Some Scientific Facts that Determined India's History

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The topic that I have chosen deliberately seeks to bridge to some extent the increasing gulf between the social science like history, and the physical sciences. As our disciplines improve and become more organized, systematic and reach higher levels of understanding of reality in their own different ways, they become more and more exclusive. They speak in languages that are typical of their disciplines and which are hardly understood by anyone who are beyond their domain. Therefore, we find that it is extremely difficult to put two persons from two different disciplines together and urge them to open up a conversation. Nevertheless, we must not forget that at least some of us, irrespective of our disciplines, are trying to achieve some kind of understanding of the reality.

As the disciplines become more and more fragmented into narrow domains of specialization, communication even within the discipline, is becoming difficult as the 'specialists' really know so little about the others' specialization.

I know that history normally tends to recount the deeds of emperors, kings, leaders and is concerned about war and peace, and various events and their dates. The life of ordinary human beings is not deeply taken into account. As a result, history usually ends up being very uninteresting narratives. For most students it is just too boring. In fact, I had carefully avoided studying history. I defected from science to the social sciences and insisted that studying history was just a waste of time. But I succumbed to its charms much later when I did my Masters in History only after I could understand the subject on my own terms. In my deliberations today, I will stress the fact that Indian history was influenced by scientific discoveries and breakthroughs and behind every momentous phase of Indian history stood one or more scientific masters.

Three phases of development

As there are too many examples, I will restrict myself to the first three phases of historical development in India, namely, the Harappan, the Aryan, and the Mauryan. I would also cover in a very elementary way sciences like chemistry, physics, metallurgy, ceramics and, to some extent, mathematics and engineering to reveal their impact on the major happenings of Indian history. It is my first submission that if Indians had not mastered theoretical and practical physics in developing accurate measurement systems, it would not have been possible for them to create or sustain the Indus Valley or the Harappan civilization for almost 2000 years. The discovery of this civilization has actually given India the unique honour of being one of the three oldest civilizations in the world. Now here is a point of interjection.

Students who studied history till the late

1950s were not even fully aware of the Harappan civilization. Harappa or the Indus Valley was factored into Indian history as the first chapter. It was called Harappa later, but first it was known as the Indus Valley. I am fond of collecting history books. So I have collected history books from 1860 and have gone up to 1960, a hundred years. But there is no mention of the Indus Valley. The last discovery of the Indus Valley, ie Harappa, was made by Sir Mortimer Wheeler in 1946. Its report was prepared in 1948-49 and facted in from archeology to history only in 1952-53. So towards the end of the fifties, the universities got text books that dealt with the civilization of the Indus Valley. This is an issue, and every book prior to 1958 states that Indian civilization begins with the Vedas, with the Aryans.

It was the discovery of the Harappan civilization that has catapulted India to the position of one of the oldest civilizations of the world. It is one of the lasting tragedies that while Mohenjodaro was discovered in 1922-26 by Sir Rakhaldas Banerji and the Archeological Survey, its report came in much later. If Harappa was discovered immediately thereafter; we would have had another point to agitate, to demonstrate before our imperial rulers. The tragedy is that these facts came to be known well after they have left!

The first of three ancient civilizations of the world is the Egyptian, that flourished along the Nile river. It is the oldest because it started around 6000 B.C. and its glorious period is known to have flourished around 4000 B.C. The Mesopotamian civilization on the Tigris and the Euphrates rivers had bloomed a little later than Harappa. The beginning of the Harappan civilization has been accepted as 3500 B.C. These dates, of course, are not negotiable as these are not what any particular government wants or any particular group of thinkers or ideologues want. Many ideologues want many things to be done. But the fact remains that history has to be tested like all other sciences on the anvil of truth or empiricism.

All the three civilizations referred to were Copper or Chalcolithic Age. But let us stop for a moment. There is a fourth civilization that claims equal antiquity and that is the Chinese. It actually had come a thousand years or seven hundred years later. All of them can be described as belonging to the Chalcolithic Age that knew the use of copper and stones. All the three, in fact, the fourth also, were also known as hydraulic civilizations in the sense that they managed to control water.

