CHAPTER - VII

PALEOECOLOGY AND ICHNOCOENOSES OR TRACE FOSSIL - COMMUNITY CONCEPTS

The Wagad Group of rocks as mentioned in the earlier Chapter IV contains a rich and varied trace, fossil fauna. These traces reflect wide range of animal behaviours and can, therefore be interpreted in terms of ecology and strategy of adaptation, and biological parameters directly related to physical aspects of the paleoenvironments. Their use in paleoecology could also be made to draw information on the fossil community distributions and on their feeding structures.

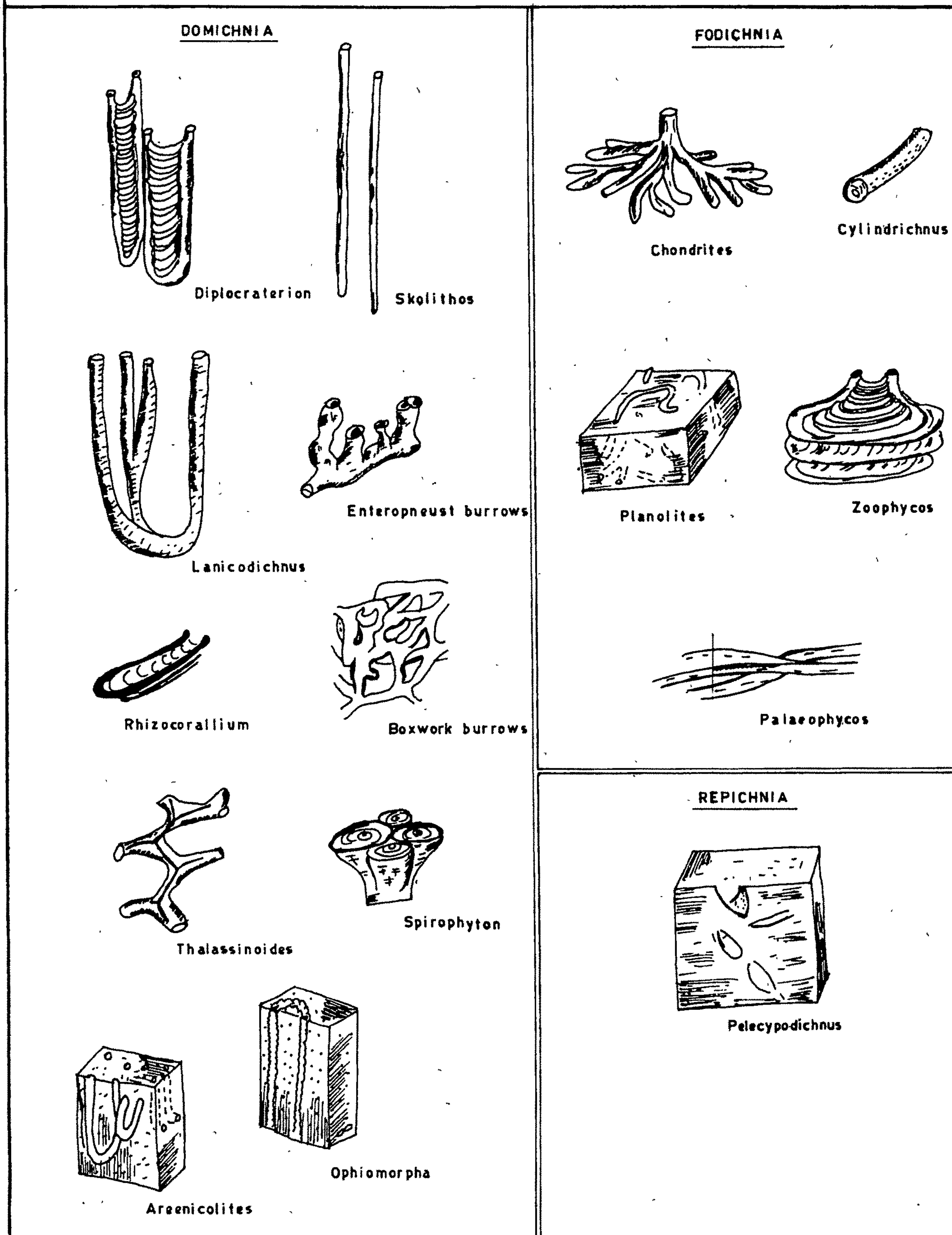
The main purpose of the following text, therefore, will be to demonstrate the utility of the Wagad trace fossils in their "community" paleoecology and environmental reconstruction. Paleoecological interpretations discussed below are based on both the ethological classification and specific analyses of the morphologies of the different trace fossils.

