THE CONUNDRUM OF ANCIENT INDIAN CIVILIZATION
Part 1 – The Indus Valley Civilization

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(The following is the first part of a 3-part article on Ancient Indian Civilization. The other two parts will come in the forthcoming issues of Breakthrough)

The Indian subcontinent is an abode of ancient civilization. Till the early decades of the twentieth century the ancient Indian civilization was equated with the Vedic Civilization. Archeological excavations in the alluvial plains of the Indus river system in the 1920s brought into light a different type of civilization, an urban civilization. Later many more sites were found in the Indus basin, and eventually the Indus Valley Civilization (IVC) came to be recognized as being earlier than the Vedic Civilization (VC). However a minority section of scholars believes the Vedic Civilization to be older. A great enigma in the Indian history is the relation between the Indus Valley Civilization (IVC) and the Vedic Civilization (VC). In recent years this controversy has acquired political overtones, and discussions and exchanges have become emotional and stridently combative. A related issue is which of the existing rivers of northwest India is to be identified as the ancient Saraswati River that occupies a prominent position in the Rigvedic hymns. We shall try to discuss the issues from a scientific point of view, sifting through the facts about the two civilizations and evaluating the different lines of evidence. However, a major handicap in resolving the controversy is the total absence of any archeological remains of the VC, while there is rich archeological material from the IVC.

Paleoanthropologists generally agree that anatomically modern man, Homo sapiens, first arrived in the Indian subcontinent 80,000 to 55,000 years ago, though the earliest fossil of modern man (in Sri Lanka) is only 34,000 years old (Petraglia and Allchin, 2007). This is what is called the first migration (Joseph, 2018). Archeological evidence (stone tools) at Dhaba in the upper Son river valley in central India suggests that Homo sapiens lived in this region between 80,000 and 65,000 years ago (Clarkson et al., 2020). Still older Middle Paleolithic tools surrounded by sediments 172,000 years old are found at Attirampakkam in Tamil Nadu (Pappu et al., 2003), but it is not known whether the tools were made by modern humans or archaic humans. It is thought that modern humans lived in India prior to the well known Toba super-eruption[1] (75,000

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[1]Lake Toba, a crater lake in Sumatra, was the site of one of the Earth's largest known explosive eruptions nearly 75,000 years ago. The erupted mass has been estimated to have a bulk volume of nearly 13,200 km^3 and an ash layer of 15 cm thickness covered the whole of South Asia, and a blanket of volcanic ash

years ago) and they lived through the super-eruption and the induced climate change (volcanic winter). The ancestors of the Andamanese population most probably represent the earliest modern humans who peopled India. The present day Indians, irrespective of their caste, social status, religion or language genetically carry 50%-65% of their ancestry from the first migrants to India.

The earliest Homo sapiens were foraging hunter-gathers organized in small bands. Transition from this stage to settled life with farming and pastoralism started in the Indian subcontinent before 7000 BCE (Before Common Era). At Mehrgarh, Balochistan, in Pakistan, there is evidence of a settled agricultural society at about 7000 BCE (Jarrige, 2008); they harvested crops of barley and some wheat and domesticated goat, sheep and cattle. Settlements of similar age have also been discovered at several excavated sites in the Indus river basin, e.g. at Bhirrana in Gujarat.

It is not certain whether farming and animal domestication developed in the Indus Valley independently or was brought by migration from West Asia, where agriculture was invented at around 10000 BCE. Genetic evidence, to be discussed later, is consistent with the hypothesis that Western Asian agricultural technology or ideas moved into South Asia through adoption of ideas from neighbours. As will be discussed later the genetic data suggest that ancient Iranian population has contributed significantly to the ancestry of the IVC population suggesting migration from the Zagros region of Iran towards India. This is the second major migration to the Indian subcontinent (Joseph, 2018). Of course it does not necessarily follow that the practice of agriculture also came along with the migrants; it might have developed indigenously. Some genetic data are significant in this context. Agriculture developed in the Fertile Crescent 7000-10000 years ago. A Y-chromosomal signature, haplogroup[2] J, is associated with people who developed agriculture. This signature has its highest frequency in the Fertile Crescent region. Majumdar (2018) mentioned that detailed examination has revealed that the J haplogroup is composed of at least four sub-signatures of which the sub-signature haplogroup J2b2 is confined to the India-Pakistan region. It arose 13000 years ago and hence its introduction into India could not have been by migrants who brought agriculture with them. There is of course some uncertainty in the age estimate because of the different estimates of the frequency of mutations (so-called molecular clock). This haplogroup probably arose in India as suggested by the highest frequency of the J2b2 in India. Multiple epicenters of the haplogroup have been discovered in India which nearly coincided with the centres of introduction of agriculture in India. Majumdar (2018) has interpreted that the haplogroup J probably arose in an ancestral population which spread into geographically separated regions and they invented rudimentary forms of agriculture independently in multiple geographical regions. This early form of agriculture was confined to India-Pakistan region.

