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Age and formation of oyster beds of Muthukadu tidal flat zone, Chennai, Tamil Nadu

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The formation of alternate oyster beds with intervening tidal clay units indicates fluctuation in the sea level as consequent to Mid Holocene to terminal Pleistocene neotectonism. This inference is based on the new radio carbon ages of the study area presented for the first time.

ASSEMBLANCE of bivalve and univalve molluscs occurs due to eustatic, shoreline and sea level changes[1]. They are signatures of former sea level positions. ^{14}C dating of these shells and the organic carbon-rich clay occurring along the inland tidal flat zones can be used to determine their age of formation.

A study was carried out to understand sea level changes and sedimentological pattern in the tidal flat occurring along the Muthukadu tidal flat zone, 37 km south of Chennai. The study was focused on the geomorphology, ^{14}C dating of oyster beds and organic carbon-rich tidal clays. The area was mapped using satellite data IRS-1A LISS II and ground checked for the various geomorphic units (Figure 1). Stratigraphic sequences of oyster beds occur along the east coast of Chennai between Muthukadu (12°50′N, 80°15′E) and Mamallapuram (12°35′N, 80°19′14″E) forming a part of the tidal flat zone (Figure 1). Presently, the oyster beds are largely exploited for lime-burning by the local fishing community. The study area receives both summer and winter rains, the latter being dominant during October to December receiving an average annual rainfall of 1200 mm yr^{-1}. The area experiences a subtropical climate with mean annual average temperature of 28°C to 30°C.

Four major zones within the tidal flat were recognized: a) outer sand flat merging with the beach dune complex and rock exposures, b) middle sand flat, c) sandy to silty inner flats (mixed flats of Reineck and Singh[2]) and, d) salt marsh. The salt marsh is separated from the inner flat by a narrow spit built of shell and shell debris. Grain size decreases slightly from the outer flat zone to the inner flat although this trend is interrupted by coarse-grained samples from the tidal channel. The channel is also characterized by relatively poor sediment sorting. The poor sorting of the innermost sample is due to input of coarser sand and shelly debris from the adjacent spits. Spit's variation in carbonate percentage is largely a function of shell content. Shell content is typically high in the tidal channel and near the spit, largely represented by lamellibranchs and gastropods.

