

Climate, Vegetation and Ecology during Harappan Period: Excavations at Kanjetar and Kaj, Mid-Saurashtra coast, Gujarat

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Abstract

A multi-proxy study was carried out to address climate- culture relationship from two trenches one each from Kaj and Kanjetar (mid-Saurashtra coast) deposited in a lacustrine setting, since ~1960 Cal BC and ~2230 Cal BC, respectively. The salinity of aqueous soil solution (0.1 ppt) and fresh water thecamoebians in both the sites indicate fresh water depositional environment. But, an increase in salinity (0.2 ppt) in the top clayey sediment in Kanjetar is attributed to water evaporation through upward capillary action from moisture deficit exposed land. The fragments of ancient potteries and other artefacts recovered from the bottom sediment provide evidences of Sorath- Harappan colonization in the vicinity which was not an urban site. The abundant cyanobacterium remains, low terrigenous organic matter, aquatic pollen and low thecamoebians in bottom sediment indicates low precipitation and arid climatic conditions ~2000 BC. During this period the dominance of evergreen and moist-deciduous arboreals from both the sites do not show equilibrium with the prevailing dry/arid climate and therefore, the pollen assemblage here represents the remnants of wetter middle Holocene vegetation in the region. Phytoliths of drought-tolerant summer season crops also reflects here changes made in the agricultural strategy by Harappans in response to climate. The increase in deciduous arboreal pollen since the last ~2000 years represents equilibrium with the dry/arid climate. But, enhanced limnic conditions recorded with the help of thecamoebians during this period is attributed to changes in wetland configuration induced by hydrostatic changes in the river mouth that was largely defined by the dynamics of sediment deposition through rain-fed rivers/ streams in the region.

Key Words: Harappan Period, Pollen, Phytolith, Thecamoebian, Climate

1.0 Introduction

The Indian monsoon influences the fauna and flora of the Asia–African region. The history of vegetation distribution indirectly reflects regional climate change, and thus, palaeovegetational records serve an important source of information revealing the past environment. Primary source of information are the fossil pollen records collected from lake, wetland, and near-shore marine sediments, supplemented extensively by plant macrofossil, phytolith, stable carbon isotope records and evidences of human habitation in archaeological perspective. During the mid-Holocene the global vegetation distributions were similar to present, although differences persist regionally in India due to differential precipitation variations and moisture balance.

Global, hemispheric and regional syntheses of palaeoclimate reconstructions for different periods have provided powerful insights into the behaviour of the earth system (Kutzbach and Street-Perrott, 1985; COHMAP, 1988). If no other factors are important, then the changes in solar insolation between 6 ka (thousand years) and today should produce increased seasonality in the Northern hemisphere and a decreased seasonal cycle in the Southern hemisphere (Wasson, 1995). In recent years, the Holocene climate in north-western India is still far from clear (Prasad and Enzel, 2006; Chamyal and Juyal, 2008). These studies have shown that the Pleistocene-Holocene transitional period was climatically very sensitive, the mid-Holocene (7-3 ka) was relatively wet and stable and the Late Holocene (<3 ka) was dry and dynamic. The climate sets the boundaries to vegetation types, and therefore, remains in equilibrium with climate except during the most rapid periods of climate change or intense anthropogenic activities. Consequently, a strong synergism between the atmosphere, relative sea level, vegetation types and anthropogenic activity is expected.

Fluvial landscapes in Harappan territory (North-western India) became remarkably stable during the late Holocene as aridification intensified in the region after ~5 ka which probably stimulated intensive agriculture initially and encouraged urbanization ~4.5 ka. However, further decline in monsoon precipitation led to conditions adverse to both inundation and rain-based farming (Madella and Fuller, 2006; Giosan et al., 2012). As the monsoon weakened, monsoonal rivers gradually dried or became seasonal, inducing hydroclimatic stress and affecting habitability along their courses. Identification of the three phases of Harappan culture- Early Harappan (3300-2600 BCE), Mature Harappan (2600-2000 BCE) and Late Harappan (2000-1700 BCE) suggests a gradual cultural process origin, development and decline. Prasad and Enzel (2006), Prasad et al. (2007) have also elucidated the

climate shift towards aridity since Middle to late Holocene in the mainland North-West (NW) of India, which coincides with the downfall of Harappan culture. These climatic conditions probably led to the expansion of Harappan domain towards moister Punjab in the North and Saurashtra coast in the South. The present work was taken up to understand the climate-vegetation relationship and agricultural strategy of Late Harappans in the Saurashtra coast.

1.1 Background of Harappan archaeology

Harappan Civilization extends from Sutkagen-Dore (Westernmost of Makran Coast, and near the present-day frontier with Iran) on the west and Alamgirpur (Saharanpur District of UP) on the east (Possehl, 2002). Its northern most sites at Manda (in Jammu & Kashmir) and Diamabad (in Maharashtra) mark the southern boundary (Figure1). Harappans, being an agrarian society, selected riverside plains for the major settlements, the concentration being along the river Indus. However, the expansion of Harappans in Gujarat was two-folds namely to exploit the rich agriculture land in Saurashtra and a long coastline available for obtaining marine resources and also establishing centers of overseas trade and commerce. Colonizing in selective ecological regions depended exclusively on the resource potential and maritime trade of varying degree rather than acquiring the territory for political dominance. Before the arrival of Harappans in Gujarat there were chalcolithic settlements which have been variously termed as Anarta ware, Pre-Prabhasa, and Padri ware (Ajithprasad, 2002). The extensive investigations of the Harappan sites in Saurashtra during the last half a century show a distinct pottery assemblage (Sorath-Harappan) in addition to the classical Harappan potteries of Sindh (Possehl and Raval, 1989). The diagnostic shape of these potteries is a stud-handle bowl that has been recorded across the Saurashtra region from Early Harappan to the Late Harappan period. A few major excavations of Harappan sites, such as Rangpur (Rao, 1962-63), Lothal (Rao, 1979), Rojdi (Possehl and Raval, 1989), Nageshwar (Hegde et al., 1990), Surkotada (Joshi, 1990), Padri (Shinde, 1992), Kuntasi (Dhavalikar, et al., 1996), Dholavira (Bisht, 1997), Bagsra (Sonawane et al., 2003) and many more in Kutch and Saurashtra region enhanced the understanding of establishment of Harappan settlement, their town planning, utilization of various resources and specialized craft in NorthWest (NW) of India.

Late Harappan or Post urban phase dose not mark the end of a cultural tradition but suggest the termination of an Urban phase and a process of 'localization' (Sonawane, 2002). In Gujarat, the level of socio-cultural attainment existed throughout its mature phase which was slowed down in its later phase (Possehl, 1980). This is represented by centrally less organized, less differentiated and less specialized than the urban phase. The studies related to vegetation reconstruction through palynology and interplay

of climatic sequence during the Harappan period are least known from the coastal archaeological sites of Saurashtra. The present study was taken up to unravel the vegetational evolution, ecology and climatic conditions during the Harappan period in mid-Saurashtra region.

1.2 Location of the sites

A large number of archaeological sites were explored in and around Kodinar, a coastal area of Junagadh district. Among them Kanjetar, is referred to as important coastal Harappan site on the mid Saurashtra coast and was selected for excavation to understand man and climate relationship. The site is situated at 20°43' Latitude and 70°38' Longitude which is about 12 km southwest of Kodinar on the coastal area of Arabian sea (Figure 2.1). A dry creek is noticeable on the eastern side of the village Kanjetar (Figure 2.3), where another site of historical period was noticed. The entire site has been converted into an agriculture land and thus the remains of habitation have significantly been destroyed. Kanjetar is a very small Harappan site categorized as a village settlement and the role of the site in context with overseas trade may be debatable.

The village Kaj is about 10 km east of Kodinar town on the Dwarka Bhavnagar highway (Figure 2.1 and 2.2). The ancient mound locally called as *JunaKaj* is situated further 2-3 km east of the village and is located at the Latitude of 20°45' and the Longitude of 70°47' (Figure 2.4). A large fresh water body is situated in the east of the mound (Figure 2.4) where migratory birds (mostly Siberian) visit annually. Only an area of 100 X 100 m remains undisturbed and the rest of the site is an agricultural land (Figure 2.6) very close to the creek. However, proximity to sea suggests that the site was located on the western bank of the creek where presently, the rainwater accumulates.

1.3 Present Day hinterland Vegetation

The northern end of the Western Ghats Range in India touches the southeastern part of Gujarat. The ecoregion here borders the Kathiawar-Gir dry deciduous forests (Figure 2.2) to the west and the Narmada Valley dry deciduous forests to the northeast. The present day annual rainfall in the Saurashtra region is ~600 mm which increases to ~1000 mm eastwards (Figure 3) receiving mostly through South-West Monsoon (SWM) and scanty winter precipitation. According to Champion and Seth (1968), classification of forest types falls under 5A/C-1a very dry teak forest following Sub-type 5/DS1-Dry deciduous scrub forest and 5/DS1-Dry savannah forests. Dry Deciduous Teak Forest comprise of *Tectona grandis*, *Diospyros melanoxylon*, *Terminalia*, *Mitragyna parvifolia*, *Wrightia tinctoria*, *Aegle*

marmalos, *Butea monosperma*, *Balanites aegyptica*. Dry Deciduous Mixed Forest constitutes *Terminalia crenulata*, *Garuga pinnata*, *Lannea coromandelica*, *Acacia catechu*, *Xeromphis spinosa*, *Grewia* spp., *Ficus* spp. Open Scrub Forest comprise of *Acacia nilotica*, *Acacia leucophloea*, *Zizyphus* spp., *Balanites aegyptica*, *Carissa* spp., *Wrightia tinctoria*. Riverine Forest includes *Emblica officinalis*, *Terminalia crenulata*, *Tamarindus indica*, *Vitex nigundu*, *Helicteris isora*, *Ficus racemosa*, *Syzigium*. Thorn Scrub Forest comprise of *Acacia nilotica*, *Acacia catechu*, *Acacia leucophloea*, *Aegle marmalos*, *Zizyphus* spp., *Balanites aegyptica*, etc. Savannah includes *Acacia* spp. Grasses like *Sehima nervosum*, *Dicanthium annulatum*, *Cymbopogon*, *Chrysopogon*, *Apluda mutica*, *Heteropogon*, *Aristida* etc. The conserved 'Gir forest' represents the vegetation in the present day dry and arid climatic conditions which form a key to infer the vegetational evolution in the present study through palynology.