An alternative migration hypothesis was proposed by Stephen Oppenheimer in

was deposited over the Indian Ocean, the Arabian Sea and the South China Sea. It caused a drop of 3°–5°C in global mean surface temperature and the ensuing global volcanic winter lasted for 6-10 years.

[2]A haplogroup is a genetic population group who share a common ancestor on the paternal or maternal side. A haplogroup denotes a a group of people that have a common set of mutations and pertains to a single line of descent. Top level haplogroups are designated by letters of alphabet. Deeper refinements are designated by adding additional number and letter combinations. Each one of the letters basically denotes a mutation in the DNA that happened at a particular time and space.

Figure 1: Important IVC sites

1998. According to his idea, approximately 60,000-75,000 years ago a small group of modern humans numbering no more than a few hundred individuals migrated from the Horn of Africa across the Red Sea to Yemen and then through India onward to Southeast Asia and Australasia.

The climate was getting cooler and the sea-level was getting lower. At the time of the last glacial maximum at ca. 20,000 years ago the sea-level was the lowest, about 130 meters below the present day sea-level. The migration to Southeast Asia and Australasia was facilitated by the lowering of the sea-level. After that the temperature started to rise, at first rapidly, and the ice-caps began melting; the sea-level started to rise and large areas in Sundaland[3] were inundated. The people migrated from the submerged areas and moved westwards to Eurasia. However, the recent genetic evidence from the IVC does not corroborate this interpretation.

In the Indus Valley region settlements ranging in age from 6300 BCE to 4300 BCE have been found at several localities, e.g., Bhirrana, Mithathal, Kalibangan and Rakhigarhi (Kenoyer, 1998, Possehl, 2002). By 4500 BCE settled life had spread more

[3]Sundaland is a landmass in Southeast Asia which was exposed throughout the last 2 million years when the sea-level was lower. It encompasses Borneo, Java, Sumatra, Malay Peninsula and the surrounding small islands and includes the Java Sea, the Gulf of Thailand and parts of the South China Sea.

widely, and began to gradually evolve into what is called the Indus Valley Civilization (IVC), also known as the Indus Civilization (IC) and the Harappan civilization (HC). It is one of the world's three earliest civilizations, the other two being the Sumerian and the Egyptian civilizations, and it is the most extensive geographically. Nearly 1400 settlements belonging to the IVC civilization are found in a wide area of the alluvial plains of the Indus and its tributaries (Figure 1). Over 600 sites have been located along the Ghaggar-Hakra channel, and about 100 sites in the Indus valley. Excavations at several IVC sites show evidence of settlements at different levels, indicating that humans occupied the sites several times over a long temporal range (op. cit.).

The IVC reached its peak between 2,500 BCE and 1900 BCE (Mature Harappan Phase). The Indus Valley people were agrarian, but developed large, architecturally complex urban centers and a sophisticated material culture[4] coupled with a robust trade system (Possehl, 2002). In early second millennium BCE the civilization started to decline and the population scattered from the large urban centres to villages. At about the same time the Vedic civilization (VC) started in the Greater Punjab area (Thapar, 2004).

INDUS VALLEY CIVILIZATION (IVC)

The IVC is a Bronze Age civilization and the archeological objects were first reported in the later half of the 19th century, though systematic excavations started only in the 1920s at Mahenjodaro and Harappa, both now in Pakistan. Later work has brought to light many sites in India, like Lothal, Dholavirah, Bhirrana, Kalibangan, Rakhigarhi etc. and Mehrgarh and several other sites in Pakistan. The civilization flourished in a large area covering the whole of the Indus River Basin and there is a high concentration of settlements along the Ghaggar-Hakra valley in western India and Pakistan (Cholistan).

