Looking Differently at Ancient Indian History — From a Scientific Angle

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The topic which I have chosen to speak today seeks to bridge, to some extent, the ever-increasing gulf between the social sciences and the physical sciences. As academic disciplines improve their coverage and become more organised, more systematic and reach higher levels of understanding of reality in their own different ways, they become more and more exclusive. They begin to speak in languages that arise out of the requirement of their own disciplines without realising that their lexicon is hardly understood by anyone else who is not a part of their limited domain. Therefore, we find that it is extremely difficult to put two specialists from two different disciplines together and expect them to open up a meaningful conversation. Within the disciplines, too, more and more fragmentation occurs and very narrow domains of specialisation emerge, which makes communication extremely difficult even within the same discipline — as each specialist really knows so little about the others' specialisation. This is why it so imperative for at least a few to connect the dots generated by separate findings and to keep trying to forge some degree of meaningful communication among these walled disciplines, to achieve a kind of a better understanding of reality.

Let us Link History and Science

Let us take a typical social science like history and try to understand it from the angle of some physical science, say, physics or chemistry. This is

difficult to think of as all that most of us remember of our encounters with history as a subject in school and college is one that is rather discouraging. We were made to think of history as an exercise in remembering the deeds of kings, emperors, leaders and challengers. It appeared more concerned about dates — of war and peace and of major events and who won or who lost. Traditional approaches to history, therefore, hardly go beyond this and rarely ever explain how scientific and technological breakthroughs and advancements impacted society. Many more would have been attracted to the subject had it narrated how the advent of technology at each stage changed not only our values and world-views but also our very existence. We normally come against an instant mental block when we try to link history with science, as we are trained to treat them as two different worlds — as belonging to two completely separate domains. At the school and college level we are, of course, told about the 'Copper Age' or the 'iron age' but we are hardly ever told how succeeding technologies or 'improved metals' actually changed the very face of civilisations. We come to know only bits and pieces of how science impacted history — like how the invention of the steam engine spurred the industrial revolution in Europe. But how many know, for instance, that improvements in the technology of iron actually resulted in the spread of the Mauryan empire?

As a result, the style of teaching history to which all of us are exposed in our early years, one that only recounted dates and events, usually ends up in being very uninteresting. For most students it is just too boring. In fact, I had carefully avoided studying history even though I had decided to study a social science for my graduation as I felt that studying history was just too stuffy. It appeared to be confined only to past incidents and of persons who are dead and gone , and appeared unconcerned with the exciting and problematic present and could not care much about the enigmatic future. Historians did not really strain to change these early impressions as they were busy writing for each other's consumption — not for us — and seemed to revel in their own world of the

past. It was only after I left the university and had taken up a demanding job that I began to read history in my spare time, on my own terms. It was only then that I began to see the links between technology and civilisations — and soon succumbed to the charms of history. My official task was very time consuming but it was either full of intense pressures and tension (as when facing law and order problems, every day) or very mentally-debilitating (when tackling excessively rule-bound locked minds and complicated bureaucratic procedures). It was during these days that found that history and social anthropology to be fascinating distractions or alternatives and they did help me understand social behaviour and political structures that I was immersed in. In fact, I became so seriously engrossed in these subjects that I took to burning midnight oil for several years, after very tiring days in office or in public affairs, and earned my Masters degrees in them, on my own. It is from this belated love for the subjects that I shall try to explain to you — in my own non-historian's language — some interesting linkages between scientific break-throughs, especially in metallurgy, and the corresponding developments in Indian history. Unless we learn to appreciate how each of the major phases of our history was influenced by the prevailing state of technology, the two worlds will remain separate and even antagonistic to each other.

