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# Palaeoenvironments around the Harappan Port of Lothal, Gujarat, western India

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**ABSTRACT**
The palaeogeography and palaeoenvironments around Lothal, a Harappan port town, are reported based on remote sensing, environmental magnetic and Fourier transform infrared spectroscopy studies respectively. The results show that the uppermost part of the sediment record north of Lothal are characterized by low $\chi_{fd}$ implying reduced monsoon rainfall. This reduction of monsoon rainfall was accompanied by high sea levels and is comparable with other global sea level and palaeoclimatic records.

## INTRODUCTION

Lothal (Fig.1a) is one of the most fascinating remnant of the ancient Harappan Civilization covering an area of 64752 m$^2$ (Rao, 1985). The essential components of the town are a dockyard 37 m in length and 21.8 m wide to the west of which are located an 'acropolis', 'lower town' and a cemetery (Rao, 1985). Harappan Lothal has been interpreted to be primarily a port town. Rao (1985) suggested that the modern silted creek extending till Lothal represented the ancient river that was used by the Harappan people.

Little is known about the palaeogeography during the period in which Lothal was inhabited. Further less is known about the climate that prevailed before, during and at the terminal phase of the Lothal town. For resolving such issues, we used remote sensing data for addressing the palaeogeographical problem and measured mineral magnetic properties (magnetic susceptibility $\chi$ and frequency dependent susceptibility $\chi_{fd}$) along with mineralogical studies using vibrational spectroscopy.

## METHODOLOGY

For the present study geocoded IRS 1D, LISS-3 data was used. A peak summer scene was chosen so as to aid palaeochannel mapping as data from other months of the year obstruct such studies due to larger cloud cover and vegetation. The satellite imagery was analyzed using ERDAS Imagine image processing software. The decorrelation stretch algorithm was used to provide maximal tonal contrast for mapping palaeochannels (Fig. 2). Mineral magnetic measurements were carried out on a Bartington dual frequency MS2B magnetic susceptibility meter. Fourier transform infrared spectroscopy was carried out on a Nicolet instrument using alkali halide pellets. The characteristic peaks of individual molecular groups were normalized with respect to the silicate absorption band at 1020 cm$^{-1}$. For the present study we employ the relative abundance of carbonate (1436 cm$^{-1}$) with respect to silicate (1020 cm$^{-1}$) in order to see the effect of any dilution on the magnetic susceptibility values.

## RESULTS

Remote sensing studies help in delineating a meandering river adjacent to the town of Lothal. The character of this palaeochannel was studied in the satellite imagery for a stretch of 30 km. The palaeochannel is a northern extension of the broad channel bed of a tributary to the Bhogavo River. The Bhogavo River tributary has a very high width as compared to its height and is typical for tidal influenced channels. The Bhogavo River tributary abruptly dies out west of the village of Saragwala.

North of Lothal the sediments are brown to brownish black. The geomorphology of this region is featureless and devoid of topography, save for the mound of Lothal. In the satellite imagery, the palaeochannels are clearly identified by darker tones (Fig.2a). 9 km north of Lothal the river becomes increasingly sinuous and shows scroll bar complexes. The channel sinuosity for the upper segment is 2.5 as compared to 1.1 for the lower reaches. Also