IVC Chronology

Archeologically several successive cultural phases are recognized in the different excavated sites. This, combined with the radiocarbon (^{14}C) and optically-stimulated luminescence (OSL) dating, has helped us to build a chronology of the IVC. Various estimates have been given for the time of the IVC depending upon the different age determinations. The conventionally accepted chronology of the different phases of the IVC and also the chronology based on recent OSL dating from excavations at Bhirrana are given in Table 1. At Dholavira a finely tuned chronology along with radiocarbon dating has been worked out as given in Table 2 (Sengupta et al., 2019).

It may be noted that the dating from Bhirrana has pushed back the different phases to dates earlier than previously estimated. Isotopic and archaeological data indicate that the Pre-IVC or Pre-Harappan (>3250 BCE) people started inhabiting the area particularly along the then mighty Ghaggar-Hakra river fed by intensified monsoon. The civilization flourished for more than 2000 years.

IVC Society and Culture

The post-Neolithic Pre-Harappan (Hakra Ware) and Early Harappan Phases were marked by beginnings of village farming communities followed by establishment of developed farming and pastoral communities (Wikipedia 1). Numerous crops like barley, wheat, peas, mustard, sesame,

[4]Material culture has been defined as the aspect of social reality grounded in the objects and architecture that surround people (Wikipedia)

Table 1: Different models of chronological Succession in IVC

BHIRRANA CHRONOLOGY Sarkar 2016		CONVENTIONAL CHRONOLOGY Kenoyer 1998		ARCHEOLOGICAL SUCCESSION	ERA Shaffer 1992
Date (BCE)	Phase	Date (BCE)	Phase	Archeological Phase	Era
800 to 1600	? Post-Harappan		Post-Harappan	Painted Grey Ware	Iron Age
1600 to 1800	Late Harappan	1300 to 1900	Late Harappan	Black and Red Ware Ochre coloured pottery	Localization Era
1800 to 3000	Mature Harappan	1900 to 2600	Mature Harappan		Integration Era
3000 to 4500	Early Mature Harappan	2600 to 2800	Transition	Kot Diji	
4500 to 6000	Early Harappan	2800 to 3700	Early Harappan	Ravi	Regionalization Era (Bronze Age)
6000 to 7500	Pre-Harappan	3700 to 7000	Pre-Harappan	Hakra Ware	Early Food Producing Era (Neolithic)

Table 2: Chronological succession at Dholavira

Dholavira Cultural Stage	Radiocarbon Date (BCE; 2σ range)	Harappan Phase
VII	<1877	Late to Post-urban(?) Harappan
Temporary Desertion and Hiatus		
Vi	2185 – 1877	Early Late Harappan to Late Mature Harappan
V	2207 – 2030	Late Mature Harappan
IV	2890 – 1969	Late Mature Harappan to Late Early Harappan
III	2675 – 2635	Transitional Phase Early Mature Harappan to Late Early Harappan
II	3008 – 2382	Transitional Phase Mature Harappan to Early Harappan
I	3541 – 3008	Early Harappan to Pre-Harappan

cotton were domesticated. The IVC people also domesticated dogs, cats, cattle, fowl and probably also buffalo, pigs, camels, and Asian elephants. By about 3000 BCE the IVC farmers succeeded in breeding the winter crops of wheat, barley and pulses to adapt to rainfall patterns. At about the same time they began to harvest summer monsoon rainfall crops of millet, rice and beans (Kenoyer, 1998, Possehl, 2002); rice perhaps arrived from Chinese lands.

After the Pre-Harappan period, the settlements expanded rapidly and the end of the Early Harappan Phase is marked by increasing urbanization with people migrating from villages to cities. The IVC in its heyday (Mature Harappan Phase, 2650-1950 BCE) was an urban culture sustained by surplus agricultural production and commerce. The Mature Harappan people built great cities like Mahenjodaro, Harappa, Dholavira, Ganeriwala (Cholistan), Kalibangan, Rakhigarhi, to name a few. More than 1000 cities and settlements have been found mainly in the region of the Indus and Ghaggar-Hakra Rivers and their tributaries (Figure 1). The large cities of Mahenjodaro and Harappa are estimated to have population of 30000-60000 and the total population of the IVC has been

