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SHORT COMMUNICATION

Arid-Humid Cycles in Mainland Gujarat over the Past 300 Ka: Evidence from the Mahi River Basin, India

A more or less complete conformable succession of sediments of Quaternary age is documented from the Mahi river basin. A description of the lithostratigraphy is accompanied by the palaeoclimatic inferences drawn on the basis of deduced depositional environments, which shows a remarkable broad correspondance with global climatic fluctuations.

Introduction: The Quaternary palaeoclimatic changes have been documented in Western India based on lacustrine deposits (Wasson *et al.* 1984), palynological analyses (Singh *et al.* 1990), stable isotopic and micropalaeontological studies of marine cores (Duplessy, 1982; Singh and Srinivasan, 1993), and studies on fossil dunes (Singhvi *et al.* 1994). Taking into consideration the presence of lower Palaeolithic tool bearing gravel deposits and a ubiquitous 120 kyrs old rubified soil horizon, Pant and Chamyal (1990) have established convincing indices for intra- and inter-river basinal correlation and for the identification of the time-frame of various sections. However, in most cases, absence of a complete sequence at one single location led to the construction of composite lithostratigraphies; this has obvious disadvantages as compared to a conformable succession. The purpose of this note is to report such a complete sequence which documents the palaeoclimatic variations over the past ~300 Ka.

Description: The section is located on the eastern flank (left bank) of the river Mahi near Rayka, 20 km NW of Vadodara (Fig.1) and is exposed as a 36 m high cliff. The sequence consists of interlayered gravels, fractured muds and aeolian silts which show intermittent pedogenically stabilised horizons (Figs.2 and 3). The basal layer is a brown weathered clay which has a polygonal motif arising due to intense fracturing. The muds having a restricted thickness of 1-1.5 m (base unexposed) document a wide range of features illustrative of pedogenesis. Of prime importance of the many lines of evidence are the vertical tubules filled with calcium carbonate and truncated at the top by a gravelly horizon. Occasional presence of calcium carbonate - impregnated vertical fissures are accompanied by extensive development of drab haloes (Retallack, 1990). These haloes are bluish-white in colour, and are circular in cross-section with frequent remnants of the progenitor root. These linear features form a network of downwardly bifurcating structures which affirmates pedogenesis of the basal clay horizon. Instances of unidentified vertical burrows criss-crossing each other are observed, which are similar to those observed in the present-day tidal flat deposits (Reineck and Singh, 1980). The contact between the gravelly sands and the underlying pedogenised fractured mud is erosive (Figs.2 and 3). The foresets of the cross-beds, have a dip around 30°. Lithologically, the gravels are dominated by clasts of quartzite with subordinate basalt. The gravel horizon shows rapid spatial variation in its thickness and pinches down to less than a metre within a lateral extent of 50 m, but is never observed to disappear.

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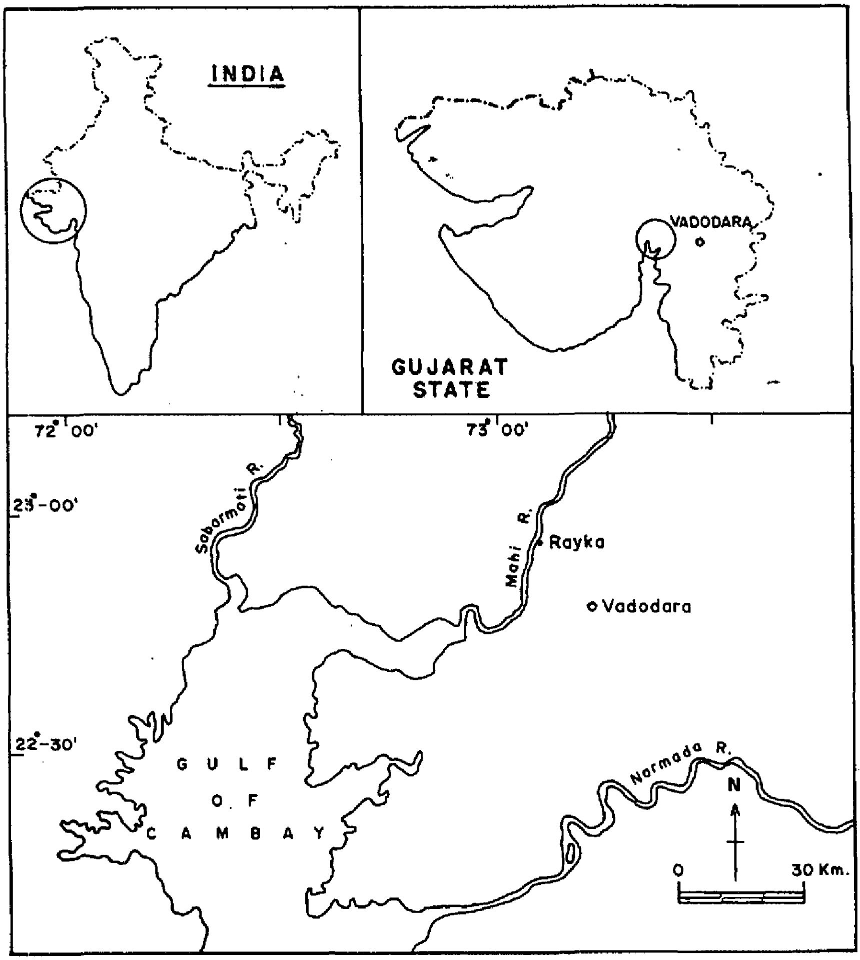

