluding Remarks

Ṭhakkura Pherū has stated two important source areas of gold in India, viz. mountains and rivers. These represented the sites for the lode or vein, and alluvial placer gold deposits respectively. The presence of gold in mountain rocks and rivers has been discussed. It has been shown as to how the gold present in mountain rocks gets transferred into streams. The deposition of gold grains along with the sand and gravel of rivers has been explained. Ṭhakkura Pherū has not given the details of the mining methods used and the subsequent process of extraction of gold from the mined ores. The methods adopted for mining and extraction of gold were well known by the time of Ṭhakkura Pherū and did not warrant any description by him. A number of Indian mountains and rivers have been described as a source of gold in several ancient Indian texts. Also, there are some archaeological evidences for the mining of lode gold deposits. On comparison with these references, it is apparent that both vein or lode and alluvial placer deposits of gold were utilized for the recovery of gold in India through ages from ancient to medeival period.

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