1.4 River and Water Courses

Most of the rivers in the studied area traverse from hilly terrains of Gir forest. About seven main rivers originate from here that finally merge in Arabian Sea. They are Datardi, Shingoda, Macchundri, Saraswati, Raval, Ardak, and Hiran of which only Hiran has perennial flow, the rest being seasonal. The Shingoda and Macchundri rivers originate from Gir forest region which forms a river mouth very near to Kanjetar and Kaj, respectively before merging into the Arabian Sea. All the rivers and streams are recharged during monsoon season and hence could have played a major role in the sustenance of the Harappan civilization. Frequent configurational changes in the water body around the river mouth due to sediment deposition/erosion and anthropogenic geomorphological modifications in the studied coastal area during the last 4000 years cannot be ruled out. Therefore, the sediment characteristic in the coastal areas supplemented by river-mouth play an important role and serve best archive that provide a clue to past vegetation and palaeoenvironment .

2.0 Materials and Methods

An archaeological, palynological, phytolith, sedimentological and fresh water thecamoebian study was carried out in trench sediments from Kanjetar and Kaj. A sediment profile from a 0.50 m deep trench (5 m length and 2.5 m breadth) was retrieved from Kanjetar (Figure 2.5) site (now an arable land). This was sub-sampled at 0.10 m interval and palynological study was carried out in the 5 samples. The bottom sediment bears archaeological artefacts. Similarly, a sediment profile from 1.50 m deep trench (5 m length and 2.5 m breadth) was dug out in Kaj in an undisturbed area (Figure 2.6). Ten samples were obtained for palynological and phytolith study, sub-sampled at 0.15 m interval, except the

sample number 7 (0.90-1.00m) and sample No. 10 (1.30-1.50m) that was demarcated here depending on the archaeological evidences between 1.00 and 1.50 m. Colour of the sediment is according to Munsel's colour chart. Salinity, pH, Conductivity and Total Dissolved solids in aqueous soil solution were measured by Thermo-Orion Analyser (U.S.A) at 25°C as a supporting data to analyze sea water influence. The archaeological evidences were studied to unravel the extent of Harappan domain in the NW part of India.

The C-14 (Radiocarbon dating in years Before Present - BP) dating of the organic carbon in the sediment was carried out at radiocarbon laboratory of Birbal Sahni (BS) Institute of Palaeobotany, Lucknow. The sediment was manually cleaned, sieved and subjected to hydrochloric acid to remove carbonate component if any. After repeated rinsing for pH stabilization, the sediment was combusted in the continuous flow of oxygen. The resulting carbon-dioxide was collected and converted to acetylene and then benzene using standard catalyst and procedures. The counting was carried out in a Liquid Scintillation Counter (Quantulus 1220). Of six bulk samples only four sediment samples (two from each section) rich in organic carbon, have been radiocarbon dated. 2σ ranges of the calibrated (Cal) date to calendar year ages (AD and BC) using INTCAL 09.14c and CALIB 6.01 (Reimer et al., 2009; Stuiver et al., 1998) is given in Table 1 & 2.

Palynological and phytolith study was carried out in order to understand the climate-vegetation equilibrium and climate-culture relationship, respectively. For palynological study, the sediment (10g) was chemically processed using standard acetolysis method (Erdtman, 1943) and ~200-300 pollen grains were counted per sample. The pollen spectrum (Figures 5 & 6) is the percentage of the pollen sum (arboreal and non-arbores). Pollen atlases of Guinet (1962), Vasanthi (1976), Nayar (1990) and Tissot et al. (1994) and reference slides from the Herbarium of Birbal Sahni Institute of Palaeobotany were consulted for identification of the palynomorphs. The aquatic pollen was present only in Kaj and not in Kanjeter and is excluded from the pollen sum. The percentage of aquatic pollen from Kaj and ubiquitous taxa like poaceae and cyperaceae from both the sites was calculated separately against the total pollen sum in the respective sediment. In the pollen spectra the arboreals were grouped into evergreen/semi-evergreen moist deciduous (indicating wetter climate) and Dry deciduous according to Champion and Seth (1968) in order to study the climate- induced evolution of vegetation in the region. Therefore, the ratio of these has been used to decipher seasonality and precipitation conditions. The ratio of arboreal/non-arboreal pollen indicates the extent of forest cover. Sedimentology was used to understand the type of depositional environment and the relative percentage of fresh water

thecamoebians has been used in ecological perspective. The study of Non Pollen Forms (NPFs) like algae, phytolith and thecamoebians here assist in palaeoecological interpretation, especially for studies of palaeoclimate (Chambers et al. 2011).

The identification of freshwater *Botryococcus* in the sediment was based on Medeanic (2006) and Medeanic and Correa (2010). Detailed examination of *Botryococcus* detritus in sediments have shown the aggregation and preservation of proteinaceous materials (Nguyen and Harvey, 2001). This enables it to get identified in sediments along with other organic matter detritus and has potentials in palaeoecological studies. It is usually abundant in shallow-water pools and survives even in case of little precipitation (Traverse, 1955 and Guy-Ohlson, 1992). The identification of cyanobacterium (*Chroococciopsis* type) was done following Geitler (1933) and Desikachary (1959). The cells of *Chroococciopsis* are unicellular, more or less spherical or irregular groups having firm colourless sheath which undergo repeated binary fission in three planes to produce more or less regular cubical cell aggregates (Komarek and Anagnostidis, 1999). Both thecamoebians and some of the phytolith cells (Figures 7 & 8) were recorded as NPFs in palynological slides. Thecamoebian data is presented as percentage of its total count (~200). Fresh water thecamoebians observed in the palynological slides provide a clue to climate induced ecological condition by its relative abundance in the sediment profile and therefore, has been included here as a supporting proxy. This method of sample preparation is normally not used by micropaleontologists where a much simpler method using water is preferred so that delicate fossils or sub-fossils are not damaged or totally destroyed (Patterson 2002). However, acid-resistant thecamoebians having autogenous proteinaceous theca have been reported from the palynological slides of Holocene sediments from the fjords of Vancouver Island, Canada (Kumar and Patterson, 2002), lake and coastal sediments of India (Farooqui and Gaur, 2007; Farooqui and Naidu, 2010; Farooqui et al., 2012; see Payne et al., 2012) and Cretaceous sediments of Saudi Arabia (Kumar, 2011). Although the loss of sensitive taxa limits the ecological information contained in testate amoeba assemblages the information preserved is likely to be useful in a multiproxy approach to palaeoenvironmental reconstruction (Payne, et al., 2012). This method was however quite successful for identifying thecamoebians in Permian hard rock sediments where the acid treatment was necessary for matrix disintegration (Kumar et al. 2011). The nomenclature and identification of thecamoebians is after Tolonen (1986) and Kumar and Dalby (1998).

The phytolith data shown in Figure 10 and its relative abundance in Figure 11 was retrieved from 5g sediment following conventional methodology (Prasad et al. 2007) in order to understand the climate

induced agricultural strategy in the studied area. The extracted phytolith were counted and classified according to Twiss et al. (1969), Piperno, (1988) and Mullholand and Rapp Jr. (1985). Phytolith assemblage was used to decipher significant archaeological and palaeoenvironmental variations supplementing the pollen/spores data. On the basis of morphotypes, the short saddle phytolith mainly occurs in subfamily Chloridoideae (C4) that consists of grasses adapted to warm summer conditions. Dumbel and cross phytoliths are characteristic of grasses belonging to subfamily Panicoideae (C4) that proliferates in the tropical region during warm and humid summers. The rondel and trapezoid phytolith correspond to subfamilies Pooideae and Festucoideae (C3) that are adapted to cool and moist environmental conditions. Rod shape, circular, bulliform and pointed morphotypes are phytolith of grass epidermal tissue without any taxonomic significance (Mulholland and Rapp Jr. 1992; Prasad et al. 2007). Besides short silica cell phytolith, volcaniform phytolith of *Musa/Ensete* and cuticular remains of crop plants (Wheat, Barley, Millets) were also identified.

3.0 Results

For the better understanding of the succession of vegetation, ecology and climate three Phases (1, 2 & 3) were identified on the basis of multi-proxy data. The data includes record of sediment characteristics, archaeological evidences, pollen/spores, phytolith and thecamoebians from both the sites which has been documented here separately.

3.1 Kanjetar

Sedimentology and Radiocarbon dating: In Phase-1 (0.30- 0.50 m depth) the sediment is light to dark brown clay (Munsel's Colour chart- 5Y3/4) with interspersed occasional concrete/ gravels that were natural (Table -1). The sediment at 0.40- 0.50m depth dates back to 3810 ± 100 years BP (~2230 Cal BC). These dates (Table-1) coincide with the Harappan settlement in the studied site which is justified by the archaeological remains of the same period in the area. Phase-2 (0.10- 0.30m depth) is also clayey and is light brownish in color. The sediment at 0.10-0.20m dates back to 780 ± 150 years BP (~1210 Cal AD). The salinity of aqueous soil solution show an increased value (0.2 ppt) in this Phase against 0.1 ppt recorded in Phase 1.

3.1.1 Archaeological remains

The Figure 4 shows major findings that include various types of pottery fragments similar to the Harappan phase. A large number of scattered stones were found during the excavation. Several stone

structures of archaeological interest were destroyed in recent years while converting the site into agriculture land that were used for bordering the cultivated area or for other purpose by human beings. However, the remaining evidences of archaeological interest include two stone tools namely a flake on red jasper with sharp edges and other tool is scraper on banded agate. Large number of pottery was collected during the excavation (Gaur, et al. 2011). The ceramics industry include sturdy red, coarse red and buff ware sherds and are similar to the Harappan pottery reported from Lothal and other Harappan sites in Saurashtra (Rao, 1985). The varieties of bowls of fine red ware recovered here in large numbers are similar to the Sorath-Harappan type (Possehl and Raval, 1989). The other important remains include jars, bowls, dish on stand and a goblet. Few sherds are painted with black, dark brown or chocolate colour over red, orange, dull red or white surface. The faunal remains include cattle, buffalo, sheep/ goat and a bird (chicken) along with a bone tool (point) probably made by splitting the bone shaft of the long bone of cattle.