The point is, why did this advancement had taken place only in three areas of the world? Why is it that the Indus Valley was so far ahead of Europe when Europe was extremely backward? We may use their colonial language in reverse gear on them by saying that the ‘natives’ of Europe were then in a rather primitive stage belonging to the Neolithic or early Chalcolithic stages, and could not even dream of the urban civilizations like Mohenjodaro, and Harappa from their cave and animal-skin existence.

Be that as it may, in order to understand the Indus Valley civilization that began in 3500 B.C., we need to go back another 3,000 years to 6500 B.C. which is around 8,500 years from today. This is a subject on which there has not been a lot of discussions, which has not yet entered our textbooks in a major way. But those who study history and archeology are aware of it. This is a site, an archeological site, called Mehergarh near the Bolan Pass in Baluchistan, ie present-day Pakistan. This cradle of human civilization was discovered only in 1974 by a group of archeologists under the leadership of a French couple—Jean-Francois Jarrige and Catherine Jarrige. They worked in two phases and the second

phase ended only in 2000 A.D. That means books about Mehergarh started coming up practically during the last five to six years. By the time knowledge goes down to all persons, it takes a lot of time. So the second phase of the exploration of the French team established that this was the precursor of the Indus Valley Civilization.

We have to understand one scientific fact that all the Stone Age civilizations tended to be located in rocky areas because their main source of strength was the use of stones or lithos. In Paleolithic, Neolithic, Mesolithic—all lithic ages witnessed the use of stones. In other words, they avoided river valleys which were infested with swamps, forests, and high grass where lived rhinoceros and other wild animals. The same river that we shall worship later was then a dreaded zone.

Now, the Bolan Pass is in a rocky region. It is that pass we have to travel to reach Hinglaj, one of the toughest among the places of our pilgrimage, and from there, the Indus river is not very far away. On this spot in Mehergarh, you see a civilization coming out of the rock stage, the hunting-gathering age, and the adroit use of flints, blades and needles. That was possible because their fingers had developed to a great extent—thanks to their repeated use of stones. This is an area in which you find the old lithic civilizations going all the way to herding civilizations. That means you are no more dependent upon the animals. You do not have to kill animals; you can domesticate them. The animal is no more your enemy but your servant. From that animal, pastoral herding stage, they would move on to agriculture. Just for your kind information, if anyone even asks you, what is the first spot in the Indian subcontinent where we began agriculture, you can answer without batting your eyelid that it is Mehergarh. Mehergarh not only saw the first domestication of animals, but also witnessed a thousand years later the domestication of other crops. It is the cradle that reveals three different stages of growth. But what is more important is that it leads us to the fourth stage—from an isolated agricultural civilization to the mightiest of urban civilization that the world has seen—in terms of Egypt, Mesopotamia and Harappa. It displays the whole sequence of how this Neolithic settlement began with animal herding, moved on to the beginning of agriculture in the whole subcontinent of India, and subsequently moved on to a mature urban civilization of Mohenjodaro. Why did it happen? Why it did not happen in Bengal or in other parts? This is the point we need to understand. What excites us is the evidence of scientific and technological advancement that made the journey through these four stages possible.

Scientific advancement in Mehergarh

Let us give a few examples of their scientific advancement. First, the scientists have discovered eleven drilled molar crowns in nine skeletons that were as old as 8,000 years. It proves that the world's first proto-dentistry was practised here. This was not evident in the rock age, the Neolithic, the Paleolithic etc in which people were still using bows and arrows. The Western scientific journal *Nature* declared in its April 2006 issue that, Mehergarh was indeed the oldest and the first Neolithic evidence of dentistry in the whole world. This is only the tip of the iceberg. We can deduce from it how scientific knowledge in general had been harnessed in a systematic manner in Mehergarh, and it is up to us to discover the other applications of the sciences in this particular civilization. We have come across furnaces, ceramics, glazed pottery and sophisticated firing techniques of 4500 B.C. But we find that by 3500 B.C., that is to say, exactly 1,000 years later, the quality and

intricacy of designs seemed to have suffered. The reasons were mass production of items and the movement away from stone and stone-earth-based ceramics and terracotta to metals.

This is the beginning of the metal age. Hence we find technologies here included stone and copper drills, up-draft skills (when the draft is pushed upward, when the heat is captured more near the neck of chimney of large pit-kilns) and copper melting crucibles.