Inserting Harappan Civilisation into Indian History

As there are many phases of Indian history, I will restrict myself to the three of the early stages of historical development in India, namely, the Harappan, the Aryan or Vedic, and the Mauryan. 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 civilisation for almost 2500 years. It was only after we understood the purport of the discovery of this civilisation in the late 1950s could we claim the honour of being one of the

three oldest civilisations in the world — a distinction that belonged only on Egypt and Mesopotamia till then. There is a fourth civilisation that is given equal antiquity and that is the Chinese one, even though it came up some seven-eight hundred years later. Until the Harappan civilisation on the Indus Valley entered our text books around 1960, all us firmly believed that Indian civilisation had really begun with the invasion by the Aryans some time in the second millennium before the present era. We shall discuss a little later how text books were changed but what is more important is once the dates of Mohenjo-Daro and Harappa were confirmed, the beginning of India's history was pushed back by almost two thousand years. The start of the Harappan civilisation is usually taken as 3300 BC and it lasted till about 1300 BC. Incidentally, these dates are not negotiable as these are not determined by any particular government, though certain groups of ideologues do often try to tamper with history to suit their own world-views. But history has to be tested like all other sciences on the anvil of truth or empiricism.

As mentioned, students who studied Indian history even in the late 1950s were not taught about the Harappan civilisation. Though Harappa was first 'sighted' in the middle of the 19th century early excavations began much later, in 1921. But it was Mohenjo-Daro's exciting discovery in 1922 that stole the show at that time. The report of the archeological excavation prepared by Rakhal Das Banerji was accepted by the-then Director General, John Marshall rather late and it took quite some time to factor in the findings from the excavations in both Mohenjo-Daro and Harappa before the 'Indus Valley' or 'Harappan' civilisation was admitted into Indian history. I am fond of collecting old history books and reading up what I cannot procure — just to get a feel of what was actually admitted as and believed to history in those decades. I checked up the 1958 edition of the Oxford History of India — a very standard text book for school students that was originally written by Vincent Smith and revised by Percival Spear. Strangely, I found no mention

of the Indus Valley or Harappan civilisation, even though it was Mortimer Wheeler who had assisted Spear in updating the facts about 'early Indian history'. This was extremely interesting because Mortimer Wheeler was certainly more aware than anyone else of the 'new civilisation' as he had led the major excavation in Harappa in 1946 as the Director General of the Archeological Survey of India (ASI). It is rather odd, therefore, that he made no mention of the great discovery of the Harappan civilisation as late as 1958. In any case, once it was admitted into the history text books of colleges and universities, the Indus Valley or Harappan civilisation ranked as the first phase of India's history and was juxtaposed before the Vedic period as the first chapter in history books.

Mehergarh Precedes Harappan Civilisation

Returning to the significance of Harappan and the other three civilisations that are referred to as the Copper Age or Chalcolithic ones, we see how the use of copper had distinguished them from the rest of humanity in all other parts of the world. Most of the latter were in different stages of stone-age technology. All the four great ancient civilisations were also known as hydraulic civilisations as they were dependent on rivers — that they had managed to control and utilise this priceless water resource. The point is, why did this advancement had taken place only in these four areas of the world? Why is it that the Indus Valley was so far ahead of Europe? We may use their colonial language on them by saying that the 'natives' of Europe were then stuck in a more primitive stage of human growth, i.e., the Neolithic one or in the early Chalcolithic stages that were characterised by small village and farming communities. They could not even dream of the urban civilisations like Mohenjo-Daro and Harappa and western and northern Europe were still very much in their cave-dwelling and animal-skin existence.

Be that as it may, in order to understand the Indus Valley civilisation that began around 3300 B.C., we need to go back by another 3,000 years —

to 6500 B.C. which is around 8,500 years from today. Not too many people have heard of the discovery at Mehergarh and there has not been sufficient public discussions on it and nor have history textbooks rooted it firmly in our minds. But those who are in the profession of history and archeology are aware of the archeological site called Mehergarh near the Bolan Pass or modern-day Quetta in Baluchistan, in present-day Pakistan. This is regarded as the cradle of Indian civilisation and it was discovered only in 1974 by a group of archeologists under the leadership of a French couple— Jean-Francois and Catherine Jarrige. They worked in two phases and it was only after the second phase that ended in 2000 A.D. could the French exploration team establish that this Mehergarh was indeed the precursor of the great Indus Valley Civilisation. Naturally, books about Mehergarh started coming up only in the last few years. We have to understand one scientific fact — that Stone Age civilisations tended to be located in rocky areas because the main source of strength of man lay in the use of stones or lithos. This is why we refer to them as Palaeolithic, Mesolithic and Neolithic —all lithic ages that were characterised by more and more skilful use of stones. In other words, they avoided river valleys, though they needed some clean water to survive. They tried to stay clear of areas infested with swamps, forests, and high grass where lived rhinoceros and other wild animals. The same mighty river that we came to worship later was then quite a dreaded zone.