3.1.2 Palynology and Fresh water Thecamoebians

Phase 1 (0.30-0.50 m): The bottom samples constitute low organic matter but pollen assemblage of arboreal taxa show an average percentage of evergreen trees (Figure 5) such as *Baringtonia* (4.3%), *Capparis* (4.5%), *Dipterocarpus* (4.4%), *Elaeocarpus* (9.2%), *Mangifera* (4.7%), *Michelia* (1.1%), Moraceae (8.8%), *Shorea* (7.9%), Sapotaceae (3.2%) and dry deciduous taxa include *Bombax* (8%), *Butea* (4.6%), *Chorisia* (5.9%), *Garuga* (3.4%), *Hardwickia*, (3.2%), *Holoptelia* (4.7%) and *Terminalia* (3.3%) (Figure 7). The non-arboreal pollen comprise of *Acanthus* (1.2), Asteraceae (4.4%), Cucurbitaceae (3.6), Chenopodiaceae (6.9%) and *Tinospora* (3.2%). The poaceae/cyperaceae pollen constitute 11.3 % of the total pollen sum. The occurrence of frequent dumbel-shaped phytolith cells were common in palynological slides. Others include saddle shape and short-cell, and trichomal cell comparative to gramineae family and pseudoschizeae (Figure 8). Percentage record dominated by *Arcella megastoma*, *Centropyxis laevigata* and *Cyclopyxis* spp.(Figure 9) along with the algal remains of only *Botryococcus* colonies (Figure 8.1 & Fig. 8.2) were recorded.

Phase 2 (0-0.30 m):The organic matter assemblage in the sediment here shows moderate to high lake productivity. But pollen assemblage of arboreals decreased over non-arboreals coupled with sharp decline in pollen assemblage of Evergreen trees (Figure 5). These included *Capparis* (1.2%), Dipterocarpaceae (1.8%), *Elaeocarpus* ((1.8%), *Eucalyptus* (5.9%), *Mangifera* (2.3%), Moraceae (1.2%) and *Shorea* (2.4%). The dry deciduous pollen comprise of introduced plant taxa such as *Bombax*

(8.4%), *Butea* (3.5%), *Casuarina* (5.1%), *Chorisia* 7.6%), *Garuga* (1.7%), *Holoptelia* (4.1%), *Terminalia* (4.6%). Herbs and shrubs comprise of high percentage of Asteraceae (5.5%), *Hibiscus* (11.4%), *Acanthus* (1.8%), Cucurbitaceae (5.9%), Papavaraceae (3.7%), Umbelliferae (3.7%) and Chenopodiaceae (19%). The ubiquitous pollen like Poaceae/ Cyperaceae constitute 17.3 per cent of the pollen sum. The diversity and percentage of fresh water thecamoebians (Figure 9) is high comprising of *Arcella vulgaris*, *A. artocrea*, *A. megastoma*, *Centropyxis arcelloides*, *C. aerophila*, *C. laevigata*, *Cyclopyxis*, *Cucurbitella tricuspis*, *Diffflugia* spp. *Trigonopyxis* spp. (Figures 8.18 to 8.26).

3.1.3 Phytolith

In Phase 1, the highest percentage is of short silica phytoliths- bilobates (19.6%) followed by cuticular remains of millets (18.1%), short saddle (13.4%) and cross (10.8%) phytoliths (Figure 11) types. The rondel and trapezoid phytolith count shows 6.8 and 2.5 % , respectively. Wheat and Barley type show only 1.0% along with collapsed saddles that account to only 2.4%. However, Bulliform and other unidentified rod shape phytoliths account to total 28.2 % of the total count of phytoliths. The phytolith morphotypes recorded are given in Figure 10.

In Phase 2, the average the highest percentage is of cuticular remains of millets (18.4%) followed by short saddle (14.8%), cross (10.5%), collapsed saddle (7.4%) and rondel shape (6.3%). No significant cuticular remains of wheat or Barley phytoliths have been recorded. However, Bulliform and unidentified phytoliths constitute average 26.1 % of the total count.

3.2 Kaj

*Sedimentology and Radiocarbon:*The colour of the sediment in the entire section (1.50 m deep) is 5YR6/4 on the basis of Munsel's colour chart. The sediment is fine clay except that the basal sediment (1.35-1.50 m) contains natural small and hard irregular clayey calcareous nodules. Table-2 shows that the sediment at 1.20-1.35 m dates back to 3600 \pm 120 years BP (~1960 Cal BC). The dates however, again coincide with the Harappan settlement in this site too. At 0.60- 0.75 m the Radiocarbon date is 930 \pm 90 years BP (~1120 Cal AD). The salinity (0.1ppt) in the aqueous soil solution remains uniform throughout in the entire section. No changes in the physico-chemical characteristics of the sediment in Phase 3 were observed.

3.2.1 Archaeological Remains

The archaeological remains of Harappan period were traced in 4 layers in the sediment limited to in Phase 1 (1.00-1.50 m depth of the trench). The large number of pottery collected here includes fine red, coarse red and buff ware. The majority of the shapes are similar to those found at Kanjetar, comprised of variety of bowls, carinated dish and dish-on-stand. A large number of pot sherds painted with various colours such as black over red, white over red, purple over red were recorded. The pattern of paintings includes wavy lines, dotted circles, cross lines (Figure 4). The faunal remains from Kaj resemble that of Kanjetar which include both of domestic and wild animals. Except one crab (*Scylla serrata*), all other skeletal elements belong to mammals. The domestic mammals consist of cattle, buffalo, sheep/goat, dog and cat. The wild mammals identified by Gaur et al., (2011) were the Nilgai (*Boselaphus tragocamelus*) and blackbuck (*Antelope cervicapra*).

In Phase 2, a large number of medieval period pottery, primarily black ware and a couple of glazed sherds were collected during the excavation. The important shapes are jars, cooking vessels and lids. A large number of copper coins (Figure 4) of medieval period were also present in the excavation site which was collected earlier by the local residents around the site.

3.2.2 Palynology and Fresh water Thecamoebians

Phase 1(1.00-1.50m): The dominance of cyanobacterium (similar to *Chroococciopsis*) (Figure 12.1-12.3) in the beginning of this Phase (1.50-1.30 m) along with the low percentage of plant organic matter and thecamoebians. Appearance of *Botryococcus* (Figure 8.1 and 8.2) colonies and high pollen percentage particularly, of evergreen /semi-evergreen tree taxa dominate in the latter part (1.00-1.30 m) of this phase. In this phase, the average percentages of the Evergreen and Semi-evergreen pollen (Figure 6 and 7) are Anacardiaceae (3.1%), Bignoniaceae (3%), *Canarium* (0.7%), *Chrysophyllum* (3.3%), *Dillenia* (0.7%), *Dipterocarpus* (4.2%), *Elaeocarpus* (6.5%), *Ficus* (8.0%), Moraceae (9.0%), Myrtaceae (2.0%), *Nothopegia travancorica* (1.0%), Oleaceae (1.0%), *Palaquium* (0.7%), Sapotaceae (3.5%), *Schleichera* (4.2%), *Shorea* (3.2%), *Tilia* (2.0%), *Trewia* (0.3%) and *Sonneratia*- mangrove tree (0.1%) (Table -3). The average percentages of deciduous pollen grains are *Balanites* (1.8%), *Bombax* (5.5%), *Casaeria* (1.2%), *Chorisia* (1.1%), *Garuga* (1.0%), *Lagerstroemia* (2.5%), *Tectona* (1.2%) and *Oldenlandia* (0.9%). The non-Arboreal pollen comprise of *Acanthus* (1.5%), *Argemone* (0.9%), Brassicaceae (0.2%), *Capsicum* (0.2 %), *Clematis* (0.9%), Euphorbiaceae (2.8%), *Hibiscus* (2.8%), *Lawsonia* (0.9%), *Plantago* (2.5%), *Tinospora* (1%), Cerealea ((9.2%). The percentage of

Poaceae/Cyperaceae is 2% against the pollen sum. Out of pollen sum the percentage of aquatic pollen is 0.8% (Figure 6). High percentage of *Cerealia* pollen indicate agricultural activity. A bug resembling human lice, abundance of burnt plant tissue and Phytolith cells of gramineae and banana phytolith (at 1.15-1.30 m depth) were recorded (Figure 8) in palynological slides. Thecamoebians like *Arcella artocrea*, *A. megastoma*, *Centropyxis laevigata*, *C. aerophila* and *Cyclopyxis* spp. were common (Figure 9).

Phase-2 (0.30-1.00 m): Palynological results show a sharp decline in arboreal pollen with an increase in deciduous pollen and non-Arboreals. The evergreen and semi-evergreen pollen reduce both qualitatively and quantitatively. The average percentage of these comprise of *Dipterocarpus* (2.2%), *Elaeocarpus* (5.3%), *Ficus*, 5.4%), Moraceae (9.2%), Myrtaceae (1.2%), Sapotaceae (7.1%) and *Shorea* (2.8 %). The deciduous pollen taxa show rare appearance and comprise of *Lagerstroemia* (2.2%), *Myrtagyna* (2.6%) and *Tectona*, (0.5%). A very low percentage of non-arboreals was recorded which include *Asteraceae* (4.2%), Euphorbiaceae (2.0%) and *Oldenlandia* (1.2%). The poaceae/ cyperaceae constitute 7.2 % of the pollen sum. The sediment here shows increase in organic matter and black unidentified debris that later reduced gradually. Aquatic pollen (average 3.7%) particularly, submerged *Myriophyllum* and swampy *Typha* were recorded (Figure 6). However, *Ludwigia* shows reduction. The dominance of thecamoebians like Centropyxids and *Arcella* spp. were recorded (Figure 9).

Phase -3 (0-0.30 m): A very low percentage of arboreal or non arboreal pollen was recorded (Figure 6). Among the arboreals, the average percentage of *Boswellia* show 2.0%, *Butea* 1.8%, *Casuarina* 2.4%, Euphorbiaceae 1.9 %, *Eucalyptus*, *Hardwickia* and *Holoptelea* constitute 4.1 %, *Mangifera* 4.8 %, Myrtaceae, 2.2% and Sapotaceae 4.6%. Other Non-arboreals (Figure 6) show about 2-3 % with increase in Asteraceae (7%). Out of pollen sum, the Poaceae/cyperaceae and aquatic pollen constitute an average of 29.2 % and 1.25 %, respectively. A heterogenous type of organic matter assemblage was recorded. Dominance of *Centropyxis laevigata* along with low percentage of *Arcella* spp. was recorded in this phase (Figure 9).