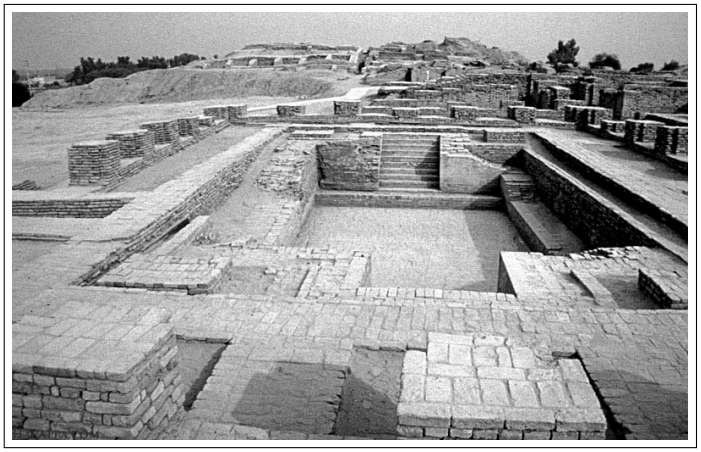

Figure 2: Great Bath at Mahenjodaro

estimated to be 1-5 million (Possehl, 2002, Wikipedia 1). The cities had sophisticated urban layout and planning with flat-roofed baked brick houses, huge community baths, elaborate drainage systems, large and small roads, and differentiated living quarters. Dholavira had a castle for an important person, while the middle town probably housed rich merchants and generals, and the lower town was for the common people (Sengupta, 2019). This points to a certain degree of social stratification. They had community baths (Figure 2) and big structures for grain storage.

The civilization was quite advanced in civil engineering, town planning and architecture. Individual houses had bathing areas and toilets connected to a sewerage system. The sewerage and drainage systems in the Indus Valley cities were more advanced than any found in the then urban sites in other regions of the world. There were terra-cota and bead making workshops and also graves. Dholavira had an amphitheater-like ground with seating for spectators all around which might have been used for cart-racing, community dancing, large bazaars etc. Mahenjodaro had no less than 700 wells for fresh water, and there is evidence that they irrigated their agricultural fields. They had to contend with the annual floods of the big rivers which simultaneously nourished the fields and destroyed crops and habitation. The cities had massive protective walls. An efficient water harvesting and management system with interconnected large reservoirs at different topographic levels has been unearthed at Dholavira (Sengupta, 2019); this was an efficient system of water harvesting and helped the inhabitants to survive in an otherwise arid region.

The Indus Valley people had developed accurate standards to measure length and weight. All the bricks irrespective of size had their dimensions in the ratio of 4:2:1. They designed a ruler that was divided into 10 equal parts. Their town planning indicates that they had some knowledge of geometry (squares, rectangles and rectangular parallelepipeds). They developed new techniques in handicrafts and mastered the metallurgical techniques to produce copper, bronze, lead and tin. They crafted beautiful objects and beads of shell, stone, semi-precious stones, terracotta, bronze and

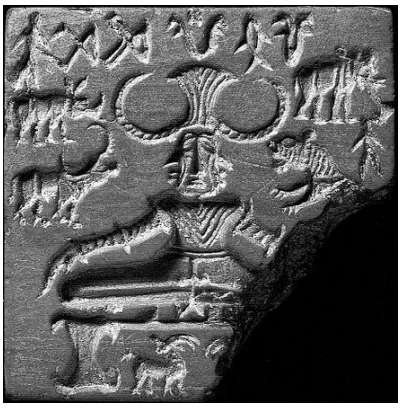

Figure 3: Pashupati Seal from Mahenjodaro, 2350-2000 BCE

gold. They produced bronze statuettes, copper and bronze vessels, tools and implements, like axe, arrowhead, knife, small saw etc., small chariots and carts, steatite carvings, terracotta figurines, toys and painted potteries; fragments of cotton textiles have been recovered. Numerous seals have been recovered and they show humpless 'unicorn' (bull), humped bull, different mythical figures and animals like elephant, bison, rhinoceros, and tiger. They were probably used for personal identification in trade. A famous seal is the 'Pashupati Seal' (Figure 3) depicting a possibly tricephalic figure seated with a Yogic posture and a horned head-dress; it is surrounded by figures of wild animals (elephant, tiger, water buffalo and rhinoceros). The figure is controversially interpreted as a male deity and early prototype of god Shiva.