The Bolan Pass is in a rocky region and quite near to Hinglaj, one of the toughest among the Shakta pilgrimages, and from there, the Indus river is not very far away. It is in this Mehergarh region that a group of humans came out of the earlier phase of depending only on hunting-gathering that required mainly the adroit use of flints, blades and needles, to which their fingers and their brains had developed to a great extent. This is the area in which we find the old lithic civilisations of India transforming into animal herding civilisations. That means that man could escape from his total dependence upon animals he killed, for food, clothing, bone instruments and so on. The Mehergarh animal-herders

did not have to kill animals all the time — they had learnt to domesticate many of them. The animal was no more their enemy or prey but their servant. From that animal-rearing pastoral stage, the inhabitants moved on to agriculture and if we are ever asked which is the first spot in the Indian subcontinent from where agriculture began, we can point unhesitatingly to Mehergarh. This culture not only saw the first domestication of animals, but it also witnessed the domestication of other crops, almost a thousand years later. It is this 'cradle' that reveals the different stages of growth of our ancestors.

But what is more important is that it leads us to the next stage—from an isolated agricultural civilisation to a sprawling and wondrous urban civilisation that the ancient world had hardly seen, except in Egypt and Mesopotamia. Mehergarh displays the whole sequence of how this Neolithic settlement began with animal herding, moved on to the early agriculture — the first in the subcontinent of India and subsequently gave birth to the mature urban civilisation of Mohenjo-Daro, Harappa and other towns. Why did it happen? Why it did not happen in Bengal or in other parts? This is the point we need to understand. It is fascinating to go through the evidence of scientific and technological advancements that were made during the journey of history. It began with the hunter-gatherer; it then moved to the animal herder; then to the agriculturist and finally to the urban civilisation along the Indus Valley.

Scientific Advancement in Mehergarh

One can only imagine what a phenomenal pooling of scientific knowledge and technological innovations must have come together to produce a civilisation like the Harappan, that was essentially urban based was huge — its core area spread over more than a thousand kilometres in length, and its width could vary from three to four hundred to seven or eight hundred kilometres. And to be its precursor, Mehergarh had obviously to reach a very high level of scientific advancement. To give an example, we note how surprised scientists

were to discover evidence of advanced dentistry in the form of eleven drilled molar crowns in nine skeletons that were as old as 8,000 years. It proved that the world's first proto-dentistry was practised here and a Western scientific journal, *Nature,* actually 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 archeological evidence how scientific knowledge had been harnessed in a systematic manner in Mehergarh, and how it had been applied in the technology of other applications in this particular civilisation. We have come across furnaces, ceramics, glazed pottery and sophisticated firing techniques that are as old as 4500 B.C. But we also find that by 3500 B.C., that is to say, exactly a thousand years later, the quality of products and the 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 from terracotta to metals. This marks 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 to capture the heat near the neck of chimney of large pit-kilns) and copper melting crucibles.

In Mehergarh there is also evidence of manufacturing activity based on metals, such as artefacts, implements, and items of daily use. It is here that we get two recorded evidence of being the *first* site in the world to use the metallurgical technique of *cire perdue*—the lost wax process. Much of our bronze and other casting work in India and in many parts of the world is still done by this 'lost wax' method. In Bengal and in central India the Dhokra artists use this technique where the moulds for metal pots are first made on a cast made of earth and plaster material. The designs and carvings that are visualised are all made on it at this stage on the dummy mould. Then wax is put over the worked-out mould, and then a second layer of earth is put over this wax coating. When finally, hot molten

metal is poured into the entire cast through a hole on the top, it just melts away the wax and takes on the space that lies between the outer and inner moulds, both of which are broken once the metal cools. The metal pot that emerges naturally has all the carvings and other design impressions that the wax layer had. This whole process of metal work is called *cire perdue* in French and adopted in English as the 'lost wax procedure'. It is one of the world's oldest metallurgical techniques, and it means a lot as it was first 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 hand in hand — as is happening even today. In India, we must have learned to live with both science and superstition from this earliest phase of our history.

