Holocene Environmental Catastrophes of Gujarat and Related Tectonics

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Abstract

The breakdown of a civilization could be indicative of major environmental catastrophes of the past. Several such gaps in human history can be traced in the dynamic land of Gujarat, which, in the present times, is prone to various natural hazards. The people of Harappan or Indus valley culture inhabited Gujarat during 2500-1400 B.C. Several causes such as i) gradual environmental changes and consequent agriculture disasters coinciding with rapid population growth, ii) invasion of tribesmen, iii) spread of epidemics, iv) tectonic events causing morphological changes, etc. have been attributed to the fall of this developed civilization, which thrived on the fertile plains of the Indus-Ganga basins for more than a millennium. The one factor that influenced the extinction maximum was perhaps related with the changes in the drainage system. Tectonic flexing of the basement beneath the Indo-Gangetic plain and consequent gradual elevation of the land surface south of the Himalayan belt are considered to be the plausible causes for diversion of the Himalayan rivers leading to the desertification of the Indus civilization sites.

The paper focuses on the fall of Harappan civilization at Dholavira, Dwarka and Lothal in the State of Gujarat. The studies suggest that the two main progenitors of environmental catastrophes have their roots in meteorological and tectonic processes.

Introduction

Gujarat, the western most State of India, was carved out from the State of Bombay on 1st May 1960. Its three principal Divisions of Saurashtra, Kutch and Mainland Gujarat, occupying an area of 1,96,024 sq km, comprise 25 districts where a population of 50.597 million people live, as per the 2001 National Census. It is a land of great contrasts, which stretches from the fertile plains of the southeast to the almost rainless salt deserts of Kutch region. The Saurashtra Peninsula is arid to semi-arid and the north-eastern part consists of small plains and low hills. Its 1600 km long coastline has two gulf regions of Kutch and Khambhat. The major rivers are Tapi, Narmada, Mahi and Sabarmati, which debouch into the Gulf of Khambhat. The three minor rivers draining the northern Gujarat and ending up in the Little Rann of Kutch are Rupen, Saraswati and Banas. The prominent rivers of Saurashtra include Machhu, Bhadar and Shetrunji.

Gujarat and adjoining regions can be classified into six physiographic divisions, *viz.* i) Aravalli hilly tract, ii) Deccan Plateau, iii) Central Plains of Gujarat, iv) Saurashtra Peninsula, v) Kutch Peninsula and vi) Rann of Kutch (GSI, 2001). The geology comprises Precambrian metamorphites and associated intrusives, sedimentaries of Mesozoic-Cenozoic ages and Deccan Volcanics. The tectonic set up of the region is governed by three principal tectonic grains *viz.* NE-SW Delhi-Aravalli trend, ENE-WSW Son-Narmada-Tapi trend and NNW-SSE Dharwar trend. Rifting along these Precambrian fractures took place during the Mesozoic times resulting in the formation of Kutch, Narmada and Cambay grabens, respectively (Biswas, 1987). A number of faults and lineaments, some active in Holocene times as well, criss-cross the landmass and shape its coastlines. The prominent among them include Island Belt

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fault, Kutch Mainland fault, South Wagad fault, Gedi fault, Cambay Marginal faults, Son-Narmada fault, Tapi North fault, Coastal faults, apart from Chambal-Jamnagar, Luni-Sukri and Lathi-Rajkot lineaments (Narula *et al.*, 1996, Biswas, 2002). The northwestern part of Gujarat is a hyperactive seismo-tectonic domain comprising Zones V and IV of the Seismic Zoning Map of India (IS 1893, Part 1, 2002). This intra-plate basin, located 400 km from the Chaman plate margin and 1000 km from the Himalayan front, lies in a compressional stress field where seismic energy at an average rate of 7.30 x 10^{20} ergs/year is being released, as per the last 182-year database (Pande, 2003 and Pande et al., 2003). From 1668 to 2001 a total of around 100 earthquakes of significance have occurred in region.

The known history of Gujarat dates back to 250 BC. During the 4^{th}-5^{th} century AD it was part of the Gupta Empire. During 8^{th}-9^{th} century AD the Gujjars, who were succeeded by the Solanki dynasty, ruled it. Later, the Arabic Muslims, Mughals, Marathas and the British before India's Independence occupied Gujarat. Prior to the historic period between 2500 and 1400 BC, the people of the Indus valley or Harappan civilization inhabited the landmass. It is believed that the Harappans started infiltrating into Kutch and settled there in great numbers. So far, 60 Indus civilization settlements have been found in Kutch, of which about 40 belong to the early phase and the remaining to the late Harappan culture. The Harappans migrated from Kutch to 500 km further south in Saurashtra and Mainland Gujarat. The important Indus valley civilization sites are Dholavira and Surkotda in Kutch and Lothal and Dwarka in Saurashtra (Fig.1).