The outer sandy flat and the beach dune complex are

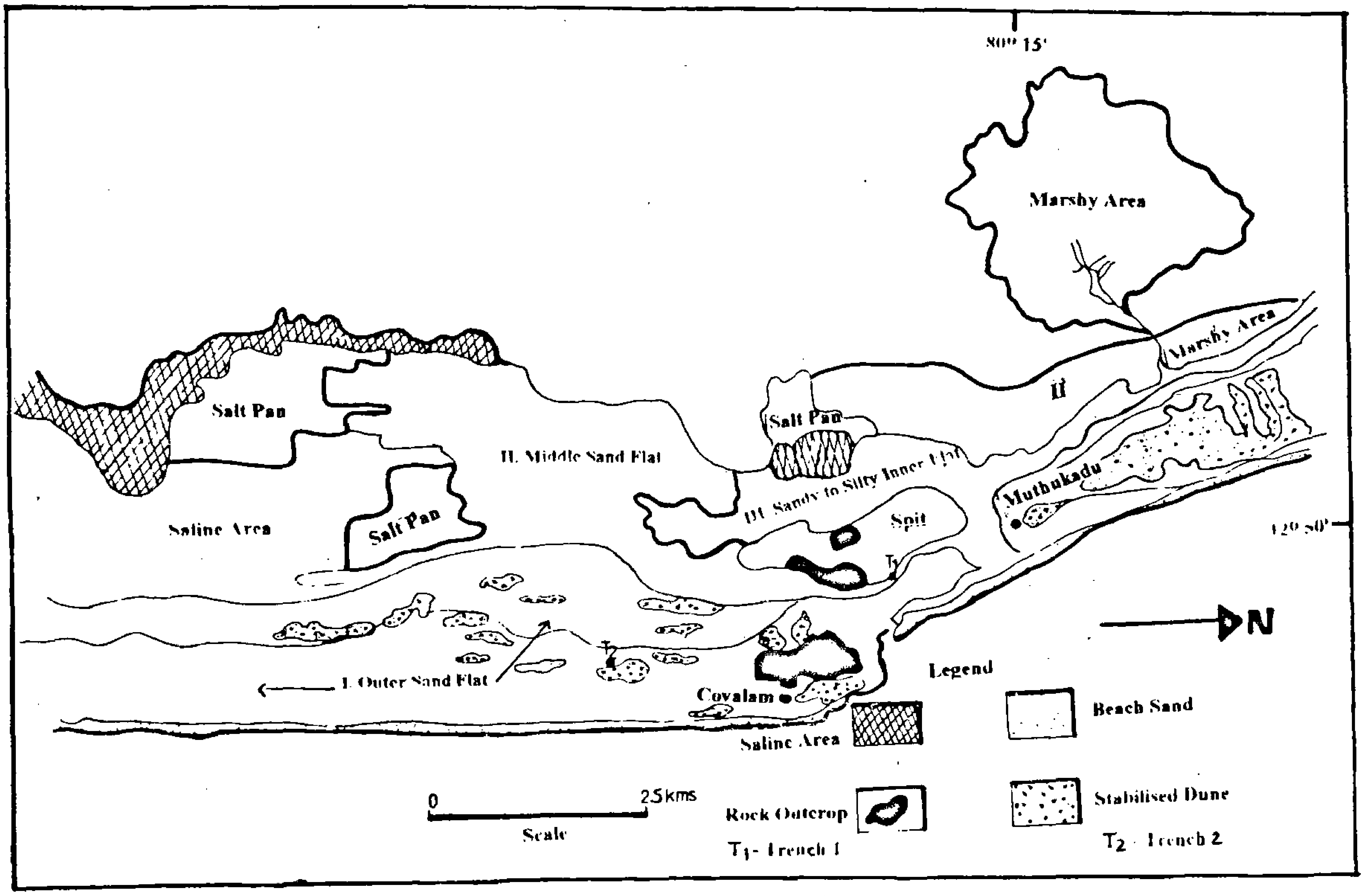

Figure 1. Location map of the study area.

characterized by sand waves (wavelength approximately 5 to 8 m) where amplitude (maximum approximately 0.50–1.0 m) decreases landward. The tidal zone is bordered by the beach dunes oriented NNE–SSE or N–S running parallel to the coastline.

The inner sand flat consists of slightly elevated grounds (fine sand bound with algal material) surrounded by shallow (2–5 m) pools of water with soft substrate. Emerged shell deposits are at or above mean high water level (MHWL) and are scattered at the points of small headlands. A trench was dug to 2.10 m depth in the sandy flat in the shallow low inter tidal zone. Observation made on the surrounding well sections and the trench revealed 1 m organic carbon-rich tidal clay unit, with alternate laminae of grey to black fine silty clay (3 mm to 4 mm) and dark grey to grey silty sand (2 to 3 mm) (Figure 2). Sedimentary structures are dominated by horizontal layering and ripple marks which are often flat topped. Typically, ripple crest are oriented at a slight angle to the shore line. Strong current velocities and coarse sediments prevent ripple formation in the channel. Mottled colours range from rusty red and brown to greyish green. This unit is underlain by an oyster bed unit I of nearly 1.10 m thick with a sharp contact. The size and the dimension of the oysters identified as *Crassostrea madrasensis*[3] (2–3 cm across), increase downwards with depth to 10–12 cm across, is a typical open-estuarine mollusc growing in saline conditions (6–20 ppt). The oyster bed unit I is subsequently underlain by a tidal clay unit II (0.80 m to 1.0 m thick) which is largely similar to the tidal clay unit I but varicoloured, compact and laminated which is once again underlain by an oyster bed unit II nearly 1.5 m thick with a sharp demarcation. The oyster bed unit I thrived well on the tidal clay unit II which formed a hard muddy bottom[3]. The tidal units I and II are devoid of oysters and shell content, although the top layers of these units contain broken fragments of shells such as those of lamellibranchs, gastropods, oysters and foraminifers. *Crassostrea madrasensis* from the oyster bed unit I of aragonite composition (identified by XRD analysis) and the organic carbon-rich clay from the tidal clay unit I were collected for radiocarbon dating and are presented in Table 1. The ages obtained were corrected using the radiocarbon calibration programme for marine data base of Stuiver and Braziunas[4] (presented for the first time).

The coastal dune field which is now stabilized by vegetation, occurs in a very high energy wind regime. The dune ridges are gradually replaced slightly inland by 10–15 m irregular dune forms. The dune field deposits have been studied by facies analysis of a trench dug (3 m depth) in the lee ward side of the dune at Muthukadu (Figure 1), natural exposures and by satellite imagery. Observations reveal that the dunes around Muthukadu can be divided into a lower unit that drapes the underlying buried oyster beds units I and II with the intervening tidal unit II. While the upper dune unit drapes the top tidal clay unit I, the lower dune unit locally is composed of two depositional subunits separated by immature soils. However, at this stage of study it is very difficult to correlate between the amount of sand surges deposited to form the dunes and the tidal flat zone.