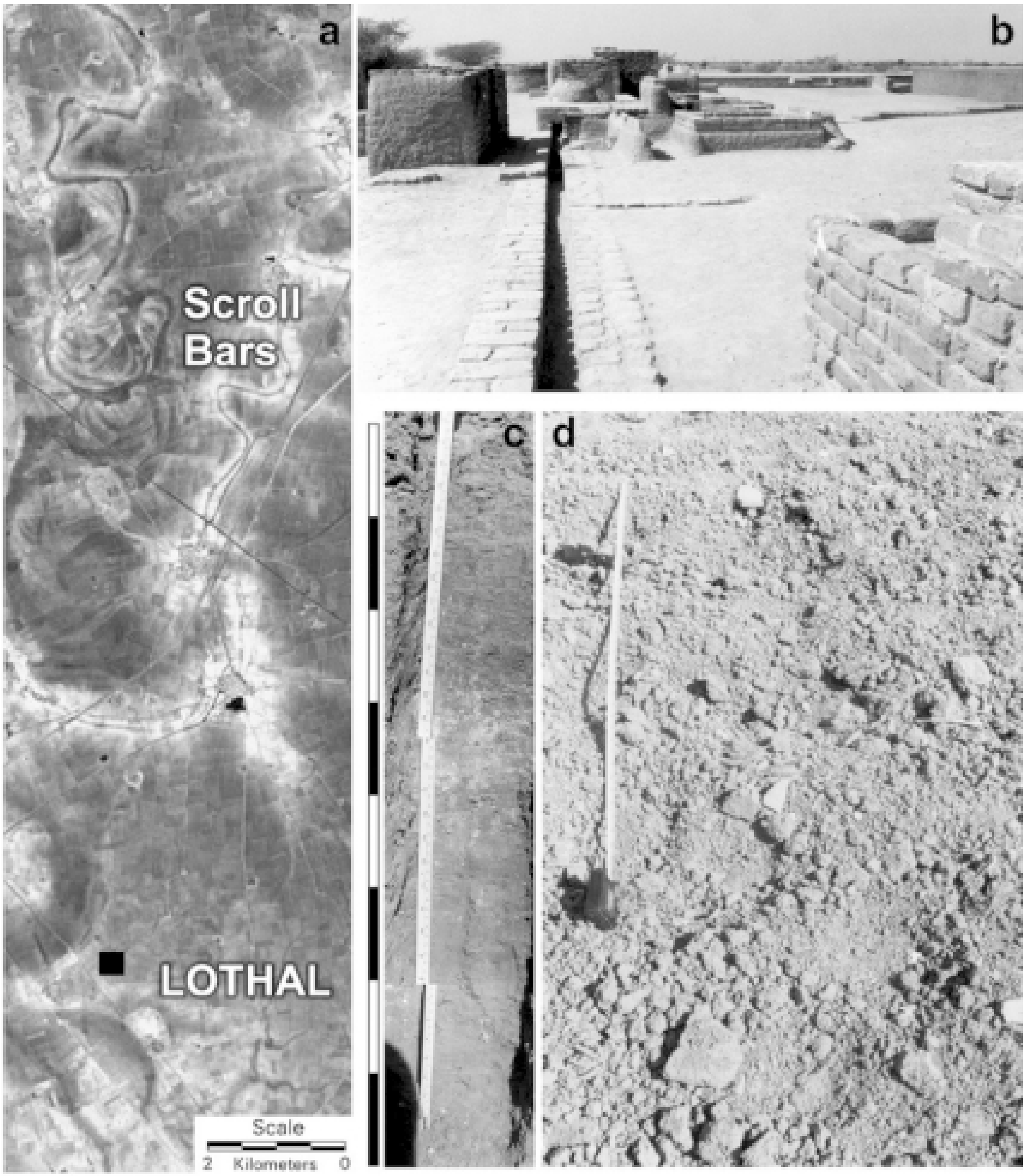


**Figure 1:** a) Multispectral LISS 3 data FCC showing the occurrence of scroll bars and a meandering channel that widens in the vicinity of Lothal, b) The Harappan town of Lothal which is interpreted as a port town flourished till 3500 $^{14}C$ yr BP, c) About 100 m north of Lothal, a trench was taken which shows coarsening downwards sediments. The upper part of the section shows dark clays which occur extensively in the region. The surface of the clays is littered with Harappan pottery which suggests that the upper part of the stratigraphy is probably coeval with the terminal phase of the Lothal township (d).