How Science & Technology Sustained Harappan Civilisation

A vast city-based civilisation like the Harappan (3300 - 1300 BCE) that arose out of the achievements of Mehergarh (7000-2500 BCE) has often astounded historians, archeologists, anthropologists and even scientists. In its heydays, this civilisation had a population of over five million inhabitants, which is an astounding number in those days. Harappan civilisation was actually among the rare ones in the world where scientific techniques were devised as early as 3000 BC to produce intricate hand-crafted carnelian products and seal carvings, in addition to a host of other items of daily use and recreation. Their incidentally, the seals used for trade , decorated with carvings of animals and mythical beings, indicate that Harappan cities conducted thriving trade with lands as far away as Mesopotamia. Indus Valley cities improved upon the technology of metallurgy of Mehergarh and it is clear that they made extensive use of copper, bronze, lead, and tin. These cities are remarkable for their urban planning, baked brick houses, elaborate drainage systems, water supply systems, and clusters of large non-residential buildings — all of which point to the commendable advancements made in so many sciences. The profusion of toys that was found in the cities and the fact that very few weapons of war are evidence that suggests

peace and prosperity. Those who wonder how such a superior urban civilisation as in Harappa suddenly appeared in around 3300 B.C. need to understand that it was *not* sudden at all as its feeder cultures like Mehergarh were already evolving and moving ahead towards this reality for 3,000 years.

Recent studies have proved that in the Harappan civilisation people were not voracious consumers of rice or wheat like most of the people of India. For a civilisation to have one or more towns or cities meant that all those who dwelt away from agriculture would need to be fed by the rural, agricultural communities. So, town-based civilisations would normally come up only after the arrival of iron, because iron-tipped ploughs were capable of generating surplus food that could then feed non-farm, town-centric people. Until the arrival of iron in the first millennium BC, every person had to play a role in agriculture as wooden tipped ploughs barely produced enough to feed only those who lent their hand in farming operations. The question now is: how did a Copper Age civilisation feed townsmen as copper could not be put on to the tip of the plough? To produce agricultural surpluses with Copper-Age technology was surely difficult but the very existence of Mohenjodaro, Harappa, Lothal and other Harappan towns proves that it was possible. This was done by a combination of diet, agronomic practices, skilful use of water, using cattle to move ploughs and by utilising wheel-based and copper-tipped auxiliary agricultural implements. Recent studies prove that the Harappan people consumed dry staples that they had begun to eat at Mehergarh — like barley, oats, jowar, bajra and other crops that grew with minimal doses of water.

The surmise we arrive at from this is that their interaction with the mighty Indus river was limited to transportation and not linked to agriculture. The Indus river was always feared for its floods. By choosing dry-zone crops, they were not at the mercy of the river and clearly preferred 'culturally accepted' food that was conditioned during the neolithic and early chalcolithic existence, in a less-

fertile dry area. 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 civilisation made extensive use of animals and the toy bullock-carts we find these are an exact replica or prototype of our standard Indian one that we have used for so many millennia. It speaks volumes about the management of water, agronomic inputs, copper, brass and stone implements that they made use of in the pre-iron Copper Age to produce reasonable agricultural surpluses to feed those who did not till the land. These were urban-settled classes like craftsmen, traders, dealers, priests, intellectuals, administrators, soldiers and sailors and, of course, the 'other thinking classes' that included scientists and technologists.

The latter were the ones who devised how loads and buildings were to be built and how water was to to flow in and how waste materials were to drain away. Very few of us know that the world's first home toilet, commonly known as the commode, was found here in Harappa. It was designed to flush out human refuse scientifically by using gradient and gravity and we wonder what happened to such advanced toilet facilities and habits in later periods of Indian history — when the culture of defecation degenerated in India. In fact, the ancient Indus systems of sewerage and drainage that were developed and used in cities throughout the region were far more advanced than any found in contemporary urban sites in Egypt and Mesopotamia — and this could only happen when science and technology had reached new heights in that age. We hardly refer to these marvels of engineering — while Europeans simply cannot stop going into raptures about the Roman system of aqueducts, that were constructed three thousand years later in the fully-blossomed 'iron age'. We hardly ever ponder and discuss how major public buildings like town granaries, massive citadels and public baths were to constructed and maintained in an age when implements and techniques had to be improvised from wood, stone, copper and brass — without the benefit of steel. This class made life more easier by factoring in science into the scheme of things and they were surely rewarded by the Harappans — whose civilisation was so

dependent on their towns and in trading activities. The planners, scientists and administrators of Harappan civilisation surely managed to devise perfect systems of food procurement, food management, storage and distribution to survive for two thousand years and more. This is evidenced in the grain storage facilities and the plentiful remains of food that have been found in the houses — which indicates that there was no shortage.