Fig.1. Location map of the area.

The clays between G_1 and G_2 show extensive calcretization in the form of laterally continuous horizontal layers which tend to lend the unit a pseudo-bedded appearance. The degree of calcretization varies, and the calcrete development is controlled by the finer-grained facies. Drab haloes too are observed in this facies which is accompanied by a horizon of extensively developed phreatophytic root casts (Purvis and Wright, 1991). At places each calcrete band shows signs of coalescene of adjacent nodules indicative of the maturity of the hardpan calcrete (Goudie, 1983; Wright and Tucker, 1991). The rhizoliths occur as long tubes of irregular thickness, with some of the rhizoliths demonstrating small knobs decorating the whole surfaces. An interesting feature is the truncated boundary of this horizon, between G_1, and G_2, with the overlaying gravel (G_2) alongwith distended sinuous calcite-impregnated root casts similar to that of the lower association. The overlying thick gravel bed is characterised by an abundance of calcretes in its clast composition. The clast-supported gravels are cross-stratified, showing a mean palaeocurrent direction towards NNE alongwith lateral accretion structures (epsilon cross-bedding) and small-scale channel-fill deposits.

The angular to sub-angular calcrete clasts show normal grading. A finely laminated silty sand horizon is observed sandwiched between the second gravel horizon and the