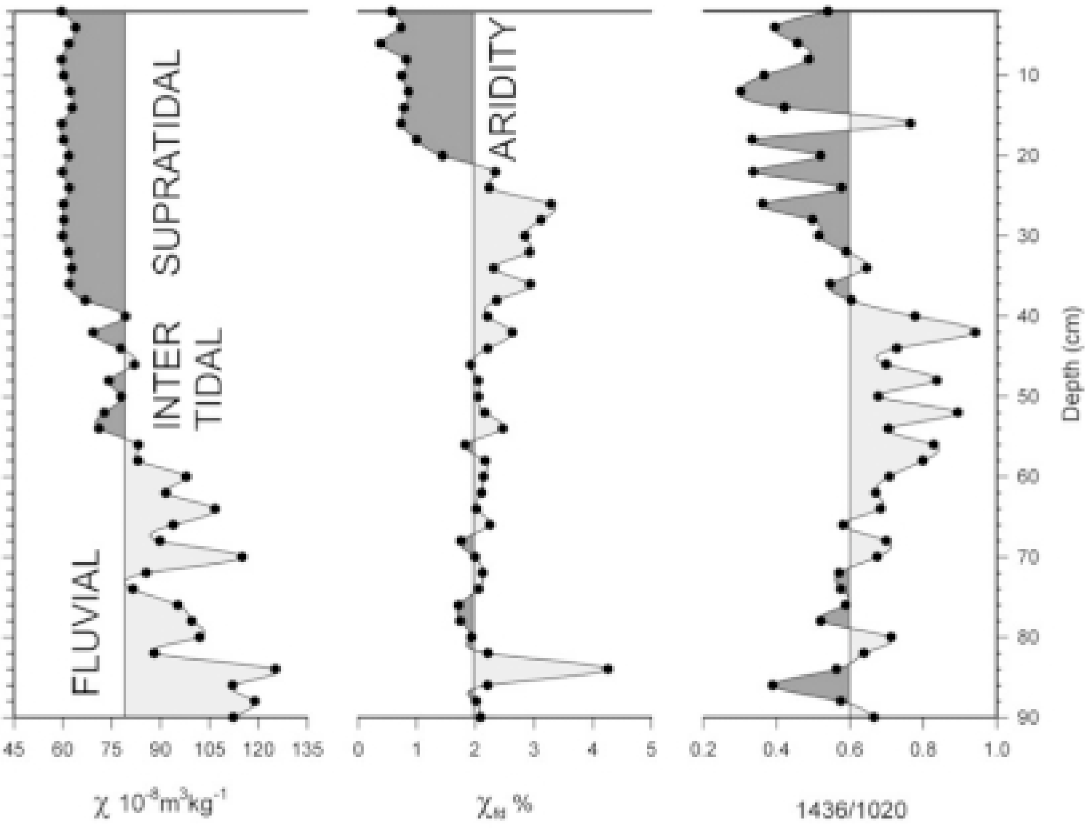


**Figure 2:** Down profile changes in $\chi$ and $\chi_{fd}$ compared with variations in the relative percentage of carbonate with respect to silicate in the sediment. $\chi$ and carbonate concentration show fluctuations that are governed by changes in the depositional environment. A marked drop in $\chi_{fd}$ is observed towards the top implying a reduction in soil performing processes. For details see text.

channel widths are very less (10-300 m) when compared with the lower reaches which has width of 1.2 –1.6 km. This suggests the presence of a strong tidal influence till Lothal and 6 km north of it. The scroll bar complexes have 4-5 ridge-swale structures, which is differentiated, based again on tonal variations. One phase of channel cut off and abandonment is clearly observed (Fig.2a).

A trench was taken about 100 m north of the mound of Lothal in an open field. The trench showed that the upper 40 cm of the stratigraphy was represented by dark coloured clays and underlain by increasingly coarser sediment, which was lighter in tone (Fig. 1b, 1c). No sedimentary structures were observed in the trench save for faint lamination in the upper part of the sediment column.

Magnetic susceptibility $\chi$ shows marked variations through the profile. At the base where sediments are coarser $\chi$ has high values ranging from 130 to 80. Some fluctuations are however present with lower values about 80 cm depths sandwiched between two phases of higher $\chi$ levels. These fluctuations in $\chi$ are accompanied by invariant $\chi_{fd}$ values about the mean value of 2 %. The relative carbonate abundance seen in the FTIR record shows lower than mean values for the basal 20 cm. Between 54 and 38 cm $\chi$ are around 75. This interval shows a greater relative abundance of carbonate. A sharp boundary is observed at 38 cm, which is marked by a sudden drop in $\chi$ to values around 60. This change in $\chi$ is not matched with $\chi_{fd}$, which shows very high values till about 26 cm after which a fall is observed at 18 cm. Carbonate contents fall after 30 cm depth somewhat mimicking inversely the $\chi_{fd}$ distribution.