The remnants of the magnificent city of Dholavira or Kotada in the Khadir Island of Kutch district are spread in a 50-hectare area. It emerged as a model city in terms of planning, architecture and water management system about 2500 BC.

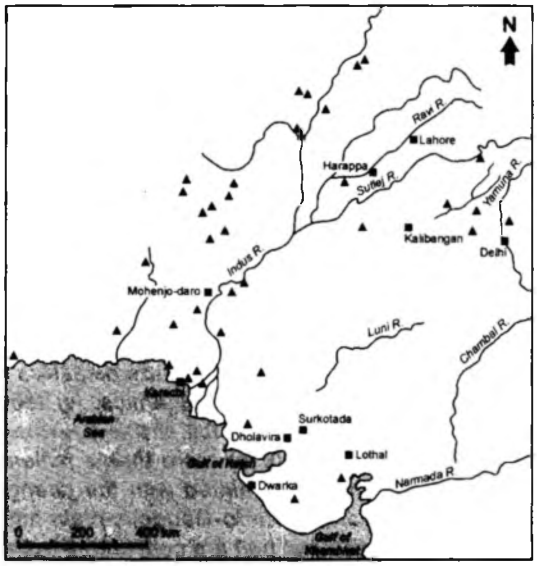

Fig.1: Map showing Indus Civilization sites (after Encyclopaedia Britannica).

However, the civilization started declining in 2100 BC and, sometime later, was reoccupied by the successors of Harappans. Around 1800 BC, the urban character was lost and the settlement shrank drastically (Singh, 2001). The city was again abandoned in 1700 BC to be reoccupied after a gap of two centuries. During this period the settlement had a totally deurbanised set-up with the inhabitants living in circular houses. Dholavira was finally abandoned in 1400 BC and was never occupied again.

Dwarka, on the west coast of Saurashtra Peninsula, is another site of late Harappan culture. The underwater explorations carried out to a depth of 20 m in the Gomti creek at Dwarka by the Marine Archaeological Centre of the National Institute of Oceanography have yielded structures such as bastions, walls, pillars and triangular/rectangular anchors that indicate existence of a late medieval period harbour (Gaur *et al.*, 2004). Underwater explorations in Bet Dwarka and Poompuhar revealed a large number of potteries from 5 to 8 m water depths (Gaur *et al.*, 2004). Dredged material from the creek also unearthed some pottery, stone sculptures, terracotta beads, bronze-copper-iron objects, etc. According to Rao (1999) the submerged township was a remnant of Mahabharat fame dating back to 1800-1700 BC.

Lothal, another site of singular Harappan culture and literally meaning *the land of the dead*, is located in Ahmedabad district just north of the Gulf of Khambhat. The remnants of this ancient port town are spread in an area of 64,752 sq m. Dating back to 2350 BC, the place had an acropolis, a lower town, a dock for berthing ships and a warehouse for storing the cargo (Rao, 1979). The site was busy foreign trades centre where copper was imported and goods such as bronze celts, spear heads, ornaments, etc. were exported.

Major Environmental Catastrophes of Gujarat

Major environmental catastrophes of the past, whose tell-tales are still preserved in the sediments, landforms and monuments of Gujarat, have often become the cause of large scale destruction of habitats, leading to mass scale migration or even permanent abandonment of a settlement. Going through the annals of archaeology, there are instances, which suggest that a settlement was occupied, deserted and then reoccupied a few times over a period of several centuries, as in case of Dholavira. These phases may be indicative of conducive and adverse geoenvironmental conditions occurring at a place in a repetitive pattern. The Holocene tectonics seems to have had a slow but profound influence on the geoenvironment of the region, particularly of the coastal belt. These pervading changes occurring in the Kutch and Saurashtra regions are discussed in the following paragraphs.