In Mehergarh there is lot of evidence of manufacturing activity based on metals, such as artefacts, implements, and daily usable items. It is here that we get the second recorded evidence of being the *first* in the world. We find the metallurgical technique of *cire perdue*—or lost wax process. Much of our bronze casting and other things are still done by this method. In Bengal and in central India the Dhokra artists use this technique where you see metal pots being made on a plaster cast, earth and other materials. The carving is done there and then wax is put on it where exactly the carvings are supposed to be. And then a second layer of earth is put on, and the molten metal is put in from the top. It just eats away the wax and takes the impression. That is the whole process of doing it. It is called *cire perdue* in French. And this is one of the world's oldest metallurgical techniques. The whole world was trying to find out the oldest evidence, and it was found in Mehergarh. This discovery came from a 6,000-year-old wheel-shaped unalloyed copper amulet. The amulet itself will explain to you how science and superstition had gone on together. It is present even today. In India we learned to live with both science and superstition without being fanatic about either of the two.

Those who wonder how such a superior urban civilization as found in Harappa could suddenly arise around 3500 B.C. need to understand that it was *not* sudden—feeder cultures like Mehergarh were already evolving and moving ahead towards this reality for 3,000 years. The excellence in town planning, housing and architecture, street and drainage layout that the Harappan civilization displayed evolved from centuries of carefully nurtured scientific and technological skills developed in India and Pakistan, at a time when the cultures in Europe were in the primitive stages in terms of scientific knowledge and its application.

Recent studies have proved that in Harappan civilization people were not a voracious consumer of rice or wheat like the people of other civilizations that had survived on agriculture. To find out why this was so, we have to understand the mind of India first. For a civilization to have a city means all the city dwellers would not be engaged in cultivation. Who would then feed them? Where would the food surplus come from to feed the city dwellers? So the city-based civilizations would come up only after the arrival of iron. I will explain that a little later. The question now is: How can you have copper age civilizations that fed cities?

The techniques of using copper could not be put onto the plough. Ploughs then continued to remain wooden—at the most they were stone-tipped, so to say. But to produce surpluses with that technique was very difficult. Yet the fact of Mohenjodaro, Harappa, Lothal and other places showed that there were many other urban centres that were fed by somebody. So the answer lies in the diet that was taken by these people. Recent studies prove that Harappan civilization was not based on rice or wheat. The people partook of dry staples of barley, oats, jowar, bajra and other crops which could grow with minimum water. This fact would also mean that their interaction with the Indus river was limited. The Indus river was still feared for its floods. Nevertheless

they lived near the Indus for reasons of using the river and its tributaries as highways for the vessels. They were not using the water of the Indus for irrigation as they had chosen dry land crops. This meant they were not much dependent on water and preferred culturally accepted food. I am using the word *culturally accepted food*, because the stone users came from places which had a dry climate; they did not come from a fertile land. So these food were culturally accepted in the diet and they continued to have it even when staying close to a river. They did have some wheat, but wheat was not central to their diet. It was like our soya. Let us not forget that the Harappan civilization did not have the benefit of the Iron Age and its agricultural equipment that could produce surplus crops to sustain the non-peasant population.

It speaks volumes about the management of water, agronomic inputs, copper and stone implements that they made use of in the pre-iron copper age to produce reasonable agricultural surplus to feed those who did not till the land such as priests, intellectuals, traders, administrators, soldiers and sailors. Because it was basically a trade-based economy that had worked out a perfect system of food procurement, food management, storage and distribution as evidenced in the granaries and plentiful remains of food that have been found in the houses, there was no shortage.

Measuring instruments

However, to excel in trade and commodity management one needs measurement and measuring instruments. The first and accurate measurement scale in the whole world has been found in Lothal of the Harappan civilization. This first ruler that is found here is dated 2400 B.C. In his book, *The Measure of All Things : The Story of Man and Measurement* published in 2007, Ian Whitelaw, a Western scholar, notes that this ruler is divided into units corresponding to 1.32 inches or 33.5 millimetres, and these are marked out in decimal subdivisions with amazing accuracy to within 0.005 of an inch. That means you needed to have another master on the basis of which you can do these markings. Ancient bricks found throughout the region had dimensions corresponding to these units. In fact, it is very interesting that these units correspond to the native Indian units called *angulam*. It was found not only in Harappa and Mohenjodaro, it continued throughout the history of India up to the so-called Islamic period and ended only when the British systems of measurements were thrust on us.