Earliest Instruments to Measure

However, to excel in trade and commodity management one needs measurement and measuring instruments. Archaeologists have found a series of weights in bundles, not just in one place, but in all the Harappan cities. These weights also had a very perfect similarity between each unit which indicates a rare degree of perfection in applied metrology. The first and accurate measurement scale in the whole world has been found in Lothal of the Harappan civilisation. This first 'ruler' with precise demarcation of linear measurement has been found here and it is dated to 2400 B.C. The smallest division, approximately 1.6 mm, was marked on an ivory scale found in Lothal, a prominent Indus Valley city in the modern Indian state of Gujarat. It stands as the smallest division ever recorded on a Bronze Age scale. In his book, *The Measure of All Things : The Story of Man and Measurement* published in 2007, Ian Whitelaw, 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 that they had a 'master ruler' on the basis of which they could calibrate and compare these markings. Ancient bricks found throughout the region were absolutely uniform in size — which, again, proves the progress of science and technology some five thousand years ago — and their dimensions corresponded exactly to these units of measurement. In fact, it is very interesting that these units match the indigenous Indian unit called *angulam*. This measure is found not only

in Harappa and Mohenjo-Daro — it continued throughout the history of India in our 'native architecture' all the way up to the Islamic period. The *angulam* as a measure in Indian architecture ended only when the British systems of measurements were thrust on us.

The Vedic Age & Problem of Material Civilisation

The next historical stage that we will discuss is usually called the Vedic Age that was dominated by the so-called Aryans who spoke Sanskrit and composed the *Rig Veda.* It is dated from 1500 B.C. to around 600 B.C. and our problem here is to locate the contribution of science and technology. The literary text, the Rig Veda, is surely a superb literary composition though it hardly follows any clear linear path, but it hardly describes the material side of this civilisation. It was composed by a very literate class, possibly for an enlightened group but to consider it as the definitive text that dominated the life of all Indians during the period of nine hundred years of its purported 'sway' is difficult to digest. This would require a lot more of historical and scientific proof than we have at present. It did not, for instance, endear itself to the people of India beyond the Punjab region, where the Rig Vedic Aryans were located then. What this means is that most people living in the subcontinent of India neither understood it or really cared about it — but Indian history is fixated on this narrative. As hinted, we are not even sure how many among the cattle-rearing group of so-called Aryans were really capable of understanding a complex oral text or really interested in esoteric philosophy. Besides, what was its corresponding material civilisation and its state of scientific knowledge?

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 we attribute the entire historical stage of the whole of the subcontinent to one text or the way of life or world

views of one superior minority as the civilisation of all of India at that time? There are proofs of the existence of several other contemporary civilisations in India many of which were technologically more advanced. These are issues that standard histories do not like to touch as it destabilises the comfortable existing narrative. But there are people like us who just have to raise these disturbing questions. Besides, were the Aryans really invincible? If we take their own evidence stated in the Puranas, we come across stories of how the *Rakshasas* and *Daityas* frequently captured Indraloka (the abode of Indra and the gods), and how they drove away the *Aryaputras.* The mighty Aryans had then to seek the intervention of some superior force — a super god or great goddess. The Puranas also mention of mythical sages like Shukràchàrya, who were the gurus of the anti-Aryan forces and were masters or technology. Sanskrit texts frequently mention that *Rakshasas* often had weapons and powers that were definitely superior to the ones that the Aryans possessed. These are just apocryphal references to the constant wars between the indigenous people of India who were hopelessly fragmented into small tribes and the better-organised invaders who had iron to slash their defences and the horse to ride over them.