IVC had a remarkably uniform level of material culture suggesting a closely knit internal administration and extensive internal trade within the state. There was flourishing Trans-Asiatic, probably maritime, trade with regions as distant as Arabia, coastal Persia, Mesopotamia and Central Asia (Possehl, 2002). They had established merchant colonies in foreign countries as attested by discovery of Indus seals in Arabia and Mesopotamia. There is ample indication that they obtained raw materials like copper, gold, lead, precious and semiprecious stones from regions adjacent to the Indus culture area. They used wheeled carts for transportation as also boats. A dock has been excavated in the coastal city of Lothal suggesting sea-faring activity. An important point is the absence of clear evidence of modern horse (Equus caballus) at the IVC sites, nor are their remains of spoke-wheeled vehicles, although there are clay figurines of solid-wheeled carts pulled by cattle. Spoked-wheel horse-drawn chariots appeared in the Eurasian steppes at about 2000 BCE, that is at the end of the Mature Harappan period. A rare find of a fossil at the Late Harappan excavation at Surkotada in Gujarat has tentatively been identified as domestic horse Equus ferus caballus (Wikipedia 2), though some contest this identification. In any way, it is indisputable that horse was not an essential or important item in the IVC.

One remarkable feature of the IVC is the absence of large palaces or temples or monuments. This probably suggests the absence of monarchy and organized religion. However, the social and political structures remain objects of conjecture. It is not known whether the entire region was organized as a single state (empire), or whether there were individual city-states with collective administration. Construction of cities in a highly uniform and well-defined grid pattern suggests planning by a central authority. Slave system existed in the contemporary civilizations like the Egyptian civilization and Sumerian civilization, but there is no evidence to indicate that slave system existed in the Indus Valley Civilization. Differentiated living quarters in some Indus Valley cities suggest that a social stratification existed, but the

general town plan gives the impression of a relatively egalitarian society with low concentration of wealth (Green, 2021). There is no archeological evidence of destruction, pillage or carnage through wars.

The civilization had a pictographic writing system observed in seals (Figure 4, top); Dholavira had a signboard with ten characters in IVC script above one of the city gates (Figure 4, bottom). Unfortunately the Indus Valley script has not yet been deciphered. The question remains whether the writing system developed indigenously or whether it was influenced by the Sumerian civilization. The earliest potters' marks found in Harappa are from 4500 BCE, and by 3300 BCE clearer writings emerged, more or less at the same time as the proto-cuneiform script in Mesopotamia and hieroglyphic script in Egypt. Fully developed script was in use during 2600-1900 BCE (Kenoyer, 2020) The widespread occurrence of inscriptions in IVC script indicates the use of a single lingua franca. The writing is believed to be from right to left. The Indus script remained in use till about 1850 BCE, possibly till slightly later in some pockets. The lineage of the Harappan language is unknown. Recent analysis of the order of signs in the inscriptions has led several scholars to conclude that the language is not of the Indo-European family, nor is it close to the Sumerian, Hurrian or Elamite languages. It has been speculated that it may have affinity with the early Dravidian (Mahadevan, 1998) or Proto-Munda language. But so far no confirmatory evidence is forthcoming.

The end of the Mature Harappan phase and the beginning of the Late Harappan phase at ca.1900 BCE was marked by extensive deurbanization, abandonment of many established settlements, decrease in population, lack of basic amenities, interpersonal violence, disappearance of the

Figure 4: Top: IVC script on a seal. Bottom: Dholavira signpost above a gate.

cubical stone weights and disappearance of the IVC script and the IVC seals with animal motifs (Sarkar, et al., 2016). In the Late Harappan period (1900-1700 BCE) there was a proliferation of small village-type settlements, especially in the Ghaggar-Hakra interfluve. At Dholavira, the excavations suggest that from the mid-Mature Harappan period (ca. 2550 BCE) the settlement expansion slowed down or even ceased till ca. 2350 BCE. Between ca. 2350 BCE and ca 2050 BCE there was an abrupt decline and near collapse of the settlement; urban decline is manifested by the degeneration of architecture, craftsmanship, material culture and deteriorating hydrological condition. In Mahenjodaro the end was sudden, but the city was already in an advanced stage of economic and social decline. Different dates for the decline of IVC have been suggested by different authors; these range from 2350 BCE to 1750 BCE. It is certain that most of the major urban sites, like Mahenjodaro, Harappa, Kalibangan, etc., were abandoned by about 1700 BCE; afterwards the IVC became a largely rural society.