We know that the Harappans had mastered the techniques or the technologies of developing huge cities, not only with perfect geometric dimensions of building roads and public places, but they also made greater contribution to the development of the science of metrology.

Next, we find a series of weights that we find in bundles, not just in one place, but in all the Harappan cities. These weights also had a very perfect similarity between each unit. I will not take your time to repeat what is taught about the Harappan civilization and its excellence in street drainage and sewerage, except to mention that the world is unanimous that the first home toilet commonly known as the commode that drained out refuge so scientifically by using gradient and gravity was built in Harappa, in India. What happened later is of course another story!

Vedic Age

The next stage is from 1500 B.C. to around 600 B.C. and it is usually called the Vedic Age as it was dominated by the so-called Aryans who spoke Sanskrit, and some

of them composed the *Rigveda*, and the companion texts. There is a misunderstanding that we need to get over. It is that every person who came in had a hand in the *Rigveda*. No. The *Rigveda* was composed by a very literate class. There is no proof that every speaker of the Aryanic languages were aware of the *Rigveda*. In any case, historians have raised the point whether it is appropriate to call the entire period as Vedic as the Aryans definitely constituted a small minority, and their influence was geographically restricted to just fifteen to twenty per cent of India's land mass. So how can you name one superior civilization to be the representative of entire India? That is another story.

There are proofs of existence of contemporary civilizations in India many of which were technologically advanced. These are proofs which standard historians would not like to touch, but people like us get in. If you take the evidence of the Puranas, you will find that they contain stories where the *rākshasas* had occupied *Indraloka* (the abode of Indra), and how the *Aryaputras* had been driven away from their homeland so that they had to seek the intervention of some superior force—a god or a goddess. The Puranas also mention some mythical persons like Shukrāchārya, the philosopher of technology, and they have all along said that the technology they had was superior to the one the 'Aryaputras' possessed. So, there are proofs of existence of some superior civilizations. I raise these points provocatively because our present subject seeks to dwell upon scientific facts and from that perspective, the Vedic Age is actually a movement in the reverse direction.

While there is no doubt about the superiority of the Sanskrit language and the philosophy that is embedded in it, there are strong doubts about their contributions to the material civilization. Evidences are of course there, but the extent of such contributions is not very vast. No archeological findings in the history of India are ever branded as 'Aryan' or 'Vedic', though before and after this phase we get archeology, artifacts and civilizations such as Harappan, Mauryan, Gāndhāra, Kushāna, Sunga and all that. We do not have a single item as Vedic or Aryan.

We have problems here. We do not want to come to terms with our history because it militates against what we have been taught. This is because we have after all left a superior world—a world class urban settlement of Harappa to reach a largely pastoral civilization of the Aryans where cattles were the most important source of wealth. In fact, an entire genealogy is based on cattle or *gotra*, meaning 'from the same cowshed'.

However, archeologists have categorized two types of pottery found in regions inhabited by the Aryans as BRW and PGW, or Black and Red Ware and Printed Grey Ware. The first BRW is an early Iron Age culture of North India, dated roughly between the 12th and the 9th centuries—usually ascribed to the *Rigvedic* period, ie three to four hundred years after the Aryans *appeared* in Indian history. We find a pastoral civilization settling down to serious agriculture. Now, when you talk of agriculture coming for the second time, one should remember that it actually started 7,000 years ago. These are fascinating ups and downs in history where you see forward and backward movements are taking place among the same people.

The second pottery known as PGW (Printed Grey Ware) began around the same time, in 12th century, but it appeared in full bloom only after the Aryans had crossed the Yamuna in large numbers, between the 9th and 6th centuries B.C. The archeological

remains of PGW also indicate the domestication of horse, an animal that is hardly seen in the Indus Valley period, and frequent use of iron. In fact, the Aryan victories which ultimately took place was not due to language or not even because of organized system of thinking and culture. It was because of the use of iron and the horse. It was something like the white Americans' sway over the Inca, Aztec and other civilizations that were in a way superior.