Kutch Region

If an appraisal of the ruins of Dholavira is made, which now lies amidst a salty-marshy desert in hostile climatic conditions most unsuitable for any fruitful agriculture or trading activity, it will be difficult to conceive why a highly developed Harappan civilization chose it for its habitation for almost a millennium? The only plausible reason is that the environmental, climatic and physio-graphic conditions then must have been conducive to support a large population and suitable for trade activity. In the pre-historic times, the Indus delta might have extended to this part of Kutch, where, apart from the distributaries of Indus like Puran, Saraswati river of Vedic times was also debouching and providing navigable routes. Dholavira saw at least three distinct hiatuses in human civilization of a few centuries each between 2000 and 1400 BC. It is likely that during this period some subtle tectonic adjustments were taking place in the frontal Himalaya, which induced gradual changes of far reaching consequences in the river regimes of west India.

Another reason for the extinction of Harappan culture at Dholavira could be the recurrence of large magnitude earthquakes in the Kutch Rift Basin. The high seismicity, in conjunction with other geoenvironmental catastrophes, could therefore be the factors that compelled the inhabitants to finally migrate from their ghost towns to safer pastures further south.

The Kutch region presents an interesting case of very recent tectonic adjustments and consequential environmental changes of far reaching anthropogeographic significance. The great Rann of today was an old inlet of the sea. This emerged landmass, only a fraction above the present mean sea level, gets flooded during the monsoon and turns into a salt marsh, most inhospitable to support any life form. Patches of slightly raised ground with a characteristic vegetation cover have come up in this part of the Rann in the recent past. The records mention of a perennial river named Puran, which flowed across the western Rann to the Gulf of Kutch through Kori creek. A fertile tract, known as Saira, which, according to Sir Alexander Burnes included the country between Lakhpat and Mundhan, bordered this river (in Oldham, 1926). The river in its upstream reaches passed into eastern Narra and this into the bed of Hakra, the lost river of the Indian desert. Fed by Sutlej and some other rivers, it carried a powerful discharge to the sea. This system of drainage continued to flow between 8th and 16th centuries AD. Later, Sutlej gradually became a part of the Indus system and by 1790; Hakra was merely a dry channel. The highly diminished flow in Puran was from an effluent of the Indus, over which embankments at Mora and Ali Bandar were constructed. In 1826, by some breach in the banks of the Indus, a heavy discharge into the course of Puran swept away all the man-made embankments.

Capt. R.M. Grindlay, accompanying a mission to Sindh, navigated through the channel of Puran from Lakhpat to Ali Bandar in the year 1808 and passed through the Customs Station at the old Fort at Sindri. In the 1819 Kutch earthquake a spectacular terrain change created an E-W trending, 80 km long natural embankment (Allah Band) of a maximum height of 6.0 m. The land to the south of this fault rupture subsided, resulting in large-scale inundation by the sea. In the 1819 earthquake the Sindri Fort was overwhelmed at once with a tremendous inundation of water from the sea, and in a few hours completely flooded the country. The strong shaking reduced many settlements to total ruins compelling the survivors to abandon them and migrate elsewhere.

Saurashtra Peninsula

The two sites of Harappan civilization at Dwarka and Lothal were lost in a short span of time, presumably by fluctuations in the sea levels and resultant submergence, coastal erosion or drying up of channels. It is believed that the whole coast of western India sank by 12 m around 1500 BC. The recent studies give reasons such as i) a change in the level of sea bed, ii) a massive earthquake and iii) sudden increase in the level of sea water for the submergence of Dwarka. The nearly straight coastlines of Saurashtra Peninsula are demarcated by active faults. A reactivation of a segment of the west coast fault and sudden rupturing could have resulted in the creation of a depression in the shore front or breaking of a sea barrier that allowed the seawater to gush in and submerge the inhabited coastal tract. Such a major faulting involving a displacement of a few or more metres is likely to have been associated with a major earthquake having foreshock and aftershock activity. The inundation at Dwarka could be compared with that of the Great Rann of Kutch during the 1819 earthquake. The geological records from the Mediterranean also reveal that a great earthquake that occurred some 7500 years ago ruptured the Bosporous strait, through which the sea water invaded the karst ecosystem of Bulgaria and resulted in mass killing of fresh water organism.

The port town of Lothal enjoyed prosperity for being a busy trade centre of Harappan civilization. It has been conjectured that the modern silted creek extending till Lothal represents the ancient port channel that was used by the Harappan people (Rao, 1979). It seems that the channel no longer remained navigable due to major fluctuations in the sea levels. Khadkikar *et al.* (2003), on the basis of MSS imagery and environmental studies, have identified a tidally influenced palaeochannel adjoining the western part of Lothal and an estuary towards the east. The authors have concluded that Lothal developed over a tidal salt marsh and was subsequently left high and dry as the sea level dropped.