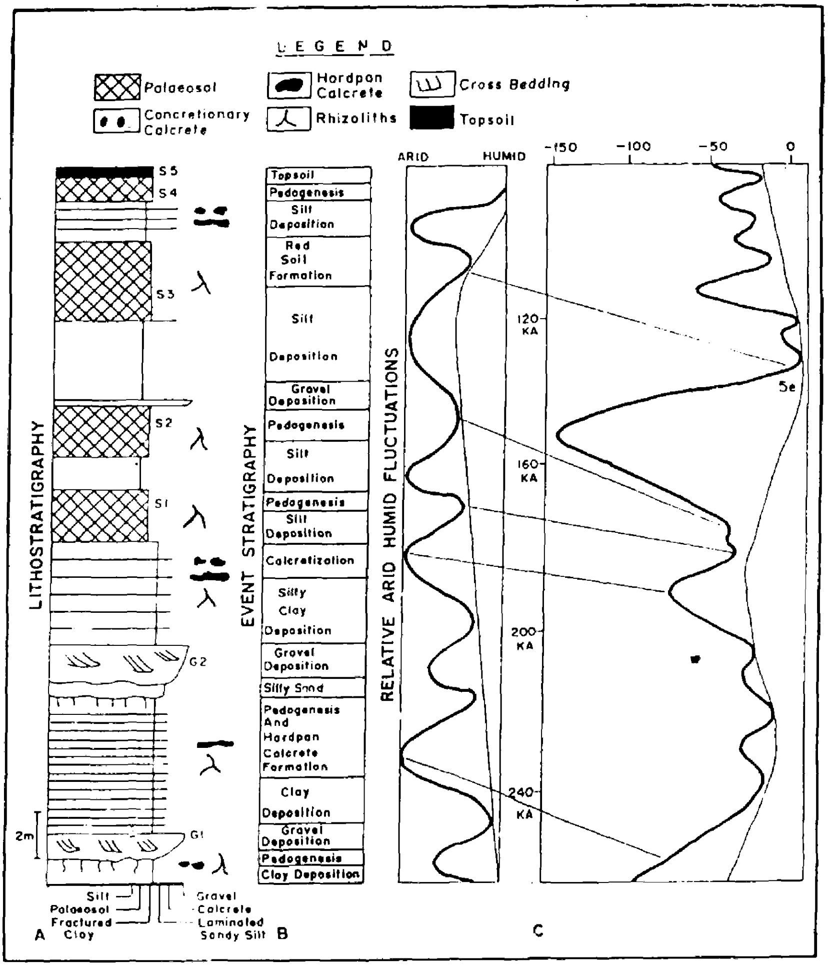

Fig.2. a) Lithostratigraphy of the Quaternary deposits of the Rayka section. b) Event stratigraphy of the section with corresponding qualitatively inferred relative and humid fluctuations based on the climatic scenarios conducive towards the formation of the deposits. c) Global sea level curves alongwith the remarkable correspondence with the inferred palaeoclimatic fluctuations evidenced in the terrestrial record.

underlying fractured pedogenised mud. Mineralogically, the silty sands are composed of quartz, basaltic lithoclasts, calcrete with subordinate feldspars and mica. A calcretised mud unit overlies the second gravel horizon which is more or less similar in gross character to the underlying calcretised horizons. The apparently homogeneous sediment displays two brown soil horizons which underlie the rubified soil horizon of Pant and Chamyal (1990). The darkened bands show traces of roots which indicate pedogenesis; a complete micromorphological study, however, is warranted for stricter classification of the palaeosols. The sequence is capped by a modern aridisol which is brown in colour.

Palaeoclimatic Implications: The basal clays were described as a blue mottled clay horizon and inferred to be of marine origin (Merh, 1992). The total suite of characteristics i.e. the lateral extent (Chamyal and Merh, 1992; Merh and Chamyal, 1993), presence of burrows and extensive root modification is suggestive of a tidal-flat environment (Reineck and Singh, 1980) with a very shallow gradient. These clays which underlie the gravel (G_1) dated at 300 Ka in the Sabarmati Valley (Sareen *et al.* 1992) represent the Middle Pleistocene transgression (Merh, 1992). The calcretization of the muds is indicative of prolonged periods of aridity (Goudie, 1983; Wright and Tucker, 1991). Although the rates of calcrete formation are presumed to be around 10,000 years for the hardpan variety (Joeckel, 1991) localised