These archeological remains associated with this Painted Grey Ware also indicate domestication and we find that Ahichatra in Bareilly district of U.P. is the most important site that is on the Gangetic plains. As I told you, the Gangetic plains were thickly forested and the maturity of the Iron Age was seen when iron was used to slash through these forests and going through. Romila Thapar calls this slash-and-burn philosophy. First they moved in from the Terai that was less inhabited and then they went along the river tackling the river-based animals, and then went in for slashing and burning. No Copper Age civilization could have captured the Gangetic belt as it was heavily forested. So we had to wait till the arrival of iron which started in 1000 B.C. and reached a maturity around 600 B.C. Without the arrival of iron, there would have been no civilization of India. And when I was in Delhi I was fond of saying that India does not begin in either the Khyber Pass or the Bolan Pass or Indus or Punjab. India begins after you cross the Nizamuddin bridge, ie cross the Yamuna and enter the Indo-Gangetic plains. That is where the crucible of Indian thought and philosophy came from.

We now come across the fortified settlements in the Gangetic plain and scientific advancements that led to iron swords resulted in the domination of Iron Age Aryans travelling on horseback who subjugated the primarily Copper Age culture of the indigenous Indians. We all know what the indigenous Indians were called—*dānavas, rākshasas, pishācas, dāsas* and so on because they had been carrying a Copper Age culture and could not stand up to iron. This, what I am mentioning here, has been demonstrated at least thirty years ago.

Science of agriculture

The science of agriculture received a quantum leap from the science of metallurgy when iron-tipped ploughs and implements would cultivate more fertile alluvial soil with lesser effort. They freed large parts of the population from agriculture, as greater surpluses that iron ploughs produced could now feed the ruling class who dominated others with iron-bearing soldiers, spears, bows and arrows, horsemen, policemen and bureaucrats. This surplus also fed the speculators of thoughts and ideas, called the philosophers. And in the sixth century alone when the use of iron had matured, we got all the philosophers of the world—Lao Tse, Confucius, Gautam Buddha, Ahura Mazda, Abraham, and Mahāvira.

Iron just freed large parts of the population from the boredom of agriculture. And the same iron that produced sword, that could cut through the copper implements, ensured the arrival of monarchies in India. The same monarchies appeared 4,000 years ago in Egypt where superior copper was used to crush the Stone Age cultures. Thus we find the rapid breakdown of typical Aryan tribal democracy and the arrival of monarchical dominations through kingdoms and *janapadas*. This is also the period when you also get the stories of tensions developing between the two. If you study mythology, also you will see the same tension growing between the free persons,

who lived in the hills, and the *rājās* who lived in the plains. *Dakshayajna* is a very good story where you find the tension between a free man of the republic, a free man of the hills, contending against the combative *rājās* possessing superior arms.

History that we are usually taught in educational institutions does not give adequate emphasis on the study to see how scientific developments changed the faith of people at periodic intervals. Now we have to look beyond the *Rājās, Rishis, Munis, Āryaputras* and the wars and conquests to go to the root technology that made it all possible.

Technology of zinc

Before we come to the last phase of our examination of the role of science in shaping history we need to take a little detour in the technology of zinc that developed in settlements in India in the late Vedic period. Brass, as we all know, is an attractive golden coloured alloy of copper and zinc and it is more ductile and strong. It has better resistance to corrosion and is a very useful metal.

A team of scientists from the British Museum and the Baroda University unearthed the first use of zinc and the early technique of zinc smelting at the old Zawar in Udaipur, Rajasthan.

I must pause for a second here, because I have not mentioned the oldest and richest settlement of copper in India. The rulers of Khetri had drawn their sustenance from this copper. Now we find the monopoly of zinc in Zawar which is today considered to be the oldest site of industrial zinc production of the whole world.