## DISCUSSION

The combined remote sensing approach and environmental magnetism provide insights into both Harappan palaeogeography and palaeoenvironments during and prior to the establishment of the Harappan town of Lothal. The sinuosity of the channel along with the presence of scroll bar complexes clearly demonstrates that a meandering river flowed adjoining Lothal. The characteristic channel width changes also demonstrate that the lower part of the channel was tidally influenced. This implies that tidal waters used to ingress up to and slightly beyond the town of Lothal. The substrate on which the town of Lothal was established appears to be an ancient salt marsh inundated by tides. This is supported by the presence of marine diatoms, foraminifera and salt marsh vegetation. It is well known that base level (i.e. sea level in the present case) changes affect the sinuosity of a channel. Meandering river planforms are usually seen in coastal regions as a response to sea level transgressions, which in other words is an increase in base level (Schumm 1993; Koss et al. 1994). Hence the channel planform also supports the conclusion that sea levels much higher during late Harappan.

No topographic discontinuity is observed between channel and overbank regions for the Lothal palaeochannel. This is implicit as modern irrigation field boundaries cut across the tonal differences between channel and extra-channel regions. This suggests infilling of the channel and formation of an extensive coastal plain through a regional transgression. This also implies that the palaeochannel was penecontemporaneous with the Lothal settlement. Moreover upstream reaches of this palaeochannel might have provided a suitable supply of freshwater to the Lothal inhabitants.

The three different levels of $\chi$ in the sediment trench record reflect changing depositional environments. The lower part of the record reflects fluvially dominated environments albeit in a coastal realm. Upward the change in depositional environment is reflected in a reduction in $\chi$ accompanied by increased relative carbonate content. The depositional environment during this interval was largely in the intertidal region and is supported by an increase in the frequency of foraminiferal linings in the samples. The uppermost part of the section having reduced $\chi$ marks a withdrawal of the sea and represents supra-tidal clays. On the other hand $\chi_{fd}$ are markedly low at the uppermost part of the section. The principal source of $\chi_{fd}$ (which represents ultrafine superparamagnetic grains) is the soil environment. Hence it may be inferred that during the uppermost part of sedimentation, weathering processes in the provenance were subdued resulting in a reduction in the contribution of $\chi_{fd}$. The very fact that $\chi_{fd}$ distribution is not affected by changes in the depositional environment attests that the signal is primary and not affected by sediment redistribution processes.

It thus appears that at the time when the Harappan port town of Lothal was inhabited, a period of lower $\chi_{fd}$ production was prevalent. Such lower $\chi_{fd}$ production is possible only when climate related weathering processes are subdued. According to Dearing et al. (1997) the accumulation of secondary ferrimagnetic minerals in soils results due to formation of ferrihydrite as the initial mineral phase under a strong supply of Fe. Bacterial Fe reduction causes ferrihydrite to transform to magnetite, which over time, oxidizes to maghemite. This suggests that at the close of the Harappan period at Lothal, a period of aridity or weakened monsoon rainfall had set in. It is only in the upper few centimeters of sediments that Harappan pottery elements are observed. The cause for abandonment of Lothal may thus be a combination of drastic palaeogeogpraphic and palaeoclimatic changes; the latter suggested by the environmental magnetic records.

High sea levels recorded at Lothal are in agreement with Indian sea level records (Hashimi et al. 1995; Banerjee 2000). The age of the sediments shows that this apparently coincides with a global eustatic sea level high about 3000-3500 $^{14}C$ yr BP (Angulo & Lessa, 1997; Grossman & Fletcher, 1998). Climates at the close of the Harappan period (~3700 cal yr BP) have also been recorded elsewhere in India. Phadtare (2000) recorded a decrease in summer monsoon rainfall between 4000-3500 cal yr BP. A similar conclusion was reached by Caratini et al. (1994) and Sarkar et al. (2001) based on ocean cores off the southwest coast of India.

At about the same time period lake levels dropped in the northern monsoon domain of Africa (Gasse 2000) and is also seen in Kilimanjaro ice core records as high dust levels (Thompson et al. 2002). This drop in lake levels is similar to an earlier drop at 8200 cal yr BP in terms of magnitude. Cullen et al. (2000) showed that the dolomite content off the Oman coast increased dramatically. This increase was accompanied by a cultural collapse of the Akkadian empire at ca. 4000±150 cal yr BP.

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