3.2.3 Phytolith

In phase 1, the average percentage of rondel shape is 7.4 and trapezoid is 7.5 (cool & moist conditions). The highest percentage is of bilobates (23.9) followed by short saddle (15.0), that are representatives of more warm and dry conditions and crops like millets is 12.6% and wheat 2.1% (Figure 10 & Figure 11). In phase 2 the average percentage of both rondel (5.4%) and trapezoid (2.2%)

phytoliths reduce steadily with a sharp increase in bilobates (24.6%) followed by bulliform (20.8%) and short saddle (14.9%). Millets (*Pennisetum* sp.) increase (14.5%) followed by a slight increase in wheat phytolith (3.5%) as well. In phase 3 the average percentage of all the forms is similar to as recorded in phase 1 with a slight reduction in crop phytolith (both millets and wheat). Phytolith evidences of *Hordeum*, *Triticum* (winter crop) and *Avena* have been recorded. *Lolium* (autumn/early winter- March to June), *Pennisetum* (drought-tolerant, short duration and most suitable fodder crop for dry farming areas) are more prominent in Phase 2 of both the sites.

4.0 Discussion

The archaeological remains in Kaj and Kanjetar such as seal, weight, terracotta cake, beads etc. were not recorded which indicate that this was not an urban centre of Harappan settlement. However, the settlement in both the sites sustained on massive exploitation of marine resources for their dietary habits and could have played an important role in developing Urban Centers at Lothal and Rojdi in the region (Gaur et al., 2009). The Sorath-Harappan potteries recovered in Kanjetar shows similarity with those found in the sites on western coast such as, Bet Dwarka (Gaur et al., 2005) and Bokhira (Gaur, et al., 2006) in Gujarat. These also resemble closely with Prabhasa ware (situated ~40 km west of Kodinar), a chalcolithic site contemporary to Harappan site (Sankalia, 1974). The ceramics include sturdy red ware similar to the mature Harappan pottery (Rao, 1985), and variety of bowls of fine ware similar to the Sorath-Harappan type (Possehl and Raval, 1989). The important shapes include jars, bowls, dish on stand and a goblet. Similarly, Kaj was initially habited during the Harappan times and later during the historical and medieval period.

The sediment depositional environment in Kanjetar and Kaj is lacustrine to fluvio-lacustrine influenced by the dynamics of Shingoda and Macchundri river mouth since ~4000 years. The salinity of the aqueous soil solution is consistently 0.1 ppt in both the sites except in Phase 2 from Kanjetar. Increase in salinity here could be due to accumulation of salts facilitated by the upward movement of water in soil through capillary action in areas exposed to evaporation. This usually occurs in moisture deficit soil resulting into calcification/ salinization. Under such conditions the clay particles are chemically reactive to attract and hold more ions (Hiller, 2003). The meager increase in salinity (0.2ppt) in clayey sediment (Kanjetar) could be due to evaporation effect from exposed land rather than saline sea water intrusion. In Kaj, the salinity of the aqueous soil solution (0.1ppt) is uniform indicating constant fresh water inundation restricting upward movement of water and salt accumulation. At present

this site is known as bird sanctuary. Both the location of the studied site was an extended part of the water body formed by Shingoda and Macchundri River mouth in Kanjetar and Kaj, respectively. Despite being very close to sea, the values of salinity is within the range of fresh water (0 - 0.5 ppt) in both the sites. The damming and isolation of the fresh water from being contaminated by sea water was perhaps monitored by the settlers for their need of fresh water in the coastal region. The source of fresh water in both the sites largely depended on the monsoon driven river/streams as the situation is at present except that the configurational changes would have occurred in the river mouth through time. The source of fresh water input was consistent in Kaj site, therefore, this location favoured as safe harbour even during historical and medieval periods as evidenced from the discovery of amphorae and stone anchor from the site.

A single pollen of *Sonneratia* and *foraminifera* lining from Kaj in Phase 1 shows nearness to shoreline and suggest possibility of contamination. Unaccountable marine palynomorphs and aqueous soil salinity ranging from 0.1 -0.2 ppt probably do not show sea water intrusion in both the studied sites. Calcareous nodules and low terrigenous organic matter in the bottom sediment shows its cutoff from terrigenous input or *in situ* production perhaps due to desiccating conditions. However, the abundance of Cyanobacterium resembling *Chroococciopsis* shows that the area was perhaps the leeward shore subjected to desiccation. This cyanobacterium is capable to survive as a common primary producer occurring in both hot and cold extreme arid conditions (Desikachary, 1959; Billi et al., 2000; Grilli Caiola et al., 1996). Low diversity of thecamoebians at this depth is attributed to either anoxic conditions created by the cyanobacterium and or scant fresh water input with dry condition during most of the time. Absence of aquatic pollen from Kanjetar and very low percentage from Kaj reveals desiccating conditions during most of the time ~2000+/- 400 BC as the fresh water influx in the area largely depended on monsoon fed rivers/streams. Overall results strongly points towards dry/arid climatic conditions during this period.

Later, the above successive sediment in Kaj shows appearance of *Botryococcus* and increase in diversity of thecamoebians along with the increase in terrigenous organic matter input indicating enhanced limnic conditions. The results here indicate a change in climatic pattern towards humid spells, but the configurational changes in the coastland and consequently the loci of freshwater input through monsoon fed riverine system cannot be ruled out. The colonies of *Botryococcus* observed in the present study show spiny folds that gets shrunked after acetolysis in palynological slides. The colonial tough and elastic membrane of *Botryococcus* on its outer surface is known to occur into irregular wrinkles,

processes and spiny lobes (West & West, 1903). It has been known that *Botryococcus braunii* (Kutzing 1849) consist of connecting strands and mucilage which is generally abundant at lee shores forming scums (Medeanic, 2006; Medeanic and Silva 2010).

Centropyxis and *Arcella* species are among the most common of the testate amoebae residing in varied lentic ecosystems and are considerably high in Oligotrophic lakes (Glime, 2012). These are sensitive to Dissolved Oxygen (DO) related to seasonality (Farooqui et al., 2012) and salinity status in coastal wetlands (Farooqui and Naidu, 2010). It is apparent from results that with the improved limnic conditions in late phase 1 and phase 2, the thecamoebians and aquatic pollen too increased in succession.

The palynological study reveals dominance of evergreen and semi-evergreen tree pollen ~2230 to 1960 BC. The dominance of evergreen moist tree taxa during this period recorded from both the sites is probably the remains of the vegetation in the region that flourished during the previous wetter climatic conditions of the middle Holocene. Therefore, it is inferred that the average annual rainfall in the studied sites and in the northeastern part, which is now conserved Gir forest would have been receiving higher than or equal to ~1000 mm rainfall during this period that facilitated the existence of evergreen/semi-evergreen and moist deciduous trees. As compared to Kanjetar the pollen assemblage was richer in Kaj. Thus, Kaj was well connected with the drainage system and most of the evergreen pollen recorded from this site would have been transported either from the hinterland forest area or from riparian forest along the streams and rivers receiving high precipitation (>1000 mm) than present (< 600-700 mm). This could be the reason for an increase in arboreal pollen in latter part of Phase 1. A considerable good percentage of burnt phytolith cells, cuticular remains of crop plants, phytoliths of palm and banana (volcaniform), pollen of *Trapa*, bugs resembling human lice and economically important trees along with the significant archaeological remains provide adequate evidences of Harappan activities. The Kaj site shows more cultural activity and forest cover along with the evidences of bones of wild and domestic animals. Therefore, among both the studied sites, Kaj was characterized by thick vegetation in the vicinity, more limnic conditions and well connected with the source of fresh water through rainfed river system representing the true picture of regional vegetation. The analysis of the relative ratio between dry deciduous and evergreen moist plant taxa and vice- a- versa in the studied samples show steady increase in seasonality since ~4000 years (Figure 13) whereby the vegetation evolved from evergreen to dry deciduous forest typical of present day Gir forest in the north-eastern side. The relative low/high percentage of thecamoebians in the sediment from both the sites reveals increase in limnic conditions perhaps due to changes in the wetland configuration induced by river

dynamics. However, during the past two millennium a gradual replacement of deciduous tree taxa from Kaj and Kanjetar clearly provide evidence of increase in aridity and dry climatic conditions in the region. However, the intervening signatures of short-term wetter phase of the Medieval Warm Period is evident in both the sites. Pollen record of exotic plant taxa like *Casuarina* and *Eucalyptus* in the surface (0-0.10 m depth) sediment supports a continuity of human habitation around Kaj till recent. The poaceae/cyperaceae pollen increase two-fold in succession indicating more open forest condition in the recent millennium than in ~2000 BC. Both Climate and anthropogenic activity enhanced the downfall of evergreen forest in the vicinity as the dwellers in the region made strategic changes and expansion in agriculture for sustenance. In the present study phytolith data shows low percentage of *Hordeum*, *Triticum* (well established winter season crops) and abundant cuticular remains of millets (*Pennisetum* and *Avena*), drought-tolerant plants in both the sites after ~2000 BC. This is in contrast with the well established winter season crops (Wheat, Barley) of early Harappans, suggesting adjustment in terms of subsistence strategies and increasingly reliance towards more drought tolerant rain-fed crops (millets). The phytolith studies of a late Holocene sequence in mainland Gujarat too provide evidence of extremely weak winter as well as South West monsoon resulting into the onset of dry climatic conditions during mid Holocene (Prasad et al., 2007). The volcaniform phytolith of banana (*Musa/Ensete*) shows that it probably grew along with the evergreen forest community in Kaj or in the hinterland provenance. With just the record of one-two phytolith of banana in the sediment it is very difficult to identify wild or cultivated banana. Had it been cultivated or in frequent use the evidences of these should have been more prominent in the studied sites. However, speculations still remain regarding an early dispersal of edible cultivated bananas from South-east Asia by the third millennium B.C (Fuller & Madella, 2009).

The entire Indian subcontinent is more affected by the south-west monsoon (SWM) precipitation except the southern tip of the Indian peninsula. The annual rainfall accounts to about 20% in the north-western part of India that configures the lake ecosystem and is complemented by lower winter evapotranspiration rates (Rao, 1981). The steep rainfall gradient ranging from 600-2000 mm in the NW India (Figure 3) makes this region quite sensitive to small scale climatic fluctuations affecting the lake ecology and vegetation. A shift in aridity ~4.2 ka from marine evidences has been linked with downfall of Harappan Civilization (Staubwasser et al., 2003). Vishnu-Mittre (1974), Prasad et al. (1997), Kajale and Deotare (1997), Prasad and Enzel (2006) too suggest the onset of drier conditions during this period that was induced by weakening of summer and particularly the winter precipitation. A correlation of

short term climatic events from the NW India has been reviewed by Prasad and Enzel (2006). During the late-Holocene, shortening in the length of the monsoon season in response to decreasing solar insolation was due to continuous southward migration of mean summer ITCZ (Fleitman et. al., 2007) from 7.8 ka to present (Fig.14). Consequently, the downfall of evergreen moist deciduous forest and its replacement by dry deciduous forest is evident from palynological study throughout in the Indian sub-continent (Farooqui, 2013) suggesting steady weakening of monsoon and increased seasonality (7-8 months of dry period per year). In view of the above and other records from India (Meher- Homji & Gupta 1999) it is concluded that throughout the Indian sub-continent and in most parts of the world (Brooks, 2006) the climate (increasing aridity) played an important role in vegetation succession and human adaptation during late Holocene. Giosan, et al. 2012 reported that as a result of climate deterioration, a drastic increase in shifting of Harappan settlements in the more moister monsoon regions of the upper Punjab, Haryana, and Uttar Pradesh was obvious. Thus, with the same strategy the Harappan domain was extended or shifted in the comparatively moister south-east or southern Saurashtra coast too.

