CHAPTER - VIII

TRACE FOSSILS, EPISODIC SEDIMENTATION, AND OMISSION SURFACES

The topic of "event stratigraphy", and "episodic sedimentation" is receiving increasing attention in the literature. Event stratigraphy includes long term stratigraphic phenomena with spans of tens to hundreds of millions of years. Episodic sedimentation on the other hand delineate various sorts of discontinuities in the stratigraphic record that vary in both spatial and temporal scale from millimeter thick annual varves to Sloss-Vail sequences representing tens of hundreds of millions of years (Dott, 1982). The discontinuities that are most familiar to the stratigraphers, however, are those that are present at the outcrop level. These reflect frequencies of episodes from second to a few million years and are the most difficult to detect and interpret (Van Andel, 1981). Heim, (1925) introduced the term "Omission surfaces" to the discontinuity surfaces of most minor nature which mark temporary halts in depositions but involve little or no erosion. Such surfaces according Bromley, (1975), often represent changes in depositional environment that in many cases are more clearly registered in the ichnological record than by other features of the of the sediments. Ichnofossils in sediments subjacent to discontinuity surfaces he claimed can be grouped into three categories according to their relationship with the hiatus; the preomission, omission, and post-omission, ichno fossils. In the following pages the author describes some such evidences of episodic sedimentation and omission surfaces as revealed by the the trace fossil suits developed in the Mesozoic rocks of eastern Kutch.

The outcrops and trace fossils that were examined for the present study are from Chitrod, Washatwa, Adhoi, Mae and Manfara sections of Wagad block of eastern Kutch. It should be noted that the description does not give an account of sequential events, but it follows illustrations of episodes from different stratigraphic sections each typical of its own.

CHITROD SECTION (Fig. 29):

Event stratigraphy and ichnocoenoses :

The evidences of Zoophycos and Rhizocorallium (Table 10) in the Kharol Shale Member indicate marine influence and represents the earliest phase of marine transgression in the eastern Kutch. The Chitrod Sandstone in most part has a structureless appearance with only a few visible stratification surfaces. It contains dense concentrations of Skolithos, Arenicolites, Diplocraterion, Spirophyton and Thalassionoides fossil

PLATE - 62 : Amalgamation of beds by intense burrowing. The record of deposition is punctuated by at least two events of scour and is greatly obscured by the overprint of bioturbation. The siltstone unit represents continuous slow deposition where the biogeneic activity is so intense that virtually all physical sedimentary structures are destroyed.

burrows. As a whole the Chitrod Sandstone represents disposition under high energy conditions and rapidly shifting sediments a combination that does not favour most kind of tracemakers except the polychate type of feeders (Plate 62). This fact is well represented by the fossils of <u>Arenicolites</u> and <u>Diplocraterion</u> with their truncated top surfaces which mark the erosional planes (Plates 1A,B; 6AB).

The <u>Arenicolites</u> burrows (Plate 1) further indicate that the sediment remained soft till the development of the discontinuity surfaces which were later thoroughly bioturbated. The bioturbation planes further indicate hardground omission surfaces and the the long time gap before the next phase of deposition commenced.

Interesting evidences of relative rates of sedimentation and burrows structures can be found in the Fort Sandstone Member exposed around Chitrod. The <u>Arenicolites</u> and <u>Ophiomorpha</u> trace fossils (Plate 63) in their initial stages appear to be associated with more or less continuous sedimentation. Erosion of the upper bedding planes, truncation of the burrow tubes and further sedimentation indicate discontinuous sedimentation leading to bioturbation and much time lapse

PLATE - 63 : Relationships between burrowing, lithification scouring and sedimentation at omission surfaces. Note:- truncation of burrow tubes. The burrows in the center and towards right exhibit "nested cone" structures indicating burrowing animals upward movement. The branching patterns of Ophiomorpha burrows indicate adjustment of the organisms in response to the conditions of rapid deposition.

before the second phase of deposition. Photograph (Plate 63) therefore, illustrate preomission, omission and post omission organic activities.

The *Ophiomorpha* burrows (Plate 64) with several of their vertical branches that terminate at progressively higher (younger) bedding planes indicate positions of erosional bedding plane surfaces. Similar *Ophiomorpha* burrow structures found in the Georgia-Florida coastal planes of U.S.A. have been interpreted by (Howard, 1975) as indicative of rapid beach progradation with each termination or bypass structure of the *Ophiomorpha* burrow marking the former position of a beach surface.

Reactivation surfaces can also be observed in some of the sandstone-siltstone rocks (Plates 62, 63). These are usually covered with thin clay drape laminae. Traces decend vertically from these reactivation surfaces. Sellwood (1975), observed similar structures in Jurassic tidal flat deposits and suggested that these horizons containing vertically oriented burrow represent periods in which the bedform ceased to migrate and was colonized by suspension feeding infauna. This was followed by scour and renewed bedform migration.

PLATE - 64 : Repeated phases of erosion and sedimentation indicated by the ichnogenra Ophiomorpha. Truncated Ophiomorpha burrows indicate positions of erosional bedding plane surfaces - each termination marks the former position of beach surface.