During the process, typical slag was not produced because of the small-sized retorts; instead, the ore was roasted. These are the indigenous processes that developed in India at that point of time. Though primitive alloys with less than twenty-eight per cent of zinc are prevalent in many other parts of the world, when we take zinc as an alloy material for brass, we normally take the twenty-eight per cent plus. That is metallurgy. The brass that we find at Takshashilā has been dated from third century B.C., and a third century brass is also found here which it contains 34.34 per cent of zinc. It is far more superior brass with zinc content. Recently two brass bangles belonging to the Kushāna period have been discovered in Uttar Pradesh which shows thirty-five per cent. These are very superior brass specimens. In ancient India production of zinc metal was common, and the process of producing metallic zinc had been described in several ancient Sanskrit works.

We also knew the use of zinc oxide in medicines. There are references of zinc oxide use in medicines in the *Charaka Samhitā*. So the mastery of zinc was another thing that goes in our favour.

To break from this North Indian focus let us go to the South, where we get solid evidence of the earliest production of high carbon steel in the whole of the Indian sub-continent at Kodumanal in Tamil Nadu area, at Golconda in Telengana and Karnataka, and in northern Sri Lanka. This came to be known as Ooty steel produced in South India by six century B.C. which was exported globally. In fact, steel technology existed here prior to 326 B.C., the year of arrival of Samudragupta as they are mentioned in Tamil Sangam poetry. In Arabic and Latin literature also the South Indian people have been described as the finest steel-makers in the world. This steel was exported to the Romans. The Arabs called it Damascus steel.

Later, in the fifth century, we find the

Chinese and local Sri Lankans had mastered the art. The Sri Lankans used the monsoon winds. The wind furnaces were driven during the monsoon period when the wind speed is very high. You see, to heat iron and alloys to get steel you need to cross a 1000^0 Centigrade temperature which is very difficult with the present state of coal. Therefore bellows were used to raise temperature. And the bigger the bellow and smaller the furnace, the higher would be the temperature. And the Northern Sri Lankans went in for a technique where the earlier blast of the monsoons were used to raise the temperature. This is how it all went.

Mauryan strength

Now we come to the last part of our discussion which explains why Pataliputra, the modern-day Patna, could dominate India and bring it under the first pan-Indian empire of the Mauryas. Dr Kosambi has explained the eastward thrust of the civilization that was successful when superior steel implements were crafted. In very simplistic terms, it was the Mauryan control of two critical resources, iron ore and coal, that made it possible. As you know, almost all the best coal reserves in India are in the Manbhum-Singhbhum areas, and all the steel plants that came up, excepting Salem, are in the same area—Bokaro, Rourekela. Why? Because you have coal, iron there. It is due to the same mastery over coal and iron that Pataliputra under the Mauryans could grow so strong. The Mauryan adventure could not succeed without those resources. They required the intelligence of Cānakya who came from an area where steel-making was already in vogue. It is said that Cānakya actually came from Kānchipuram. And you can imagine his flexibility! Born at Kānchipuram, he walked across to Takshashilā.

Kautilya, in his *Arthashāstra*, mentions in the twelfth chapter that the superintendents of metallurgy had to be proficient in geometry, geology, metallurgy and smelting of gems. Among the tasks of the mines department was to locate new mines with ore-bearing earth, rocks and liquids. It shows that Kautilya had exceptional knowledge of mining. So he was giving its clues.

Thomas Trautmann has written a new book called *Arthashāstra : The Science of Wealth*. And here he explains how scientific discoveries and technologies were used to strengthen all kingdoms. The treasury had its source in the mines. From the treasury, the army came into being, and with the treasury and the army, the world was subjugated.

Trautmann further points out that discussions of economic topography in the *Arthashāstra* connect trade with routes and not market places. A close reading reveals that trade is thought in terms of transporting goods from workshops to the buyers, not inter-city trading. That was centralization. It was almost like a erstwhile Soviet state. The Mauryas had reached a stage where they could control everything. In fact, Asoka's devastating Kalinga war is attributed to shortage of raw materials such as surface coal and iron. The richest ores were then available in the Kalinga region. He had to go there not to expand his empire, but because he had to get his supplies.

Commentators usually have focused on what is visible and what is there in the texts. They also take records into account. But I usually stay away from such gurus. Instead I am impressed by Dr D. D. Kosambi's approach in studying history. He left a wealth of information on the material view of history and distinguished it from common beliefs, myths, legends and superstitions. He

(Continued to page 36)