Major fluctuations in the sea levels around 1500 BC were not a global phenomenon. It appears that such changes were more on a local or, at most, regional scale, perhaps induced by tectonic disturbances.

Holocene Tectonics and Drainage Modifications

Several causes have been attributed to the rise and fall of the Harappan civilization, which thrived on the fertile plains of the Indus-Ganga basins for more than a millennium (Fig.1). The one factor that influenced this developed culture maximum was perhaps related with the changes that took place in the drainage system. These modifications, brought in over a period of several centuries, seemed to be governed by the tectonic processes operative in the Indian plate.

The studies carried out in the Indo-Gangetic foredeep, skirting around the southern face of the Himalaya, reveal the presence of several horst, graben and ridge structures, bounded by gravity and strike-slip faults (Fig.2). The major subsurface geological structures lying below an alluvial mantle of a maximum thickness of about 4 km in the central and western parts of the basin are i) Sarghoda-Delhi ridge, ii) Sahaspur low, iii) Aravalli-Delhi fold belt, iv) Sarda low, v) Agra-Lucknow horst and vi) Gandak graben (Srinivasan & Khar, 1996). The NE-SW trending Delhi-Aravalli belt, bounded by Mahendragarh-Dehradun (MD) and Great Boundary (GB) strike slip faults, is a prominent transverse structure that seems to divide the Indo-Gangetic basin into two parts. The western boundary of the structure lies around the great water divide of Indus and Ganga basins. A NW-SE trending geological structure referred to as Delhi-Sarghoda ridge, runs 200 km south of the Himalayan front and has been traced up to Jhelum River in Pakistan, for about 650 km from MD fault.

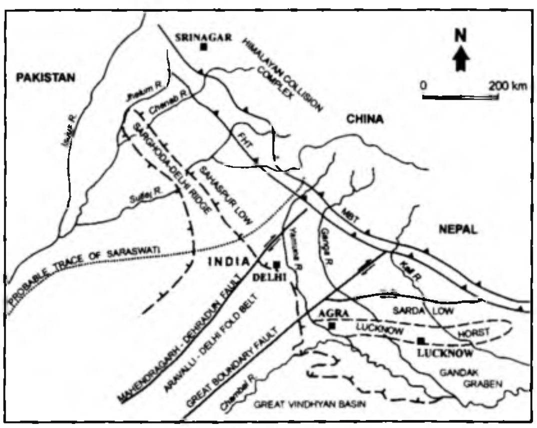

Fig. 2 : Tectonic framework map of Himalayan Belt and Indo-Gangetic Foredeep (modified after Srinivasan & Khar, 1996).

The area between the present courses of Sutlej and Yamuna rivers, flaring from 85 km between Rampur (H.P.) and Barkot (Uttaranchal) to 475 km between Fazilka (Punjab) and Mathura (U.P.), is devoid of any major drainage and shows an anomalously subdued seismicity. It has been theorized that in the proto-historic period, Yamuna with its tributaries (referred to as Saraswati of Vedic times), flowed in a south-westerly direction through this tract and debouched into the Rann of Kutch, which was then an arm of the Arabian Sea (Oldham, 1886; Valdiya, 2002; Bakliwal & Grover, 1988, Radhakrishnan & Merh, Eds., 1999 and others). Due to certain terrain modifications, the drainage config-uration experienced a slow but drastic change and the Yamuna (Saraswati) system was won over by the east sloping Ganga basin. The gradual drying up of a major drainage network proved to be fatal for a dependent civilization. Similar changes, though occurring much later, have been documented from Sutlej, which being an independent river, like Saraswati, in the historic times, later became a tributary of the Indus basin (Oldham, 1926).

Bilham *et al.* (2001), on the basis of geophysical evidence, state that south of the Himalaya, the top surface of India's basement rock flexes and slides beneath the Himalaya – not steadily but in lurches during great earthquakes. Bilham (2001) opines that a region 300-600 km to the south of the Himalaya is elevated by the flexural stress imposed on the bent Indian plate. It is likely that the extent of the basement flexure, which might have its manifestations on the surface as well in the form of up warps and depressions, is different at different places, due to varying stress conditions in a highly fragmented Indian shield.

It seems that the Delhi and Sargodha ridge structures, flexed under the influence of late Holocene tectonics, brought in gradual relief changes in an area between the present courses of Yamuna and Sutlej. This gradual terrain change caused deflection of drainages over a period of time. The west flowing Saraswati slowly got deflected towards east, perhaps occupying the course of one of its tributaries, as it no longer remained capable of negotiating the imposed topographic high. In later stages, the Sutlej also met with a similar fate and changed its course. These morphotectonic changes and consequent drainage deflections are explained with the help of diagrammatic sketches in Fig.3.