While there is no doubt about the superiority of the Sanskrit language and the philosophy that is embedded in the Rig Veda, there are strong doubts about the contribution of the Aryans to the material civilisation of India. In fact, we note a perceptible movement backwards, — from the highly urban civilisation of the Harappans to the rural-pastoral culture of the Aryans. We find it strange that there is no archeological stage in the history of India that is branded as 'Aryan' or 'Vedic', even though before and after this phase we get other archeological phases like the Harappan, Mauryan, Kushàna or Sunga that are denoted by the ruling class. The Harappans or Mauryas left their indelible stamps on their material civilisations, through their contribution to art, architecture, pottery, crafts, techniques, colours and many other aspects. We do not get any

such or corresponding items that are known to be representing the culture of the Vedic people or the Aryans. We have no Aryan style of art, sculpture or architecture. The main problem with historians and ideologues is that they do not want to come to terms with our real history and declare that there is really very little by way of a material civilisation left behind by the Aryans — because it militates against what they have been taught. We hardly ever raise the issue of degradation in terms of material culture and of science and technology during the Vedic period. We are so dazzled by just one bright text of a small minority that we fail to notice how we moved downwards from a superior world of international commerce of the Harappan phase to we reach a phase when cattle and cow-sheds become the centre of life, and the most important source of wealth. In fact, an entire genealogy is based on cattle or *gotra*, meaning 'from the same cowshed'.

Pottery During That Period

However, archaeologists have categorised two types of pottery found in regions inhabited by the Aryans as BRW and PGW, or Black and Red Ware and Printed Grey Ware, though they do not directly attribute it to the Aryans. The first, namely the BRW pottery represents the early Iron Age culture of North India, dated roughly between the 12th and the 9th centuries BC, which overlaps with the Vedic period, ie three to four hundred years after the Aryans appeared in Indian history — when we note how a pastoral civilisation was trying to learn some agriculture as well. When we can admire this 'journey' from the cow to the plough, we are actually referring to the second agricultural economy when farming started occupying the centre-stage once again, some four millennia after the story of Indian agriculture began in Mehergarh. These are the fascinating ups and downs of history where we witness how its forward and backward movements take place among people in the same broad geographical area.

The second type of pottery of this period is known as the PGW (Printed Grey Ware) and it began around the same time, in 12th century. But it appeared in full bloom only after the Aryans and their mixed groups had presumably 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 also to the frequent use of iron. In fact, the Aryan victories which ultimately took place was not due to a superior language or not even because they surely had a more organised system of thinking and culture. It was largely because of the use of iron and the horse that simply over-powered the indigenous stone-age or copper-age civilisations of India. It was something similar to the hegemony of the white Americans over the Inca, Aztec and other native civilisations that were inferior in terms of warfare and fire-power. The 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.

We must remember that the Gangetic plains were thickly forested and full of rivers and swamps till the middle of the first millennium BC. Historians generally believe that it was during the mature stage of the Iron Age that iron and fire were used to slash and burn through these forests and clear the Ganga-Yamuna region. Romila Thapar calls this slash-and-burn philosophy, when the Aryans moved in from the terai that was less inhabited and then moved downwards. They went along the river, killing or capturing people and animals who inhabited the river and swamp areas. Coming to technology, we must admit that no Copper Age civilisation could have captured the Gangetic belt that was heavily forested. So we had to wait for the arrival of iron which started in 1000 B.C. and reached maturity around 600 B.C. Without iron and without the new lands and people of the Ganga basin that were brought under ‘Aryandom’, there would have been no true Indian civilisation. When I was in Delhi I was fond of

saying that India does not begin from either the Khyber Pass or the Bolan Pass or even from the Indus and Punjab. India begins after we cross the Nizamuddin bridge over the Yamuna and enter the Gangetic plains. That is where the crucible of Indian thought and philosophy was developed and from where it spread. The *Janapadas* or kingdoms that came up in the Gangetic plains dominated the landscape with iron swords and iron weapons. They were actually the result of scientific and metallurgical advancements — when Iron Age Aryans on horseback subjugated the primarily Copper Age culture of the indigenous Indians. It were the defeated indigenous Indians who were called *dànavas, ràkshasas, pishàcas, dàsas* and so on. Genetic sciences have proved that most Indians have predominantly the blood of the defeated people, with just a dash of so-called 'Aryan' genes — which is irrespective of which caste we refer to.