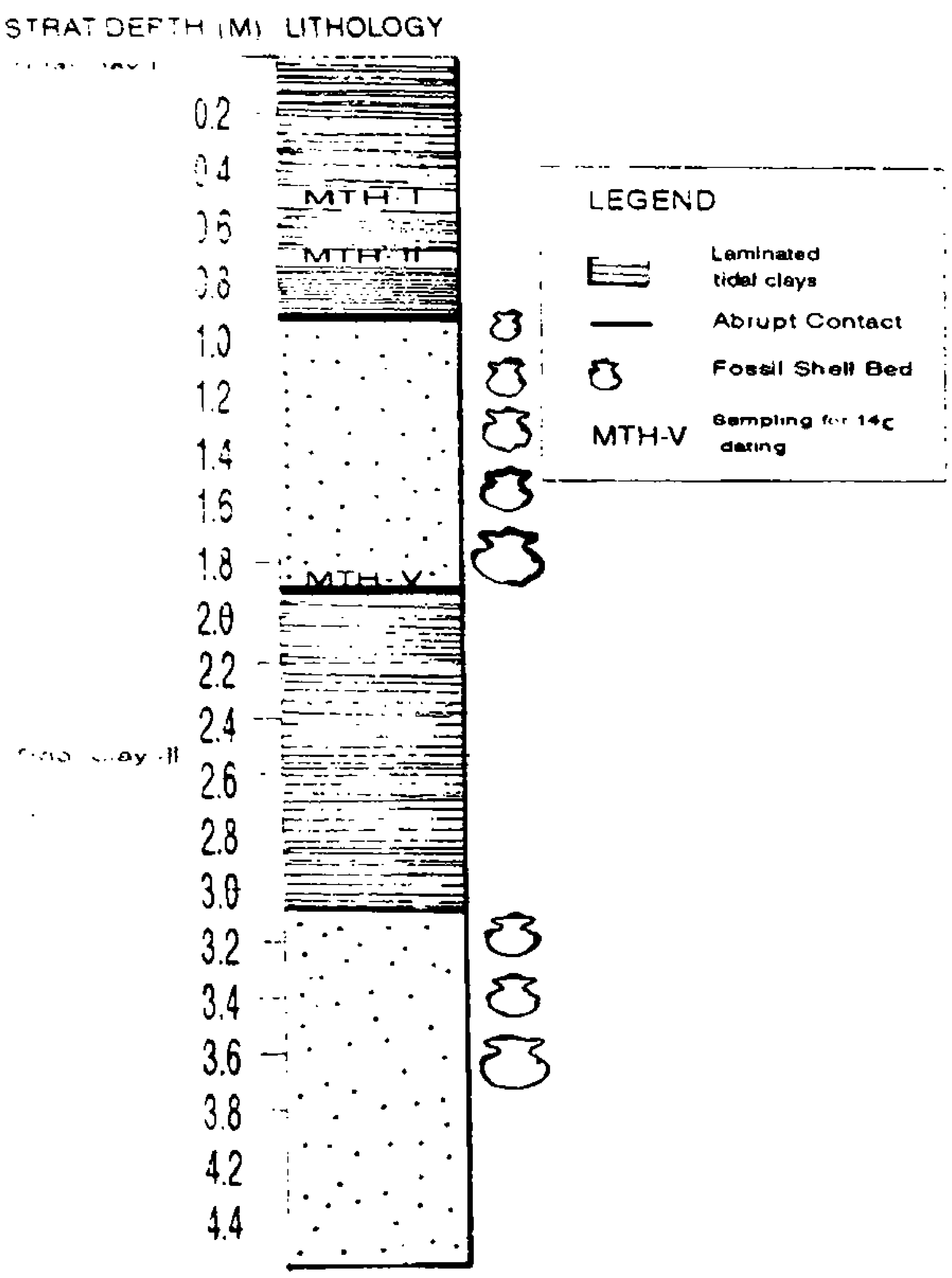

Figure 2. Lithostratigraphic column at Muthukadu near Chennai.

The present study reveals that oyster shell units I and II mostly accumulated *in situ* consequent to the low sea level before 4000 yrs BP, i.e. during the mid Holocene to Terminal Pleistocene period. The occurrence of oyster bed unit II (–3 to –5 m depth) also indicates a low sea level phase and high saline conditions probably formed during the Early Holocene–Terminal Pleistocene period. The terminal Pleistocene period was characterized by an overall strong climate and relative low sea level with high saline conditions and resulted in an increased availability of sand in the shore zone. The sand in the dune field originated from beach deposits. A large but pulsating supply of sand was supplied to the beaches by the southwards running coastal currents, probably by the return monsoon rains. This also resulted in a high flux of sand into the dune field. Short periods of decreased storminess are recorded by the occurrence of immature soil formation in the dunes. With the available radiocarbon dates of the tidal clay unit I at the depth of 0.50 m and 0.70 m (3145 ± 55 to 3475 ± 55 yrs BP), the rate of sedimentation is approximately 0.9 mm yr^{-1}. Extrapolating this data, the buried oyster bed unit I ceased to form since the last 3805 ± 55 yrs BP or approximately 4000 yrs BP. The oyster bed unit I of nearly 1 m thick seems to have formed rapidly in a high saline condition, i.e. within one thousand yrs BP as the bottom oyster is dated to 5000 yrs BP. The tidal clay unit I was deposited during the high sea level condition since 4000 yrs BP with reduction in saline conditions. The lithostratigraphy reveals a repeated shift from open-estuarine to brackish condition with average salinity decreasing as a consequence (less than 6 ppt) and hence the tidal clay units I and II are devoid of oysters.