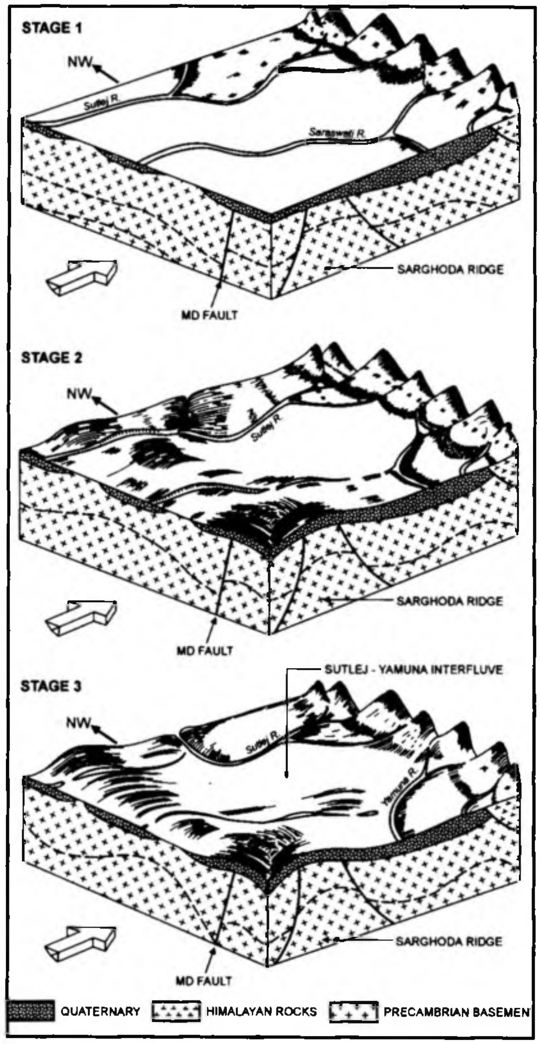

Fig.3: Sketches depicting the evolution of Sutlej-Yamuna interfluve. Stage 1: Southwest flowing Sutlej (west) and Saraswati (east) descending from the Himalaya. Stage 2: Flexure of Indian plate along Sarghoda and Delhi ridge structures, resulting in the formation of up warps and depressions in the Indo-Gangetic plain. The drainages first got entrenched at and then partially deflected by the topographic highs. Stage 3: Complete deflection of Saraswati (Yamuna) and Sutlej, leaving behind relict valleys, which later got filled up or buried under aeolian deposits.

Concluding Remarks

- The ancient civilizations generally grew on the banks of rivers or on shores at the mouth of drainages to cater to the prime requirements of agriculture and trade activity. Fluctuations in the sea levels, drying up of rivers or repeated flooding either due to river piracy or drastic climatic changes, apart from epidemics or invasions, and sometimes, major earthquakes, have often proved to be catastrophic, leading to mass migration or abandonment of settlements.

- Tectonic adjustments during Holocene period even at far off places had a slow but profound bearing on the geoenvironment of the Indus valley civilization. The drainages were the most sensitive to such tectonic perturbations and the changes brought in them led to anthropogenic disasters. In case of major earthquakes or fault ruptures, the effects were almost instant though not so grave.

- There seems to be a hiatus in civilization in the Indian subcontinent around 1500-1400 B.C. or at the boundary of bronze and iron ages. The records tell that major catastrophes in the form of coastal submergence, drying up of rivers, sea level fluctuations and related environmental disorders took place in a very large area in this time frame. There is a distinct possibility of these being genetically related with regional tectonics.

- A tectonic process takes a long time to manifest its effects on the environment. But when the process reaches the stage of criticaiity, the changes take place rapidly and the effects start becoming evident on the surface, influencing the geoenviron-ment in an appreciable way. This is why the tectonic effects, many a times, appear episodic in nature rather than creep type.

- Since time immemorial, the one factor that has governed the rise and fall of civilizations is water. In times to come also, water will maintain this status, since the very essence of life emanates from it.

- In the modern times, for reasons such as better understanding of the mechanism of environmental catastrophes, evolution of prediction models, development of alert systems, existence of building design codes and a higher degree of preparedness and awareness, the impact of natural calamities may be less severe than in the past. However, now a catastrophe, which could lead to a hiatus in civilization, as in the past, may not be natural but man-made.

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