HOLOCENE PALEOENVIRONMENTAL CHANGES IN THE LOWER MAHI BASIN, WESTERN INDIA

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ABSTRACT. Evidence of paleoenvironmental changes during the Holocene from the Lower Mahi basin of Western India have been documented. The unpaired S_2 surface all along the estuarine zone of the Mahi basin has been identified as an uplifted marine terrace. The terraces have preserved in their lithosections fairly distinct horizons of grayish brown clays rich in marine microfauna. The intervening silty-sand horizons are indicative of freshwater origin. The sedimentary structure and faunal assemblage indicate that these units have been deposited in a marginal marine environment. The ^{14}C ages obtained on these marine mud horizons show that between 3600 and 1700 BP the sea level was higher than at present. The geomorphic evidence suggests that a late Holocene uplift has played a significant role in lowering the relative sea level to its present position.

INTRODUCTION

Studies of paleoenvironmental changes in the Lower Mahi basin have not been carried out yet. However, various other aspects of the Quaternary geology of this basin have been investigated (Zeuner 1950; Pant and Chamyal 1990; Khadkikar *et al.* 1996; Maurya *et al.* 1997; Rachna and Chamyal 1997; Malik 1997). Maurya *et al.* (1997) have emphasized the role of climate, tectonism and base level changes in the evolution of the Lower Mahi basin. The sediments occurring along the Mahi estuary contain marine microfossils. We have investigated the sediment characteristics and faunal assemblages of the Mahi estuary and subjected these to radiocarbon dating to generate data on the paleoenvironmental changes during the Holocene. To achieve our objectives, the Kothiyakhad and Mujpur sections were studied in detail (Fig. 1). The sediment succession exposed at these localities shows distinct organic-rich clay horizons alternating with silty sand (Fig. 2), indicating the oscillating nature of the sea during the Mid-to-Late Holocene.

Geomorphology and Stratigraphy

The Mahi River originates in Madhya Pradesh and drains through the vast alluvial tract of Gujarat before emptying into the Gulf of Cambay (Fig. 1). The pre-Holocene morphology of the Lower Mahi is rather difficult to reconstruct because the Holocene eustatic sea level changes and neotectonic movements have considerably modified the Lower Mahi basin. The general topography of the area is that of a flat alluvial plain broken only by numerous ravines. The most conspicuous geomorphic features include a line of imposing river cliffs, ravines, unpaired valley fill terraces, modern point bars and mud flats. All of these geomorphic features form two distinct terraces, which show contrasting sediment records in the Lower Mahi. The older terrace (S_1) is dominated by fluvial and aeolian lithofacies, whereas the younger surface (S_2) is dominated by marine clay with intervening freshwater silty-sand horizons (Fig. 2). The older surface rises up to 40 m from the river level, is paired, highly eroded and extensively dissected. The sediments of this surface are comprised of semi-consolidated cross-stratified gravels, sands, silts and multiple paleosol horizons from the Mid-to-Late Pleistocene.

The S_2 surface is an unpaired 4–6-m high flat terrace. The surface is made up of two major lithounits: dark, greenish-brown clay with organic content, and grayish silty sand. The contact between these units is erosional and marked by mud flasers. The silty-sand horizon has a well-developed herringbone structure with an average mean current direction of 120°NW and 135°SE (Maurya *et al.* 1997). The clay unit has yielded a good population of foraminiferal assemblages.

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Proceedings of the 16th International ^{14}C *Conference, edited by W. G. Mook and J. van der Plicht*
RADIOCARBON, Vol. 40, No. 2, 1998, P. 819–823