Genetic Profile of the IVC People

Recent technological advances has permitted the retrieval of ancient DNA from skeletons many thousands of years old, and using modern techniques the whole genome sequence in ancient DNA can be

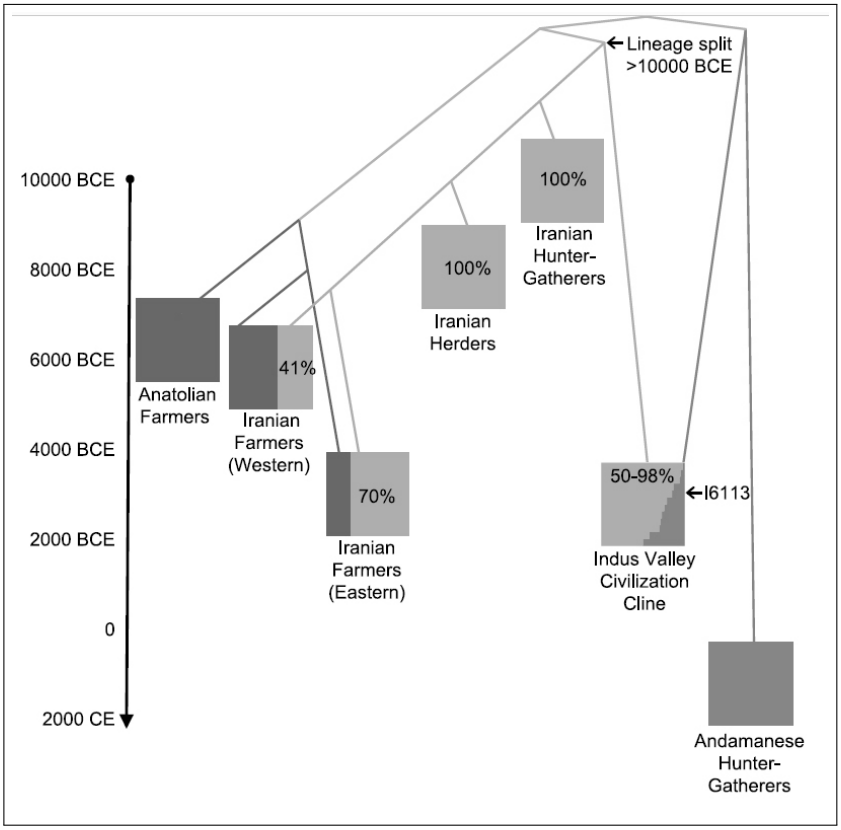

Figure 5: Genetic make-up of the IVC population (Shinde et al., 2019)

determined relatively rapidly and less expensively. A basic principle of population genetics studies is that the different population groups which descended from a common ancestral group are genetically more similar than the groups descended from different ancestors (Reich, 2018). It is however to be noted that if two populations having two different ancestors admix significantly they may appear to have arisen from the same common ancestors because similar genetic characteristics would be shared by them. Hence great caution must be exercised in interpreting genetic data and all aspects of the populations must be considered to arrive at a robust conclusion. Modern population genetics uses statistical methods and simulations to study the small differences in the DNA sequences of unrelated groups of individuals and attempts to decipher the ancestry of a particular population group. An important finding of modern population genetics is that almost all the existing population groups in the world are the result of mixing between prehistoric/historic migrant groups. Statistical methods have been developed to estimate the relative proportion of different ancestral components in a particular population group (Reich 2018, Majumdar, 2018). If an ancestral population with a specific genetic signature gives rise to populations which migrate from the original location of the ancestor, then the frequency

of that signature would diminish away from the ancestral location where the signature arose. By studying the frequency of mutations it is also possible to estimate how far back in time the descendant had splitted from the ancestor.

The DNA profile of an IVC woman dated to 2800-2300 BCE (Mature Phase of IVC) at Rakhigarhi fits a mixture of Iranian-related ancestry (50-98%) and Southeast Asian hunter gathers (Andamanese Hunter Gatherers, AHG), suggesting Pre-Harappan migration of Iranian population and admixture with native population (Shinde et al., 2019) (Figure 5). This is the period of the second migration to the Indian subcontinent mentioned earlier. What is important is that there is no indication of any steppe pastoralist admixture, and no detectable ancestry from Anatolian and Iranian farmers. The Iranian-related ancestry present in the Indus Valley people were hunter-gatherers and split from the Iranian plateau lineages before 10000 BCE, before crop farming began there around 7000–6000 BCE. This would suggest that farming in the Indian subcontinent was either introduced through cultural diffusion or arose from local foragers rather than from large scale migration of farmers from the West. Admittedly more data are necessary to arrive at a firm conclusion about the genetic make-up of the IVC people. Another line of indirect evidence supporting this contention is described below.