5.0 Conclusion

The multi-proxy data obtained from the sediment profile retrieved from Kanjetar and Kaj shows fluvio-lacustrine depositional environment influenced by the configurational changes in the river mouths of Shingoda and Macchundri, respectively since ~4000 years. The vegetation in the region evolved from evergreen/ moist forest to deciduous forest. The pollen record was not in equilibrium with the prevailing climate during the amelioration period (moist to dry) between ~4000-2000 years. But stabilized after ~2000 years and remained in equilibrium with the prevailing dry/arid climate that continues till date in the region. Human habitation in both the archaeological sites in Kanjetar and Kaj depended on fresh water that was channeled and dammed from the mouth of Shingoda and Macchundri rivers for agrarian/ domestication activities. Among both the sites, Kaj was characterized by thick vegetation, more limnic conditions and well connected with the source of fresh water representing the true picture of regional vegetation. The moister climatic conditions and comparatively rich forest cover around the Saurashtra coast was one of the main attractive reasons for the expansion and settlement of Harappans as they largely sustained on agriculture and domestication along with the maritime activity. Change in agricultural strategy by introducing drought-tolerant crops like millets due to the climate shift towards aridity and other cultural evidences from both the studied sites indicate Harappan settlement which was not an urban site.

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Table 1- Physico-chemical properties and Radiocarbon dates of the sediment (organic carbon) in Kanjetar, Junagarh, Gujarat

Depth (cm)	Color	Texture (Kankar type)	Salinity (ppt.)	pH	Total Dissolved Solids (mg/l)	Conductivity ($\mu\text{S}/\text{cm}$)	^{14}C Dates (yrs. BP) $\delta^{13}\text{C}$ value (-25 \pm 3)	2 σ Calibrated date range & Calibrated Age
0-10	5Y3/4	Coarse Clay	0.2	8.2	207	423		
10-20	5Y3/4	Coarse Clay	0.2	8.3	3187	319	780 \pm 150 3187 (BS)	970-1440 Cal AD 1210 Cal AD
20-30	5Y3/4	Coarse clay	0.1	8.4	3158	259.6		
30-40	5Y3/4	Coarse Clay	0.1	8.7	140	286.4		
40-50	5Y3/4	Coarse Clay	0.1	8.9	110	225.2	3810 \pm 100 3158 (BS)	2490-1970 Cal BC 2230 Cal BC

Table 2- Physico-chemical properties and Radiocarbon dates of the sediment (organic carbon) in Kaj, Junagarh, Gujarat

Sample No.	Color	Texture	Total Dissolved Solids (mg/l)	Conductivity ($\mu\text{S}/\text{cm}$)	Salinity (ppt.)	pH	^{14}C Dates (yrs. BP) $\delta^{13}\text{C}$ value (-25 \pm 3)	2 σ Calibrated date range & Calibrated Age
0-15	5YR 6/4	Fine Clay	75	154.1	0.1	8.1		
15-30	5YR 6/4	Fine Clay	74	151.8	0.1	8.2		
30-45	5Y6/4	Fine Clay	76	154.7	0.1	8.3		
45-60	5YR 6/4	Fine Clay	59	120.5	0.1	8.3		
60-75	5YR 6/4	Fine Clay	68	139.0	0.1	8.2	930 \pm 90 3157 (BS)	970-1270 Cal AD 1120 Cal AD
75-90	5YR 6/4	Fine Clay	62	127.1	0.1	8.3		
90-105	5YR 6/4	Fine Clay	69	140.1	0.1	8.3		
105-120	5YR 6/4	Fine Clay	70	142.8	0.1	8.3		
120-135	5YR 6/4	Fine Clay	74	150.5	0.1	8.4	3600 \pm 120 3151 (BS)	2290-1640 Cal BC 1960 Cal BC
135-150	5YR 6/4	Fine Clay (Kankar type)	63	129.4	0.1	8.4		

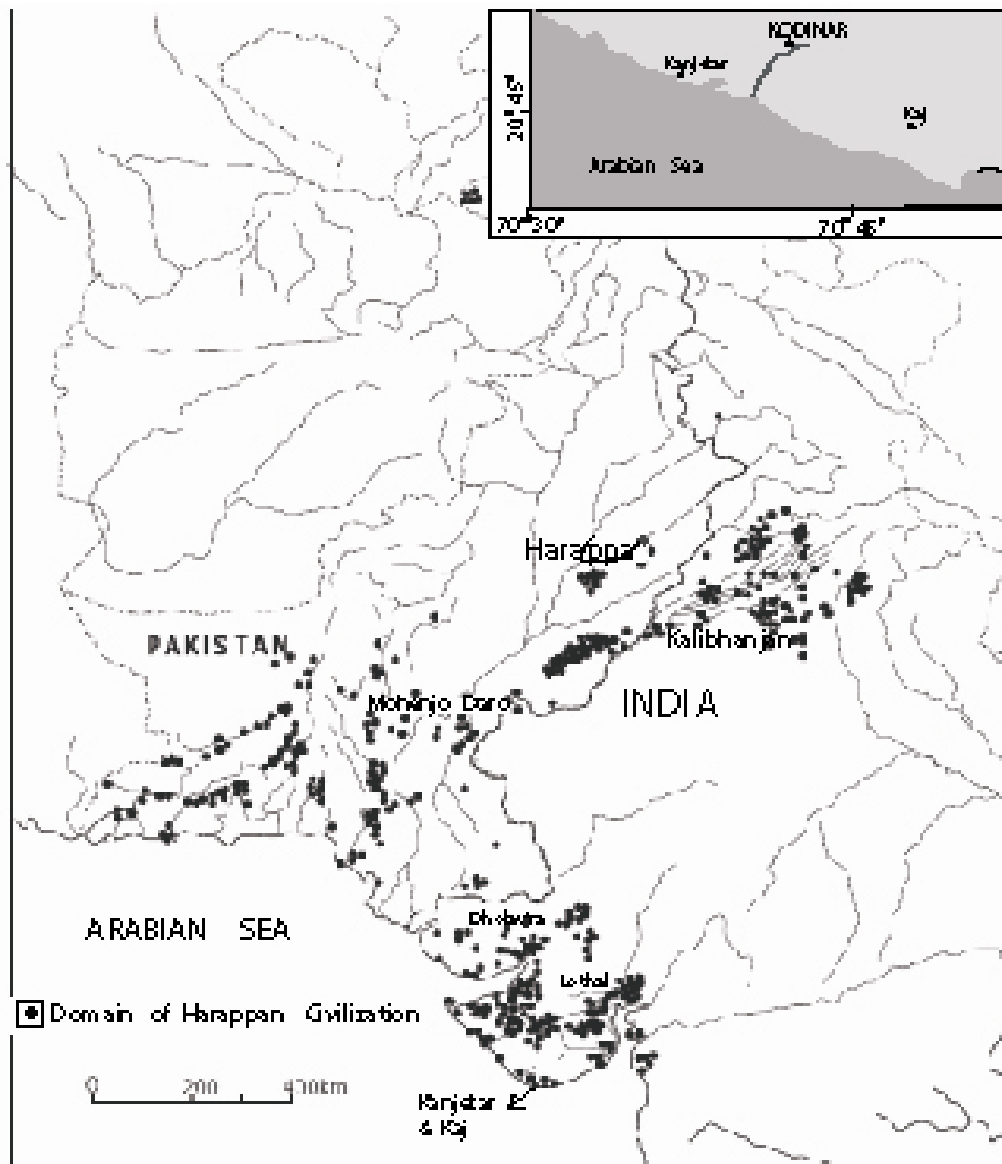


Figure 1

Figure 1- Location of Kanjetar and Kaj in the domain of Harappan Civilization

Figure 2

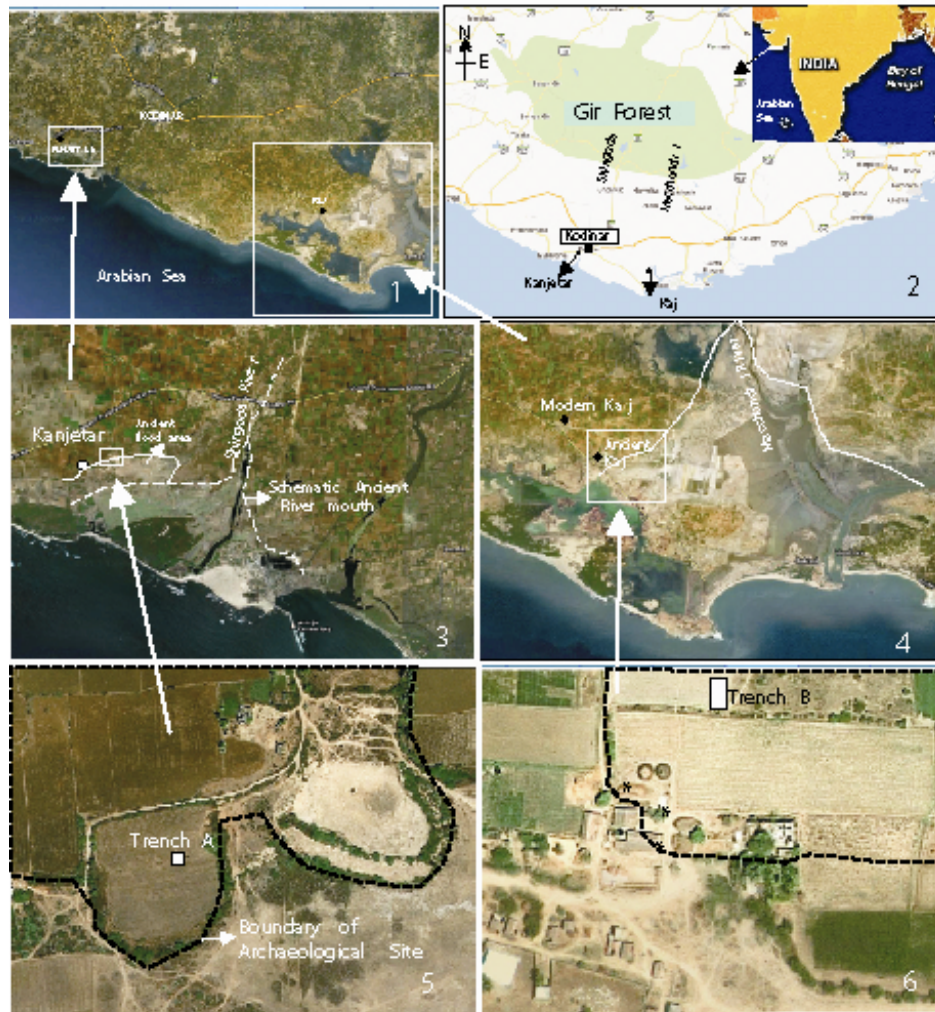


Figure 2

Figure 2-The maps showing proximity to conserved Gir forest and the details of the studied site Kaj and kanjetar along the Saurashtra coast, India

- 2.1, Location of Kanjetar and Kaj along the Arabian sea coast;
- 2.2, Proximity of Gir Forest from the studied sites;
- 2.3, The proximity of river mouth from Kanjetar;
- 2.4, The proximity of river mouth from Kaj;
- 2.5, The location of trench in Kanjetar within the archaeological site;
- 2.6, The location of trench in Kaj within the archaeological site.