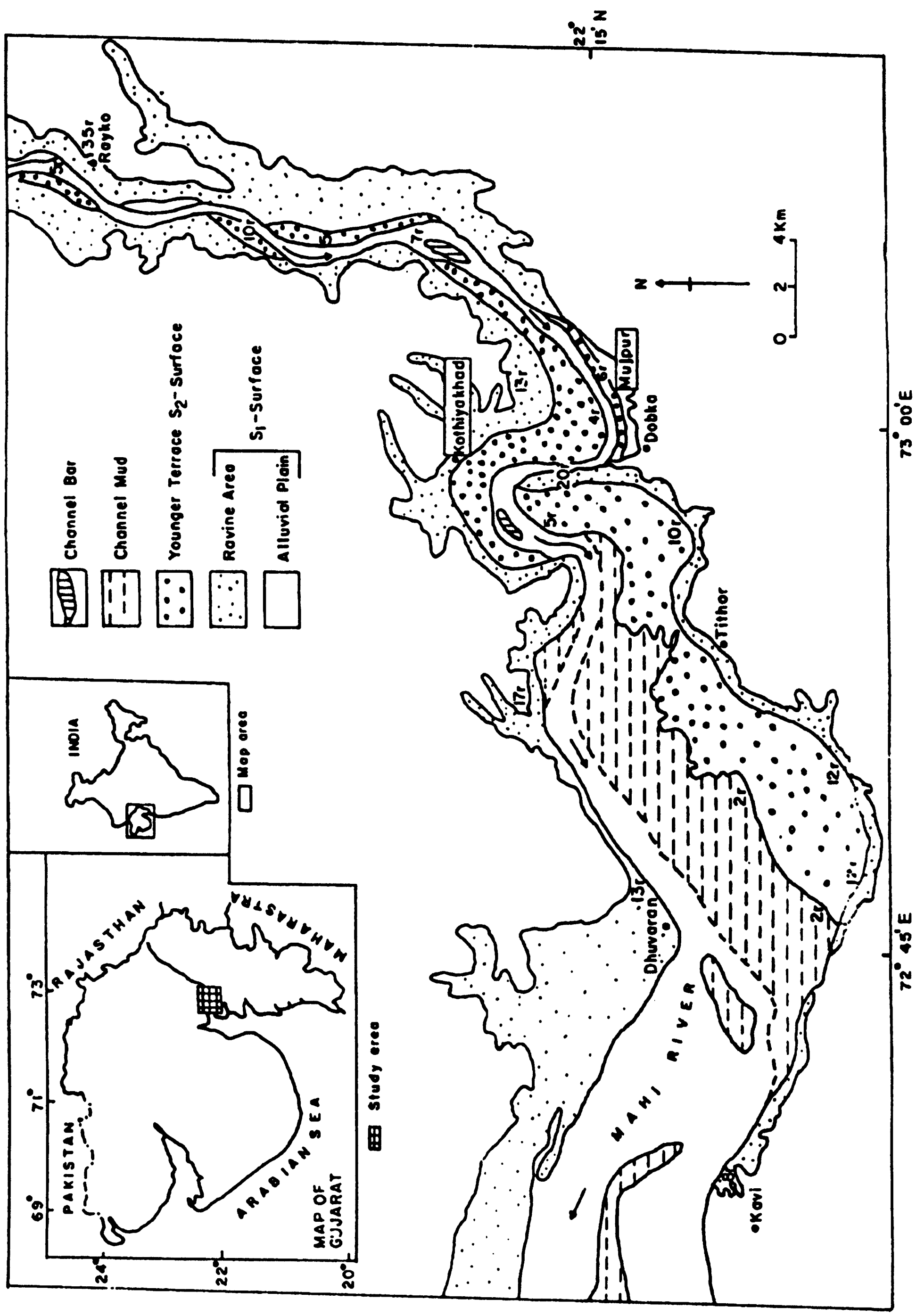

Fig. 1. Location and geomorphic map of the Lower Mahi basin (after Maurya *et al.* 1997)

https://doi.org/10.1017/S0033822200018774 Published online by Cambridge University Press