Narasimhan et al (2019) described that from the ancient DNA studies of graves at Bronze Age sites in Turkmenistan and eastern Iran 11 individuals of South Asian descent have been identified. These are presumed to be of Mature Harappan origin (Narasimhan et al., 2019) because these are buried in sites with cultural connections to the IVC. These 11 samples are identified as genetic outliers with respect to other individuals from the same sites. They harbour hiigh proportion (11%-50%) of AHG (Andamanese Hunter Gatherers)-related ancestry which the other individuals from the locality lack, and the remainder (50%-89%) is a mixture of Iranian farmer- and WSHG (West Siberian Hunter Gatherer)-related ancestry. Because of their genetic and cultural affinity to South Asia and their outlier status at their respective sites, Narasimhan et al. (2019) suggested that they were migrants from the IVC into Central and Western Asia, and the genetic gradient represented by these individuals was designated by them as the Indus Periphery Cline[5]. The genetic composition of the Rakhigarhi individual falls on this cline, and Shinde et al. (2019) has named it as the Indus cline. This can reasonably be taken to be representative of the Indus valley population, though more data are necessary to confirm it.

Therefore, the genetic evidence is consistent with the hypothesis of migration of ancient Iranians to NW India and admixture with the native stock (Ancient Andamanese Hunter Gatherers, AAHG) giving rise to the IVC population. Narasimhan et al. (2019) proposed that the ancestors of the group formed by admixture at 5400 to 3400 BCE. An important characteristic is the lack of any Anatolian farmer-related ancestry and also Steppe pastoralist ancestry in the IVC genetic profile. This indicates that the Anatolian farmers did not migrate to India and admix with the native population and the IVC people lived at a time before any migration from the Eurasian steppes to India. This point will be elaborated later. As more data are obtained covering different ethnic groups, maintaining scientific rigour, these conclusions may be enriched and strengthened or modified.

[5]The term cline denotes a gradient of genetic characters within a species.

Climate Change and Decline of the IVC

Various hypotheses have been put forward to explain the demise of the IVC. The Rigveda describes attacks on walled cities of the Asuras and of war-god Indra destroying forts, and Mortimer Wheeler first put forward the idea of the Aryans invading from the Northwest and destroying the IVC, and the Asuras were the IVC people. Later scholars have pointed out that there is no supporting archeological evidence for this idea (no signs of warfare, deliberate destruction, or arson). On the contrary the evidence suggests a process of decline covering a long period with emigration away from the cities to small rural settlements. Therefore, the notion of Aryan invasion is now discarded by almost all scholars. Various other hypotheses for the IVC demise have been proposed, like, catastrophic flood or drought, change in monsoon pattern or river dynamics, sea level changes and trade decline, social instability and increased interpersonal violence and infectious diseases. The decline took place probably in several stages and over a long period, with emigration away from towns predicated by climate change, natural disasters and environmental degradation.

Though multiple factors might have contributed to the decline of the IVC, climate change is now believed to be the principal factor. Paleoclimatic evidence collected from different localities suggests that rainfall, aridity, patterns of cultural behaviour and response to climate variability were not uniform throughout the Indus region. The paleoclimate deduced from stable isotope studies at Bhirrana indicates weak summer monsoonal phase before ca. 7500 BCE, during the Pre-Harappan period. Monsoon intensification stage extended from 7500 to 5000 BCE (Sarkar et al., 2016). This transformed the Ghaggar-Hakra into a large rain-fed river and the Early Harappan settlements flourished in the floodplains of this river. Summer monsoon precipitation started to decrease from about 4050 BCE and monotonically declined through the Mature Harappan time to ca. 800 BCE. It is to be noted that the peak of the Mature Harappan phase was a period of weakened monsoon. Gradual drying of the region's soil might have been the initial spur for the urbanization. The civilization prospered on the banks of relatively depleted rivers and some sites are found in the river bed itself. Isotopic studies from paleolake sediments in the vicinity of Rakhigarhi and Kalibangan suggest that relatively wet conditions prevailed from ca. 3150 BCE during the Early Harappan phase and the monsoon rainfall somewhat intensified during ca. 3050 to ca. 2450 BCE (Mature Harappan) (Dixit et al., 2018). Drier condition set in after ca. 2450 BCE and continued during the declining phase of the IVC. Intensified aridification along with the decline of the monsoon converted large monsoon-fed perennial rivers like the Ghaggar-Hakra to ephemeral, even dry ones. This led to less extensive and more erratic floods which made inundation agriculture less sustainable. All this affected the habitability along the river courses.