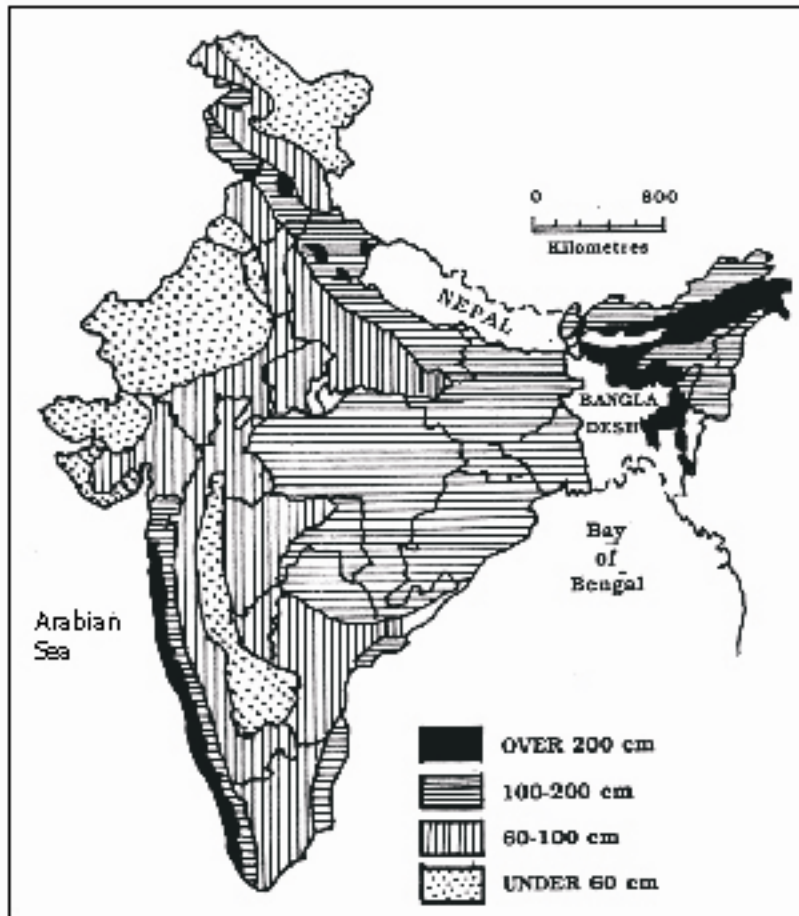


Figure 3

Figure 3- Map of India showing average annual rainfall



Figure 4

Figure 4- Archaeological artefacts recovered from Kaj and Kanjetar (scale -0.05 m).

- 4.1. Harappan ceramics (bowls) from Kanjetar.
- 4.2. Harappan ceramics (various other shapes) from Kanjetar.
- 4.3. Painted potsherds from Kanjetar.
- 4.4. Bowls with painted designs from Kaj.
- 4.5. Shell remains from Kaj.
- 4.6. Remains of stud-handled bowls from Kaj.
- 4.7. Medieval period coins from Kaj.

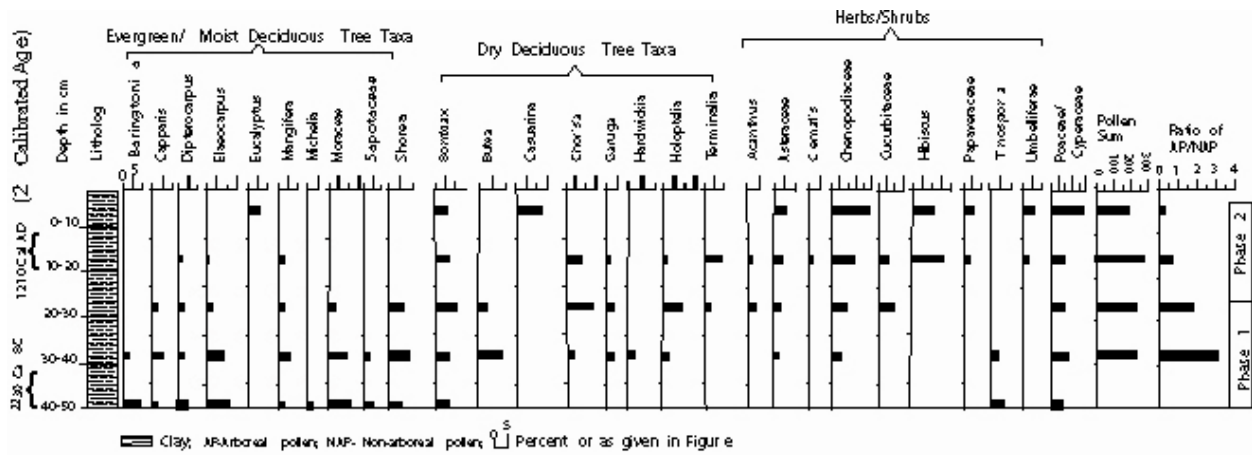


Figure 5

Figure 5- Palynological Spectrum of Trench A in Kanjetar, Kodinar, Gujarat

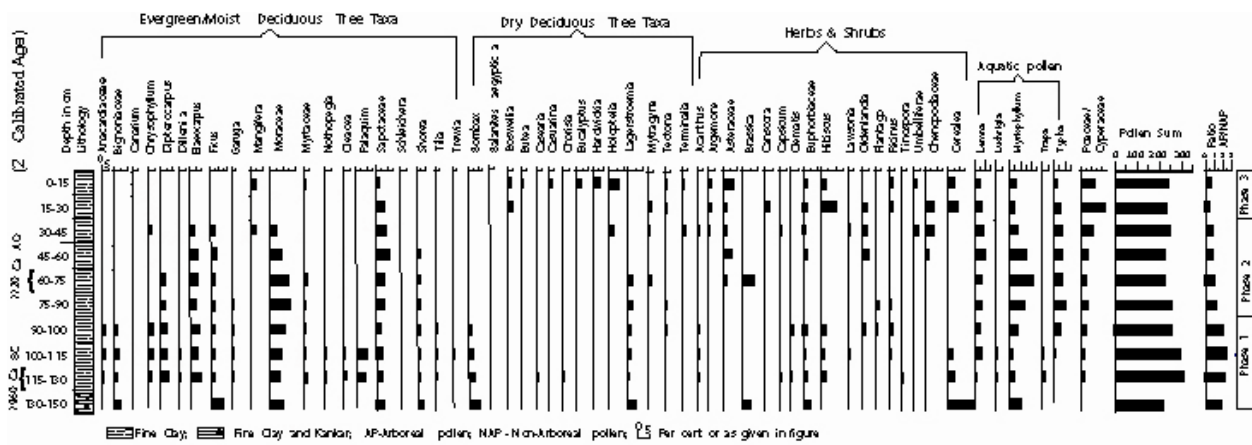


Figure 6

Figure 6- Palynological Spectrum of Trench B in Kaj, Kodinar, Gujarat



Figure 7

Figure 7- Light Microscopic photomicrographs of pollen (all scale=10 μ m)

1 *Casearia*, 2 Sapotaceae *Chrysophyllum*, 3 *Balanites aegyptica* (desert date), 4&5 *Nothopegia travancorica*, 6 Moraceae, 7 *Clematis*, 8 *Eichhornia*, 9 Bignoniaceae, 10 Euphorbiaceae, 11 *Elaeocarpus*, 12 Dipterocarpaceae, 13 *Sonneratia*, 14 & 15 *Lawsonia*, 16 *Ricinus*, 17 *Trewia*, 18 *Brassica*, 19 Rosaceae, 20 *Argemone*, 21 Euphorbiaceae, 22 *Dillenia*, 23 Moraceae, 24- 26 Rubiaceae, 27 *Lagerstroemia*, 28-29 *Tectona*, 30 *Schleichera*, 31 *Ficus*, 32 Cucurbitaceae, 33 & 34 *Mangifera*, 35 *Oldenlandia*, 36, *Holoptelea*, 37 *Boswellia*, 38 *Canscora*, 39 *Hibiscus* 40 *Xeromphis nilotica*, 41 *Mytragyna*, 42 Rosaceae, 43-45 Asteraceae, 46 Chenopodiaceae 47 *Holoptelea*, 48 *Typha*, 49 *Nuphar*, 50 *Plantago*, 51 Poaceae, 52, 53 *Cerealia*, 54 Caryophyllaceae ? 55 Bombacaceae, 56 *Canarium*, 57 *Cassia*, 58 *Eucalyptus* 59 *Ludwigia* 60 Burseraceae, 61 Uidentified, 62 *Acalypha*, 63 *Casearia*, 64, *Holoptelea*, 65 Uidentified, 66 Olacaceae, 67, 68 *Chorisia*, 69, *Bombax*, 70 Apocynaceae, 71&72 *Trapa*, 73 *Lemna*, 74 *Salvinia* microspore inside an empty cyst like body.