The occurrence of two buried oyster beds with the intervening clay units perhaps points to a local fluctuation of the sea level due to the uplift which may not be directly related to the 'global sea level change' during the Holocene to Terminal Pleistocene period but a local

Table 1. Radiocarbon dates

Sl no.	Litho unit	Sample depth from the present surface	^{14}C date yrs BP	^{13}C PDB%	Corrected age	Clay mineral by XRD	Salinity Low	Salinity High
1.	Tidal clay AA#18459	MTH I 0.50 m	3145 ± 55		1520–1260 BC	Kaolinite, dehydrated illite, vermiculite, montmorillonite		
2.	Tidal clay AA# 18458	MTH II 0.70 m	3475 ± 55		1920–1620 BC	Kaolinite, dehydrated illite, vermiculite, montmorillonite		
3.*	Oyster shell 8374	MTH V 1.85 m	5000 ± 70	–2.5	4358–3991 BC	Kaolinite, montmorillonite, aragonite oyster shells		

uplift of the coast during the Terminal Pleistocene period. Reactivation of the boundary fault which trends almost NE and projecting into the sea near Mamallapuram could have been responsible for the neotectonic activity. This gains support from the data that Holocene to Terminal Pleistocene beach rocks and oyster bed deposits are globally a regional formation and that during this period the 'sea level' was several meters (120 ± 20 m) below the present position[5,6]. Since the Terminal Pleistocene period the coastal geomorphology in the study area has not changed drastically but for meagre channel shifts in the tidal flat zone. From the present study, as the results reveal, it is possible to offer a first order interpretation of the ^{14}C dates and data, but the interplay among the elements of neotectonism, global sea level change and sedimentation makes interpretation all the more difficult.

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Isolation of a cadmium tolerant *Curvularia* sp. from polluted effluents

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A fungus exhibiting high level of tolerance to cadmium was isolated from polluted effluents by selection on cadmium-containing agar medium. The fungus, identified as *Curvularia lunata*, showed high tolerance towards cadmium in both solid and liquid media (I_{50} 30–60 mM). The mechanism of tolerance is shown to be due to most of cadmium (90%) being accumulated on mycelial surface, extractable by EDTA. Metal–chelate affinity chromatography of cell-free extracts showed that most of the cadmium was in ionic form, not associated with any specific proteins. Biosorbent prepared by alkali extraction of mycelia of *Curvularia* bound metal ions up to 6% of biosorbent (w/w).

METAL toxicities have received widespread attention because of increasing number of toxic metals being released into the environment, their extended persistence and toxicity to a wide variety of organisms. Cadmium has been recognized as one of the most toxic elements and its mobilization into the biosphere has been accelerated by rapid industrialization[1]. Hence this aspect received wide attention with respect to its mechanisms of transport, toxicity and resistance in micro-organisms. In general, cadmium is reported to be toxic at relatively low concentrations to micro-organisms[2]. The most tolerant fungi which include species of *Rhizopus*, *Trichoderma*, *Penicillium* and *Cunninghamella* were found to grow at 1000 ppm of cadmium, while sensitive ones grew between 10 and 100 ppm (ref. 3). *Penicillium lilacinum* which comprised 23% of the total fungi isolated from polluted mine drainage was reported to be tolerant up to 10,000 ppm of cadmium[4]. But in the above cases the mechanism of tolerance/resistance has not been investigated. In case of yeast the maximum concentration tolerated was found to be 600 ppm of cadmium on solid media[5].

Heavy metal resistance in fungi has been investigated in greater detail in mutants isolated in the laboratory[6–8] by gradual adaptation on toxic metal ion containing media or by mutagenesis[9,10]. A number of metal-resistant fungi isolated from polluted environment have also been reported[10,11], but the mechanism of resistance in most cases was not studied. Resistance to heavy metals in micro-organisms can be due to any one of the two broad mechanisms (i) transport block which restricts the entry of toxic metals and/or, (ii) intracellular sequestration