There is evidence of large scale droughts at 6250 BCE and 2250-1950 BCE (Das, 2018, Dutt et al., 2018). It is possible that the people in the large urban centres during the Mature Harappan Phase utilized groundwater and followed agricultural practices sustainable under a limited and seasonal supply of water. The Harappans did not employ extensive canal irrigation; they relied primarily on fluvial inundation for winter crop and additionally on rain for summer crops. Rain water was supplemented by well irrigation. Monsoonal precipitation could have led to seasonal activity in the ephemeral channels. Weakened

monsoon at ca. 3000 BCE and the attendant fluvial quiescence suggests a gradual decrease in flood intensity; this stimulated intensive agriculture initially and encouraged urbanization at around 2550 BCE. Later hydro-climatic stress increased the vulnerability of agricultural production supporting Harappan urbanism, leading to settlement downsizing, diversification of crops and drastic increase in the number of settlements in the moister monsoon regions of upper Punjab, Haryana and western Uttar Pradesh after the Mature Harappan phase (Dixit et al. 2014). The decline of the settlement at Dholavira, Kalibangan, Rakhigarhi and Lothal took place between 2350 BCE and 2150 BCE (beginning of the Meghalayan Stage[6], (a time division of the Holocene). It is to be noted that the beginning of the Meghalayan Stage is marked by centennial-scale global drought. Giosan et al. (2018) inferred from paleoclimatic records that strong winter monsoon conditions existed between ca. 2550 BCE and 1050 BCE, an interval spanning the transition from peak development of the urban Harappan civilization to the demise of its last rural settlements. This was contemporaneous with the decline of summer monsoon and consequent aridification. This coordinated climate reorganization has been correlated with the deurbanization process and it transformed the urban Harappan civilization to a rural society through a process of push-pull migration from summer-monsoon-deficient river valleys to Himalayan piedmont plains with augmented winter rains. The decline of the winter monsoon happened between 1350 BCE and 1050 BCE and led to the demise of the rural late Harappans at the same time as the Iron Age Culture (Painted Grey Ware) was established in the Ghaggar-Hakra interfluve. Painted Grey Ware sites (c. 1000–600 BCE) have been found at former IVC sites at the middle and upper Ghaggar-Hakra channel, and have also been found in the bed and not on the banks of the Ghaggar-Hakra River, which suggests that river had certainly dried up by this period. There was a change in crop pattern from wheat and barley during the Early Harappan period of intensification of monsoon to drought-resistant species of small millet and rice during the period of declining monsoon. The later crops had much lower yield and the organized large storage system of Mature Harappan period gave way to smaller individual household-based crop processing and storage system in the Late Harappan Phase (1900 BCE and later).

On the basis of high resolution isotopic studies, Scroxton and his team (Scroxton et al., 2020) proposed a 'double drought hypothesis'. According to them the first drought was an abrupt 300-year long winter rainfall drought between 2020 BCE and 2310 BCE (Meghalayan drought) that led to Harappan site abandonment in the Indus valley and the end of the Mature Harappan period. The second drought was a more gradual but longer lasting reduction in summer monsoon rainfall beginning 2020 BCE leading to the further site abandonment at sites in Gujarat, a transition towards a more rural society, and the end of the Late Harappan. With climate drying came less extensive and less reliable river floods, which led to migration to monsoon-rain-fed areas and abandonment of cities. Note that the same cultural phases at different excavated sites, (e.g., at Bhirrana and Dholavira) are not of the same age. At Dholavira the decline of the settlements

[6]Meghalayan is a unit in the geological time scale extending from 4200 BP (2250 BCE) to Present. It is defined on the basis of studies in the Mawmluh Cave deposits in Meghalaya. It began with a 200-year drought that impacted many ancient human civilizations including the IVC.

happened at a time when at Bhirrana the settlements were flourishing. This may be due to spatial and temporal variability of the summer and winter precipitation as well as the influence of seasonal excess or deficient rain on river discharge.

The great urban Indus Valley Civilization collapsed by about 1700 BCE. After the abandonment of the large cities, smaller settlements continued and moved from the Indus and Ghaggar-Hakra valleys eastwards to the Ganga-Yamuna interfluve, to the Himalayan foothills or to Gujarat and Rajasthan (Giosan et al., 2012). □

(Part 2 of the article will discuss the characteristics of the Vedic Civilization, its chronology, its relation with the Indus Valley Civilization, the Genetic Evidence and the Question of Aryan Migration.)

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