PLATE - 65 : Preservation pattern of mineralized Thalassinoides tubes. These are rare examples of reworked and buried fossils exhumed by erosion.

A case of "reworked trace fossils" and their "burial preservation" at omission surface where the mineralized burrow tubes of Thalassinoides (Plate 65) that withstaod gentle exhumation and later redeposition was observed on the uppermost bedding plane of the Fort Standstone Member. Such preservations at the omission surfaces are rare, the trace fossils generally being the autochchonous structures (Bromley, 1975, p. 402).

WASHATWA SECTION (Fig. 30)

Event stratigraphy and ichnocoenoses:

A great number of interesting evidences related to event stratigraphy and episodic sedimentation are found in the rocks of Washatwa Dome Section. The beds represent accumulation of several erosional and depositional events and as such can be interpreted as multiple event beds.

The most distinctive structures observed in the fine-grained sediments of Kharol Member (Plate 66) are the low-dipping sharply defined laminae and the concave upward antiformal structures in their higher up bedding planes. Similar structures displaying ordered sequence of laminations were also noted in the overlying Patasar Shale Member (Plate 67).

PLATE - 66 : Beds revealing a complex series of erosional depositional events. Bioturbation patterns indicate rapid continuous to slow discontinuous conditions of deposition from bottom to top. Note the concave upward antiformal structures in the center and at the top of the sequence. "Hiatus concretions" due to interplay of deposition and scouring and lithification by organisms into micro omission surfaces is also seen.

Such transitions upward from plane to concave upward antiformal structures called hummocky ripple laminations are recently attributed to the action of storm waves. Harms and others (1975), inferred that hummocky cross stratification results from transport offshore in suspension of much fine sand and silt either by flooding rivers or retreating storm surges. As this sand settles it is subjected to vigorous and eratic oscillation of storm waves which it is thought mold the bottom into circular hummocks and shales. Similar episodes in Washatwa further appear to be followed by the seafloor being repopulated by epi and endobionts. Whenever the burrowing was abundant and deep, bioturbation appears to have destroyed the primary beddings completely (Plate 66).

The bedding styles (Plate 66) further displays formation of "hiatus concretions", a phenomena referred by Voig t (1968), due to interplay of deposition, scouring and lithification. The sequence of events are explained as under. The lag intraclast bored and encrusted by organisms is reburied and grew by further accretion. This growth was interrupted by reexhumation through scouring and the new surface was once again encrusted and bored by organisms. The cycle of events appears

PLATE - 67 : Beds revealing erosional and dispositional events as in Plate - 66.

PLATE - 68 : The alligned Cylindrichnus burrows oriented in the Paleocurrent direction.

PLATE - 69 : Pelecypod tracks on the hummocks indicating the time of crises.
Note the trace maker being preserved.

to be repeated several times each instance producing a micro omission surface within the intraclast.

Excellent examples of burrow orientations (Cylindricum Burrows - Plate 68) alligned in the paleocurrent directions are also found in the Fort Sandstone Member. This evidence indicate that lithification proceeded while burrowing animals were already living in the sediment and have preferably oriented themselves in the current direction to receive their nutrients. This phase, however did not last long and was followed next by the development of hardground surfaces (Plate 14).

The hummocky tops of the sandstone beds below the Lower Astarte bed have dense palecypod trails perhaps dating an event of crises (Plate 69). Further evidence to such a crises comes from the Astartic bed itself. This Lower Astarte bed (Plate 70) is a bed of shell rich layers without hummocky stratification. Such shell layers alternating with barren interval according to Dott (1983, p. 16) are evidences of some sort of episodicity. The possible origin of such layers as explained by him is due to violent disturbances of shells through bottom-stirring by unusually large waves which disturb and concentrate the shells by winnowing away all fine sediments. Subsequent return to normal

PLATE - 70 : Lower Astarte bed with shell coquiana - indication of an episodic event due to storm.

conditions as suggested by him would produce fine sediments containing scoured shells.

ADHOI DOME SECTION (Fig. 32):

Event stratigraphy and ichnocoenoses:

The Fort Sandstone very often displays both the primary and biogenic sedimentary structures. Photograph (Plate 71) displays largescale symmetrical rippled surfaces with traces of *Scolicia* - an irregularly meandering trace fossil on the bedding planes. *Scolicia* according to Frey & Howard (1970), occurs in rocks representing a variety of environments, but is most common in turbidites. The evidence in Adhoi, however, marks the time of hiatus when the trace maker actually lived at the sediment water interface.

MAE DOME SECTION (Fig. 36):

Event stratigraphy and ichnoconoses:

The most prominent feature of event stratigraphy in the Mae section is the one displayed by the shell coquinas forming the upper Astarte bed (Plate 72). The concentration of the lamillibrachia Astarte Shells as shell coquinas can be interpreted as under:

During peak storm conditions the shallow seafloor in Mae was subjected to erosion. The coarser material

PLATE - 71 : Large Scale Symmetrical and Asymmetrical ripple surfaces with traces of Scolicia. (top central part) - Man for Scale.