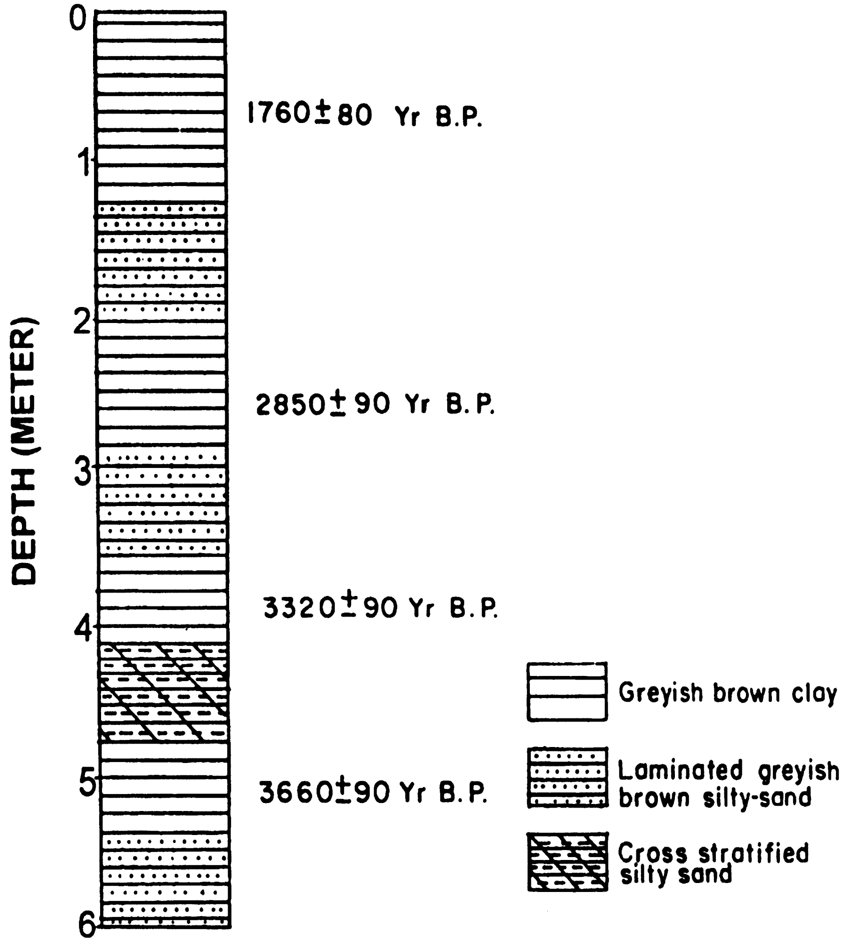

Fig. 2. Composite stratigraphy of the S_2 surface along with ^{14}C ages

Microfaunal Evidence

The mud horizons of the S_2 surface contain marginal marine fauna from an estuarine environment. Considering the morphology, these are classified into two morphogroups: 1) angular asymmetrical; and 2) rounded symmetrical. The presence of the angular asymmetrical morphogroup indicates deposition in a brackish shallow intertidal environment (Murray 1973; Cearreta and Murray 1996), whereas the rounded symmetrical morphogroup indicates deposition near the mouth of an estuary in a turbulent environment (Nigam and Khare 1994). The foraminifera are small with thin, fragile calcareous shells. The presence of these fossils indicates a low salinity environment. Such forms are limited to the area influenced by large rivers and it is believed that they result from the increased difficulty of calcium carbonate precipitation in low salinity waters (Walton 1964). The abnormal size of the tests is attributed to effects from salinity, oxygen concentration and water temperature. This interpretation is consistent with structures and related environments of foraminiferal assemblages in modern seas (Brady 1964).

The intervening horizontally laminated and cross-bedded silty-sand horizons are devoid of marine microfauna and have been found to contain sponge spicule(?), fragments of pelecypods and gastropod shells usually of freshwater origin. The absence of marine microfauna suggests the temporary shift from the brackish to near-freshwater environment that alternates in rhythmic fashion. There are 3 to 4 alternating periods of marginal marine to freshwater facies represented in our section.

Radiocarbon Dating

Four samples have been collected from Kothiyakhad and Mujpur. These samples were taken from the clay-rich horizon after careful documentation of the section. As discussed above, the clay-rich horizons are characteristic of shallow marine estuarine environments and appear at different elevations ranging from 4 to 6 m above the present river level.

The samples obtained were treated with a 5% HCl solution to remove the carbonate fraction. Contaminants such as rootlets were physically removed. Benzene was synthesized from the organic fraction of the sample following the procedure given by Gupta and Polach (1985). A liquid scintillation Quantulus™ instrument was used for ^{14}C activity measurement. Reporting of conventional ages (BP) is according to standard procedures.

Results and Discussion

The S_2 surface has an important bearing on the paleoenvironmental history of the Lower Mahi basin. The sediments of this surface occupy the incised (down-cut) valley consisting of Pleistocene deposits and suggest that the unpaired terraces (Fig. 1) have been deposited during the Middle Holocene high sea-level stand (Maurya *et al.* 1997).

The lithofacies' characteristics and faunal assemblages show that the deposition commenced in the near coastal and estuarine environment. The deposition of the Holocene transgressive mud facies was interrupted periodically by the deposition of intervening silty-sand horizons. The ^{14}C ages obtained from the marine organic-rich clay horizons indicate that the sea level was relatively high *ca.* 3600 BP and continued until *ca.* 1700 BP with minor periods of freshwater-type deposition. The four exposed organic rich clay horizons dated to 3600, 3300, 2800 and 1700 BP, along with the intervening silty-sand horizons, are consistent with a regression. However, the general trend was a continuous rise in relative sea level up to 1700 BP. Since that time, the relative sea level dropped and has remained at a relatively low position.

The geomorphological field evidence indicates that the 4–6-m terrace cannot be attributed solely to eustatic changes in sea level. There are no data available to suggest that the Holocene sea level was 4–6 m higher than at present during that time (Hashmi *et al.* 1995). This suggests that at least a portion of this difference is due to tectonic uplift. Maurya *et al.* (1997) have identified two phases of tectonic uplift during the Early and Late Holocene in the Mahi valley. The incision of the S_2 surface is attributed to Late Holocene uplift that continues today (Maurya *et al.* 1997). A reactivation along the deep-seated Mahisagar fault (Mathur *et al.* 1968) has probably contributed to raising the S_2 surface to its present elevation. The work of Pant and Juyal (1995) along the Saurashtra coast also suggests a tectonic component to relative sea level estimates. Hence, the marine transgression/regression cycles observed in the S_2 surface are likely to be influenced by some tectonic component, particularly over the past 1700 BP.

Conclusion

The Lower Mahi basin has preserved marine uplifted terraces as high as 6 m above the present-day tidal amplitude. The clayey units have been deposited under a marginal marine estuarine environment, whereas the intervening silty-sand horizons show a distinct freshwater environment. The ^{14}C chronology of the section indicates transgressions which caused deposition of marine clays between 3600 and 1700 BP with minor intervening regressions. After 1700 BP, the relative sea level dropped to its present position. The geomorphic features observed here were caused by a combination of eustatic sea-level fluctuations and tectonic activity.

Acknowledgment

Rachna Raj and L. S. Chamyal gratefully acknowledge the financial assistance provided by CSIR (9/114(97)/97/EMR-1) and DST (Project No. ESS/CA/A1-21/94), respectively.

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