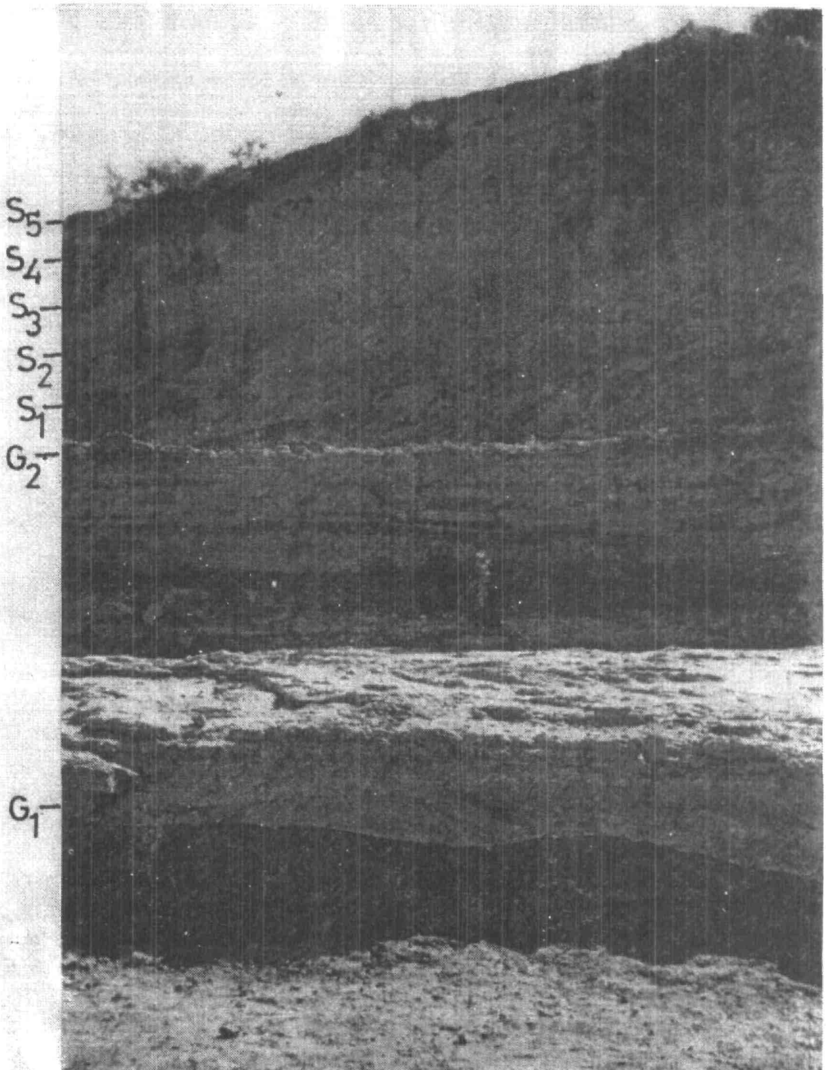

Fig.3. The conformable succession of Rayka showing the various lithounits described in figure 2. G_1, G_2 = Gravel horizons, S1, S2, S4 = Brown soils, S3= Rubified soil horizon, S5 = Brown topsoil.

abundance of calcium sources (in the present case the proximity of the sea, and abundant carbonate production as evidenced in the miliolites of Saurashtra (Merh, 1980) may lead to faster accretion rates. Up to 50 bands of calcretes are recorded sandwiched between gravel 1 and gravel 2. However, the horizons show differential maturity (reflected in the clastic content of the nodules) suggestive of different periods of stagnation of the water table. The dominant role of calcrete production was through precipitation above the water table (in the capillary fringe zone) as evidenced by extensive phreatophytic root mats associated with the calcrete bands (Purvis and Wright, 1991) through evaporation and the abundance of rhizoliths preclude one from neglecting the role of roots in carbonate precipitation. The banded calcretes are interpreted to reflect progressive aridity in a falling water table situation. The overlying fluvial gravels are indicative of regression of the sea during global glacial periods. The brown soil horizons although not prominently developed, are indicative of a hot humid climate with thick vegetation cover (Pant and Chamyal, 1990) subsequent to the deposition of the silts in which they have formed. The rubified soil horizon which shows a prolific development at Dabka (Lower Mahi, Pant and Chamyal, 1990), Mahudi (Sabarmati, Merh and Chamyal, 1993) is relatively less spectacular in the Rayka section, although it shows abundant rhizolithic structures indicative of pedogenesis. Since a rubified soil horizon occurs only once throughout the exposed section and formation of the same in most cases requires an oxidising environment, a rather significant climatic event must be recorded in this palaeosol. The oxygen isotope substage 5e (Chappel and Shackleton, 1986) records a period of maximum warmth (McManus *et al.* 1994) and the same has been equated with the rubified soil horizon (Pant and Chamyal, 1990). Based on this semiquantitative correlation we have attempted to match the global sea level curve of this period (Fig.2) with the event stratigraphy of the section. A broad and rather convincing correspondence has been observed which has been aided by a temporal restriction on the basal gravel through the presence of lower Palaeolithic tools (Pant and Chamyal, 1990) which places the deposits at approximately 300 Ka along with minimum TL age from the Sabarmati Valley (Sareen *et al.* 1992). Though not much chronological studies on the palaeoclimatic events in Saurashtra during miliolite accumulation have been carried out, recent studies do throw some light on this aspect. The dominantly aeolian depositional events (Patel and Bhatt, 1995) in Saurashtra, when considered in conjunction with the radiometric dates given by Baskaran *et al.* (1989), also broadly indicate a more or less comparable sequence of palaeoclimatic events.

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Department of Geology,
M.S. University of Baroda,
Vadodara - 390 002.

A.S. KHADKIKAR
L.S. CHAMYAL
J.N. MALIK
D.M. MAURYA
S.S. MERH

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