Iron Age Impacts Agriculture & Society

We had briefly touched upon agriculture in the Copper Age earlier but when the metallurgy of the Iron Age introduced iron-tipped ploughs and implements, agriculture went through a quantum leap. Not only was it possible cultivate more areas and tougher soils with lesser effort, it was also possible to free large parts of the population from agriculture. The greater surpluses that iron ploughs produced could now feed the townsman and the craftsman as well as the ruling class which dominated all others with soldiers with iron swords, spears, bows and arrows, besides horsemen, policemen and bureaucrats. This ushered in the arrival of monarchical domination through kingdoms and *janapadas* and led to the rapid breakdown of typical tribal democracy that Aryan cultures had practiced for so many centuries. This is also the period when we get the stories of tensions developing between the two. When we study mythology we see the same tensions between the free people who lived in the hills, and the new *ràjàs* who lived in the plains. *Daksha-Yagna* is a very typical such story where we come across the tension between a free man of the hills represented

by Shiva taking on the might of several Gangetic monarchies and combative *ràjàs* who possessed superior arms. In fact, both Buddha and Mahavira were born in hill republics and preached its greater egalitarian spirit among the hierarchical population of the plains kingdoms.

That reminds us that iron-tipped ploughs freed large parts of the population from the boredom of agriculture and led to speculation. In other words, the same agricultural surplus produced in the Iron Age also fed the speculators of thoughts and ideas, called the philosophers. We find that it was in and around the sixth century when the use of iron reached a certain maturity, the world got all its philosophers — Lao Tse, Confucius, Gautam Buddha, Ahura Mazda, Abraham, and Mahàvira. History that we are usually taught in educational institutions does not give adequate emphasis on such linkages and tell us how scientific developments changed the very faith of people at periodic intervals. We just have to look beyond the *Ràjàs, Rishis, Munis, Aryans, Danavas* and their wars and conquests to go to the root technology that made it all possible.

Technology of Zinc, Brass & Steel

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 for several centuries and it was one such ruler who had helped Swami Vivekananda attend the World Parliament of

Religions in Chicago in 1893. Zawar is famous not only for its monopoly of excellent zinc ore, it is also considered to be the oldest site of industrial zinc production of the whole world. During the process, zinc ore was roasted in smaller-sized retorts which prevented the production of typical slag, which made extraction more efficient and economic. These are some examples of the indigenous processes that developed in India at that point of time.

Good quality brass alloys require more than 28 percent zinc in them but in most parts of the ancient world we come across brass or other alloys with less than twenty-eight per cent of zinc. In India, however, we come across better quality brass and the one we come across in Takshashilà, dated around third century B.C contains as high as 34.34 per cent of zinc — which is far more superior brass. Recently, two brass bangles belonging to the Kushàna period have been discovered in Uttar Pradesh which revealed thirty-five per cent zinc of exceptional quality. 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 and we come across references to zinc oxide use in those prescribed in the *Charaka Samhità*. So the mastery of zinc was another factor in our favour but how much of it came to good use in warfare remains questionable.

In the South, we get solid evidence of the earliest production of high carbon steel in the whole of the Indian sub-continent. These sites were at Kodumanal in Tamil Nadu, at Golconda in Telangana and nearby north-eastern Karnataka, and in northern Sri Lanka. This came to be known as Ooty steel of South India and by the 6th century B.C. it exported globally. But the fact that Tamil Sangam poetry mentions that the South had knowledge of exceptional steel technology long before the fourth century BC could not prevent it from being defeated by the Mauryas. This is being underlined to also explain that history is not always decided by scientific and technological advances. We come across references in Arabic and Latin literature to the people of

South Indian people as the finest steel-makers in the world. This steel was exported to the Romans and the Arabs called it Damascus steel. We need to cross 1000 degree Centigrade temperature while heating iron and alloys to get steel — which was very difficult with the quality of coal that was available and the design of furnaces. Therefore, bellows were used to raise temperature and the bigger the bellow and smaller the furnace, the higher would be the temperature. In the fifth century, we find the Chinese and local Sri Lankans had mastered the art. Incidentally, Sri Lankans used the monsoon winds and their steel furnaces were driven by very high wind speeds during the monsoon period.