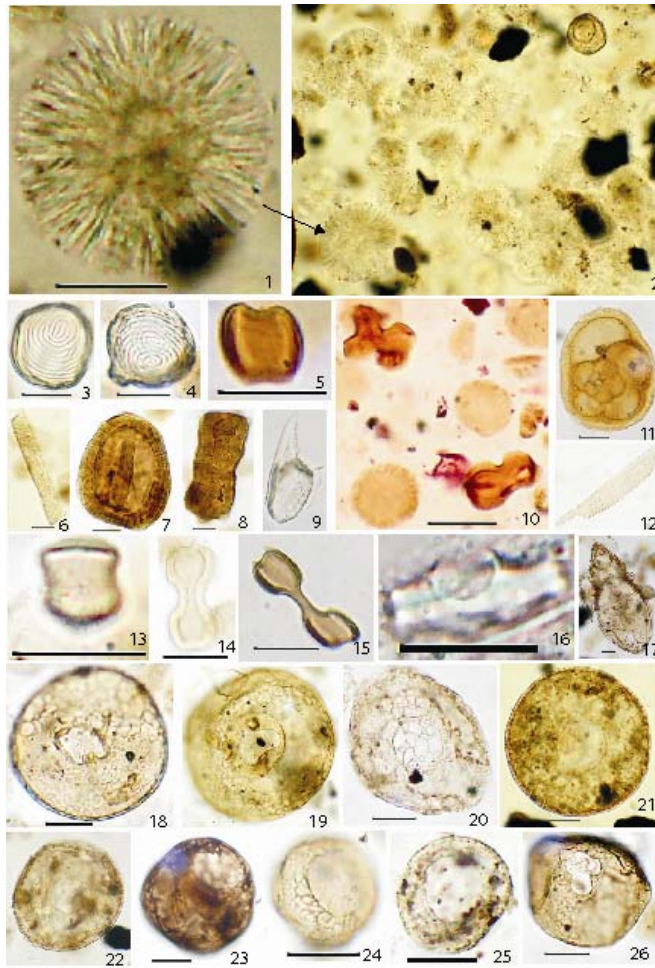


Figure 8

Figure 8- 1 *Botryococcus* colony (lobes shrunk to sickle like structure), 2 A view of *Botryococcus* abundance and thecamoebian (rt. corner), 3-4 Unique *Pseudoschizae* with an opening like structure, 5 saddle shaped phytolith, 6 phytolith (trachieds), 7-8 Palm cells, 9 siliceous spines of grass leaf, 10 Dumble shaped phytolith cells and *Botryococcus*, 11 Foraminifera lining, 12 Siliceous elongated cell of gramineae, 13-15 graminaceous leaf phytolith, 16 Volcaniform phytolith of banana leaf, 17 Human lice, 18-19 *Centropyxis laevigata*, 20 *Centropyxis arcelloides*, 21 *Arcella vulgaris*, 22 *Centropyxis*, 23 *Cucurbitella* 24 *Cyclopyxis*, 25 *Arcella megastoma*, 26 *Trigonopyxis* spp.

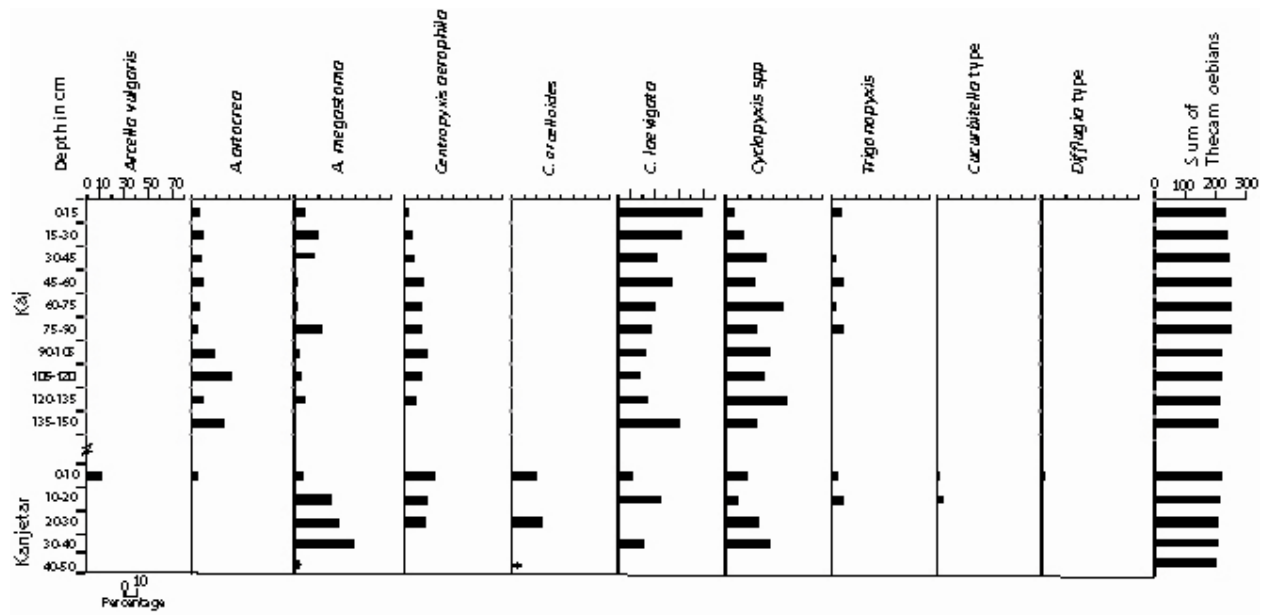


Figure 9

Figure 9- Percentage of thecamoebians recovered from Kanjetar and Kaj.

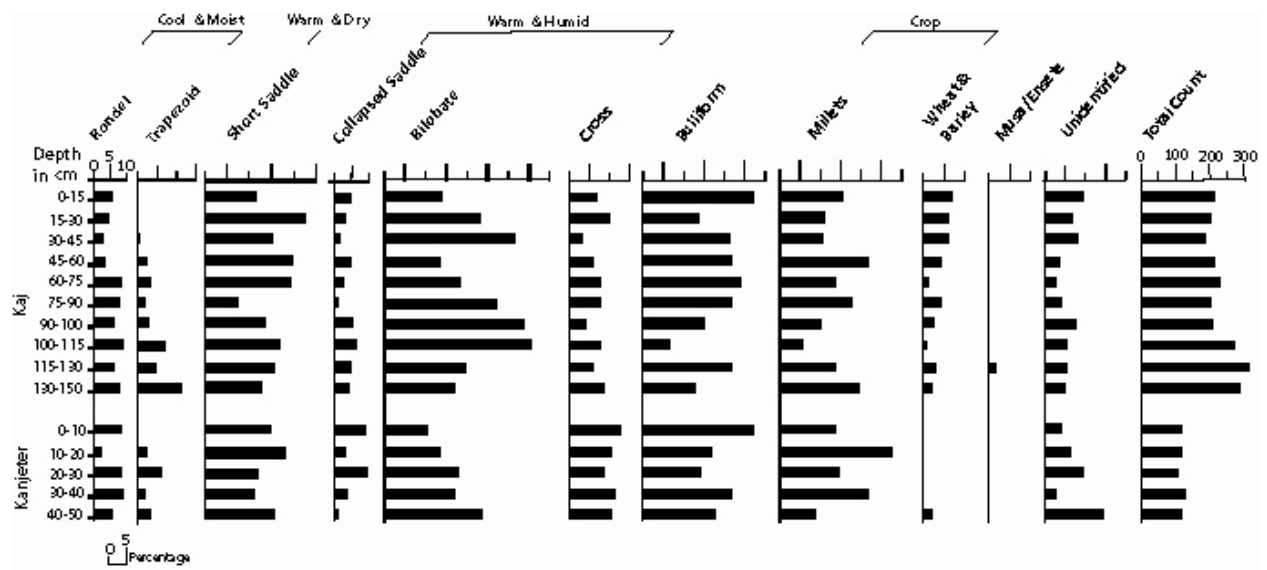


Figure 11

Figure 11- Phytolith counts in sediments from Kaj and Kanjetar

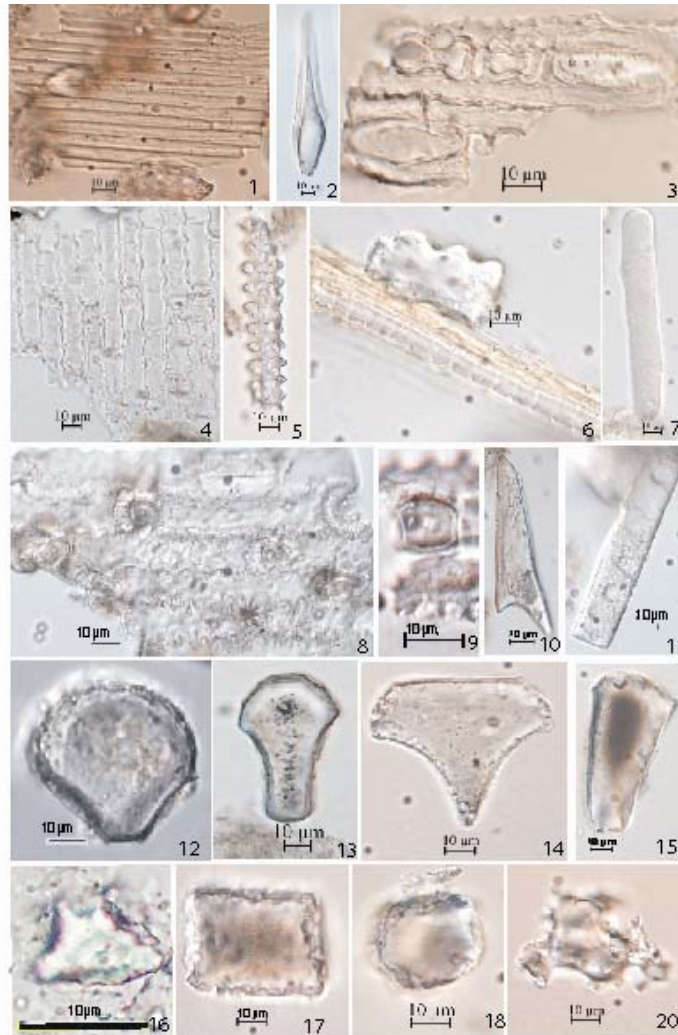


Figure 10

Figure 10- Light microscopic photographs of Phytolith morphotypes.