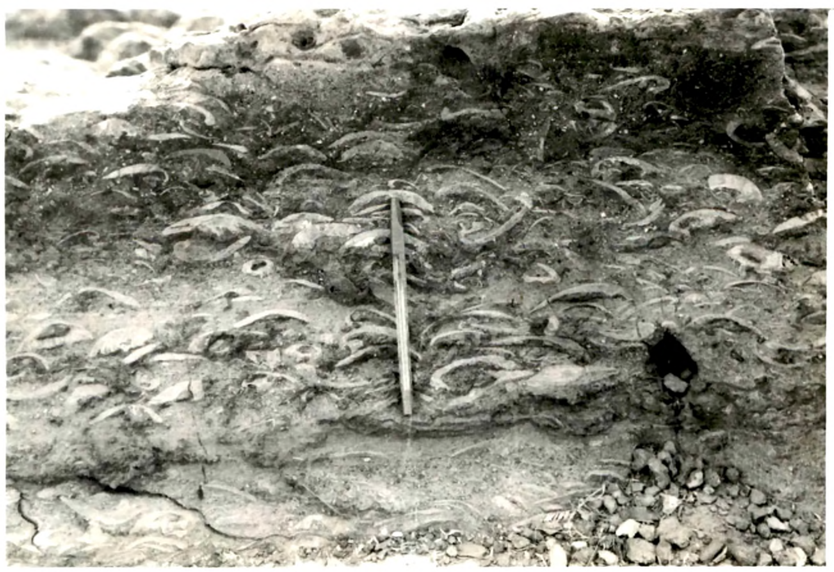

PLATE - 72 : Shell Conquiana forming upper Astarte bed. The shells are convex up and stack directly upon each other. Bed formation suggest storm effect.

including the Astarte shells formed winnowned layer, while the finer material was held into suspension. As the storm was over the finer material dropped rapidly from suspension, some intermixed the coarser grained winnowned lag deposite including the shells and formed weakly graded beds with distinctive wave generated structures including the infiltration fabrics, shelter porosity and micrograded sediment perched on the individual shells etc. Shell beds formed in this way have contained reworked but untransported Astarte Shells.

MANFARA SECTION - (Fig. 38):

Event stratigraphy and ichnocoenoses:

The ripple marked Adhoi sandstones are commonly interlayered with siltstone and shales. Crawling traces of Gyrochorte, Scolicia (Plate 73) in these rocks indicate organic activity within a normal oxygenated environment. The Rhizocorallium structure (Plate 8A) on the bedding plane indicate process of rapid diageneses that has fossilized the Rhizocorallium and rendered it suitable for exhumation. The upper Astarte bed exposed once again in this section (Plate 74) indicates an episode that suddenly changed

PLATE - 73 : Crawling traces of Gyrochorte on rippled sandstone indicating shallow water environment of deposition.

PLATE - 74 : The Upper Astarte bed indicating a repeated episode of storm action.

the depositional style. The shell bed represents, reworked, disturbed material winnowed in place rather than having been transported long distances although affected by storm.

The spectrum of information that was available from the above outcrop studies and their ichnofossils can be summed up as follows:

(1) Events indicating both the positive and negative deviation from the normal process intensities of sedimentation are recorded in the Mesozoic rocks of the eastern Kutch.

(2) Discontinuities representing changes in the depositional style are well documented by the trace fossils and the omission surfaces.

(3) Preomission trace fossils that are in contact with the distontinuity surfaces predate the hiatus by considerable period of time.

(4) The development of hard ground surfaces and its network of burrows indicate that lithification can proceed while burrowing animals are actually living in the sediment, or where burrows are vacated but unfilled by sediment.

(4) The development of hardground surfaces and its network of burrows indicate that lithification can proceed while burrowing animals are actually living in the sediment, or where burrows are vacated but unfilled by sediment.

(5) Truncation of burrow tubes indicate erosion and in some cases allow one to estimate relative rates of sedimentation.

(6) The trace fossils and their associated beeding styles very often indicate relative rates of sedimentation.

(7) Interaction of bioturbation and clay drape laminae have usually resulted in to"Reactivation surfaces".

(8) Rare cases of reworked trace fossils, their burial preservations and further, their exhumation indicate minor erosion surfaces as evidenced in some localities.

(9) "Hiatus concretions" a phenomenon due to interplay of depositions, scouring and lithification indicates development of "microomission" surfaces.

(10) Allinment of burrow tubes in a particular direction often gives indication of paleocurrent direction.

(11) Preservation of hummocky hardground surfaces and its prelithication trace fossils suite (pelecypod trails

in the hummocky valleys) suggest rapidity of lithification (in a sense equivalence to the omission surface).

(12) The concentration styles of Astarte shells as shell coquinas in the lower and upper Astarte beds indicate two different episodes of storm events. One characterised by the violent disturbances of the shells by large storm waves and the other by the spread of dustry cloud of storm sediments over the displaced pelecypod shells.