Strength of Mauryas Lay in Iron & Coal

Now we come to the last part of our discussion where we try to explain why Pataliputra, the modern-day Patna, could dominate India in the 4th century BC and bring almost all of it under the first pan-Indian empire of the Mauryas. DD Kosambi has explained that the eastward thrust of Indian civilisation was successful because it could access the best ores and good quality of coal. In very simplistic terms, it was the Mauryan control of two critical resources, iron ore and coal, that made it possible for it to forge superior steel weapons and implements — with which it dominated the sub continent. As we know, almost all the best coal reserves in India are in the Manbhum-Singhbhum-Raniganj areas, and all the steel plants that came up in India initially (except Salem) are in this area— Bokaro, Bhilai Rourkela, Asansol, Kulti, Durgapur. Why? Because we have both coal and iron ore. It is due to the same mastery over coal and iron that helped Pataliputra under the Mauryas to become so strong and invincible. But, as touched upon, a major power required not only the best of resources and scientific achievements — it also needed organisation and leadership. Chandragupta Maurya had the benefit of the intelligence of Chanakya, who could capitalise on the technology of mining and steel-making.

It is said that Chanakya actually came from Kànchipuram in Tamil country, who travelled all the way to Takshashilà in the extreme North West to study and teach and then moved to Pataliputra in the East for his career. His text, the *Arthashàstra*, laid down the basis of the first great empire in India. Its twelfth chapter deals extensively with mines and metallurgy. He declares that the Superintendents of metallurgy had to be proficient in geometry, geology, metallurgy and smelting of gems as well. One of the tasks of the Mines department was to locate new mines with ore-bearing earth, rocks and liquids, which proves beyond doubt that not only had Chanakya exceptional knowledge of mining and metallurgy but also that the Mauryan empire was making good use of science and technology.

In his new book called *Arthashàstra : The Science of Wealth*, Thomas Trautmann explains how scientific discoveries and technologies were used to strengthen the kingdom. He states that 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 *Arthashàstra* 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 centralisation in the style of the erstwhile Soviet state. The Mauryas exploited their advantages and reached a stage when 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 and Ashoka just had to go there because he had to get his supplies.

In Conclusion

We have gone over a fairly long talk and what irks me the most in history is that it is so firmly rooted in agreed narratives and approved texts. Conventional history focuses on what is proved beyond doubt and is thus acceptable as material

for standard textbooks and reference books. They hardly link the text to the context and are tied down to hard records and evidence, thereby often limiting their perspective. Since I am not a teacher of history, just a perennially curious student, i have the liberty of staying away from safe histories. Instead I have always been impressed with D. D. Kosambi's approach to studying history, which gives as much importance to the context as it does to the text. He has left behind a wealth of information on the material view of history and has also been bold enough to deal with popular beliefs, myths, legends and superstitions. He was one who was not content to just narrate the history of the the eastward surge of the Aryans in terms of dates and events, but explained it in terms of the necessity to access India's finest natural ore deposits that lay in the east Gangetic plains. The east became the centre of two of the greatest empires of India, the Mauryas and the Guptas, because it had excellent copper, iron and coal. We need to take a look at history from such points of views. I will refer to a statement made by Dr Kosambi where he remarked that Magadha's great source of power was not only in its resources but also in the formation of a state. He called it "a state that used metals systematically to clear the land and to bring it under the plough. It was also iron that allowed it to dominate the rest of India."

I wish to point out that the way we are taught history in schools and colleges needs to be changed to make it more interesting. We need to understand not only what has actually happened which, of course, has to be factually correct, but what were the reasons that made them happen. Because the inquisitive minds of students at that stage would like to know why is it that 'X' happened and why 'Y' won over 'Z', not just the fact that 'Y' won over 'Z' in such-and-such battle in so-and-so year. Historians have a wealth of knowledge at their disposal and can surely connect the dots. They are capable of the "big, grand, narrative", the "panoramic view from above" but professional compulsions drive them to swim near the shallow banks of rivers and not be too adventurous

in stating what they believe could well have happened but they are unable to lay their hands on hard evidence. We may or may not accept that economics necessarily determines human history, but none can deny that developments in material civilisation, which arises from consciousness of resources and their harnessing through advancements in science and technology do dominate society and its values. We need to see the science that lies hidden behind history.