1 Culm epidermis of *Hordeum vulgare*, 2 *Hordeum* leaf spine, 3 Millet (*Pennisetum*), 4 *Lolium* (rye grass), 5 Wheat leaf phytolith, 6 Wheat phytolith, 7 unidentified, 8 *Hordeum* leaf phytolith, 9 saddle shape, 10 *Avena* long cell appendage, 11 Palm, 12 Rice Bulliform phytolith, 13& 14 Bulliform phytolith, 15 Burnt bulliform phytolith, 16 *Musa* (volcaniform phytolith), 17 Trapezoid shape, 18 Rondel shape, 19, multifaceted tree phytolith.

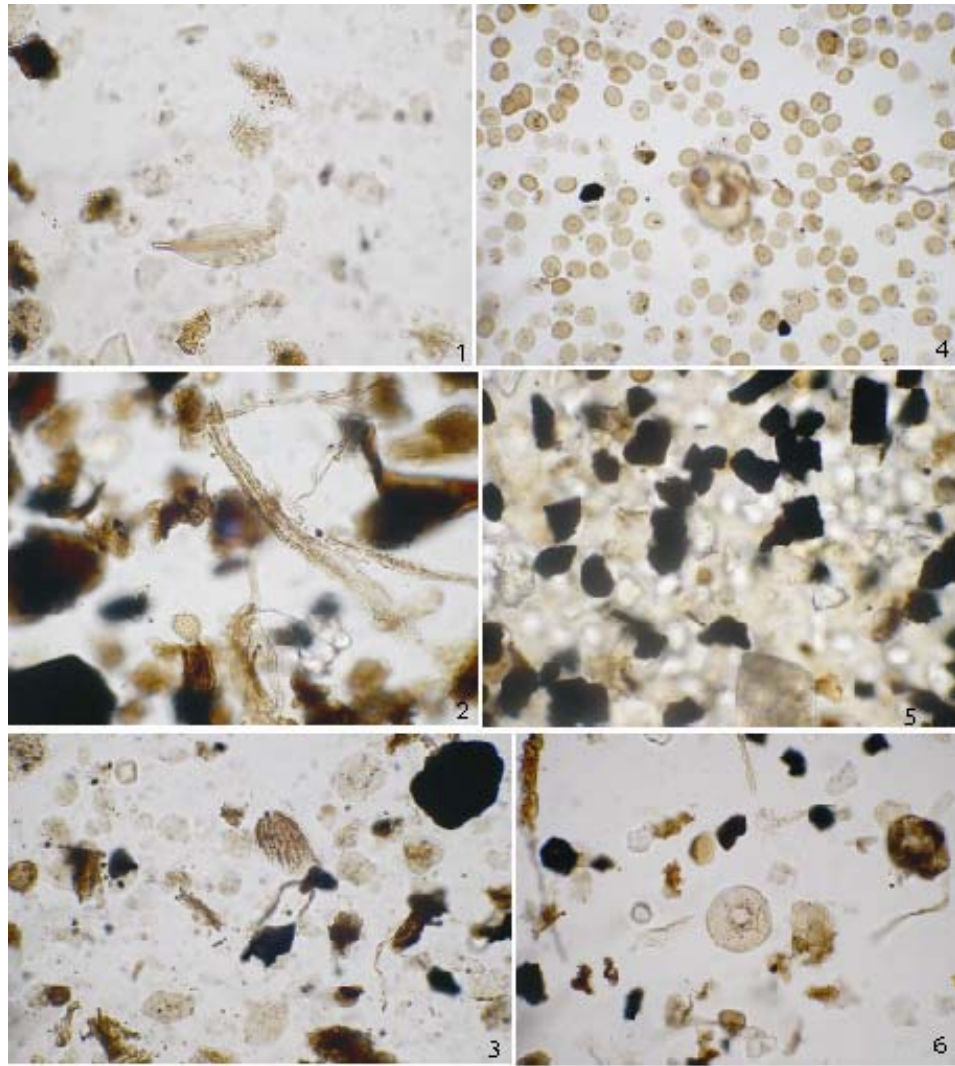


Figure 12

Figure 12- Qualitative nature of cyanobacterium. 12.1- Pollen grain of *Bombax* along with cyanobacterium; 12.2-12.3- repeated binary fission in three planes producing more or less regular cubical cell aggregates typical of *Chroococidiopsis*.

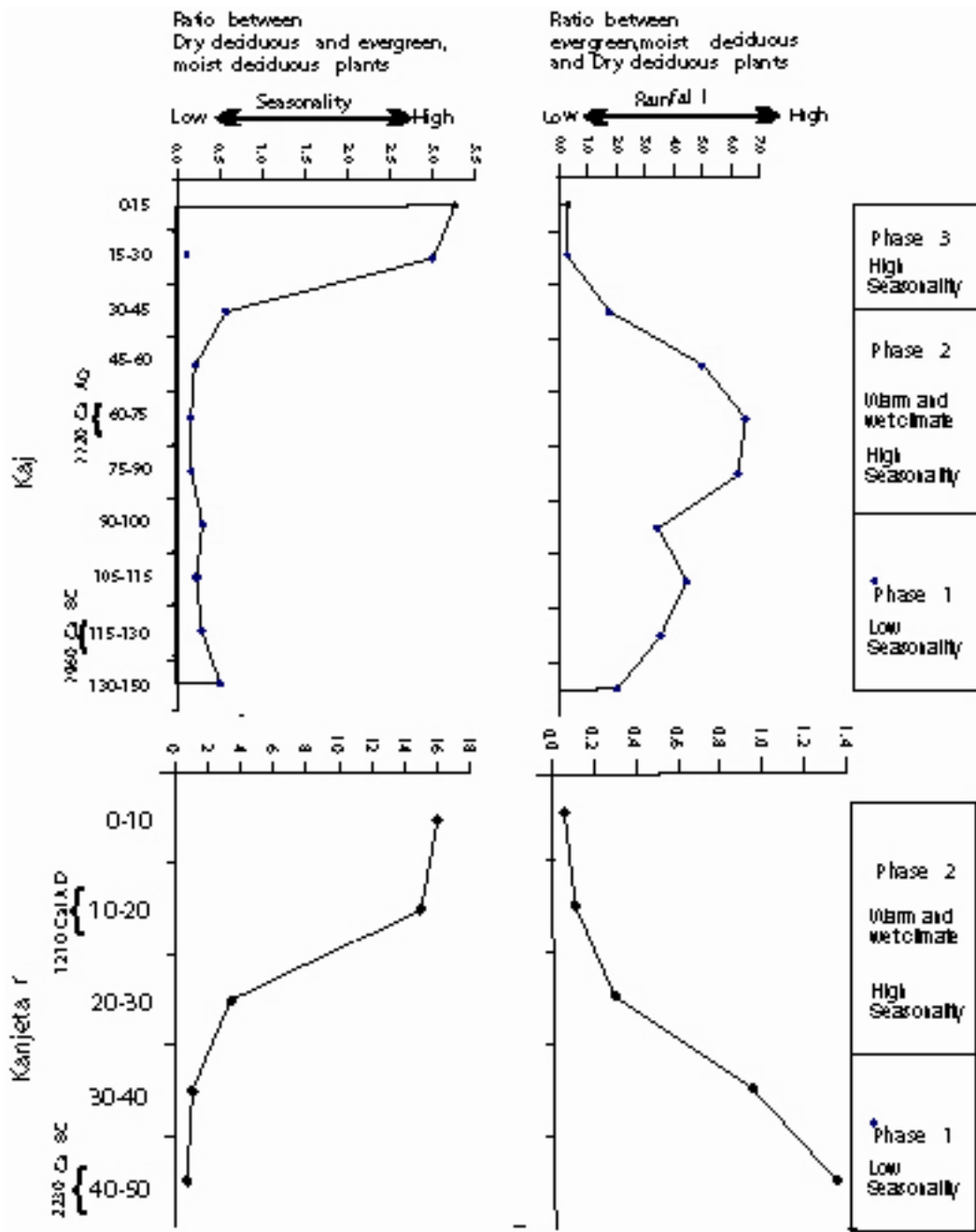


Figure 13

Figure 13- The climate-vegetation equilibrium in Kaj and Kanjetar

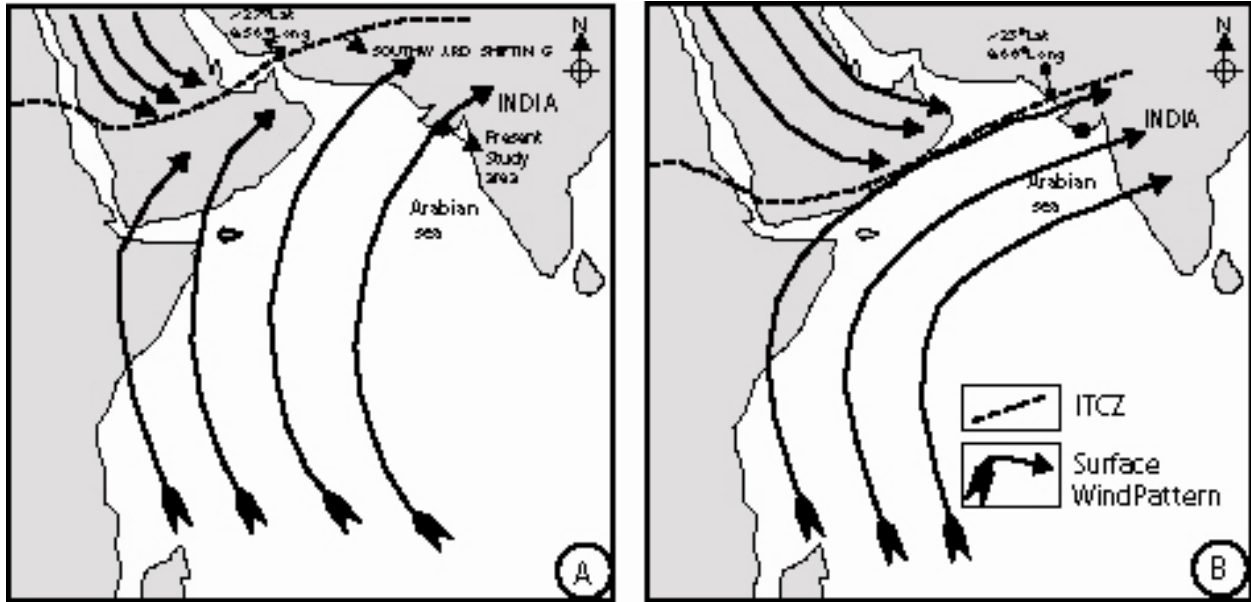


Figure 14

Figure 14- Southward shifting of Inter Tropical Convergence Zone (ITCZ) and surface wind pattern. A- around 7ka; B- Present position (Fleitmann, et. al., 2007).