Ecological grouping of the trace fossils:

The Wagad trace fossil comprise a number of well defined ichnogenra and ichnospecies as well as some less

FIG. 22.

Feeding types of Washatwa trace fossils



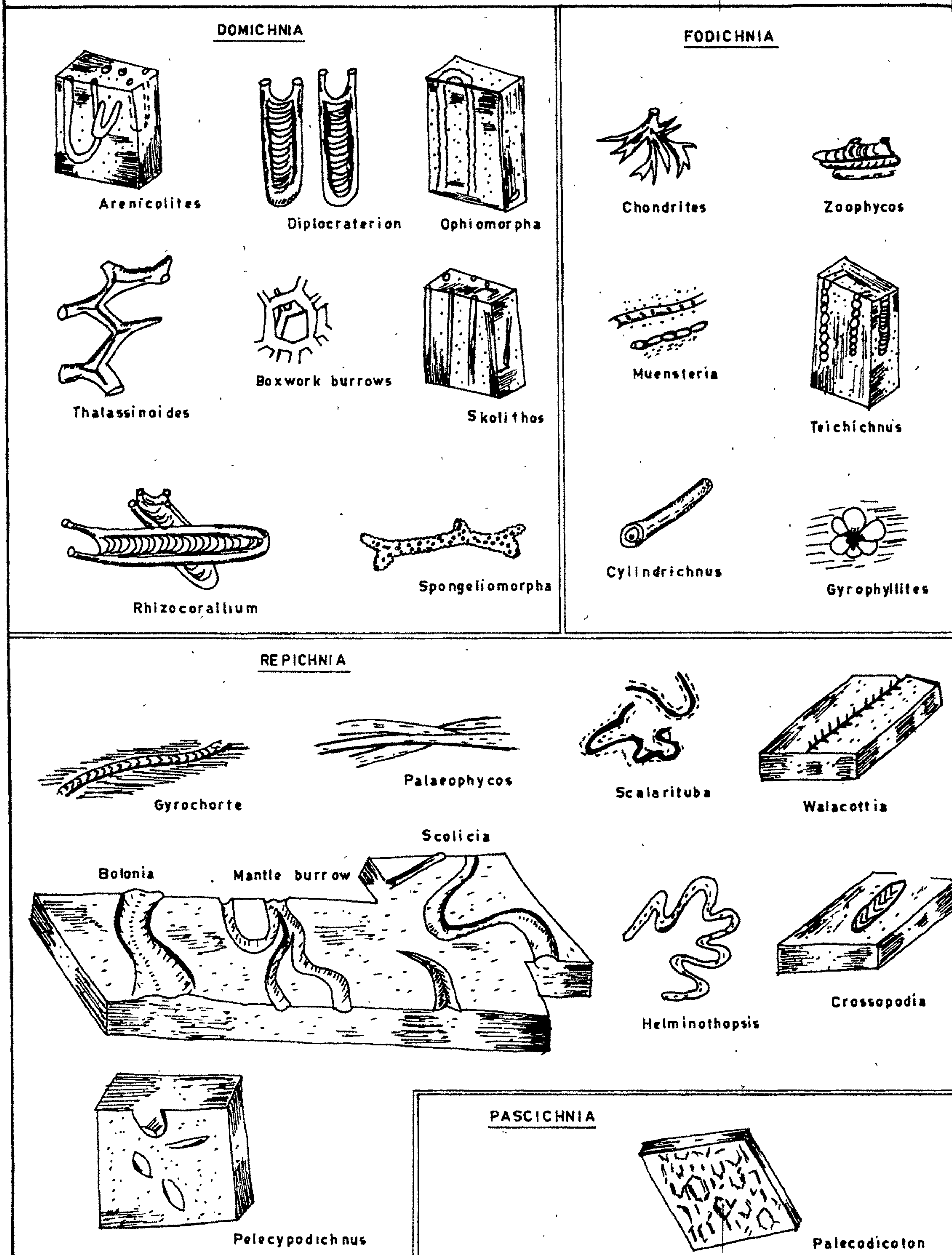
distinct forms. These have been interpreted in terms of origin and behaviour of their producers in Chapter IV. Their resulting ecological groups are summarized in Tables IV/1, IV/2, IV/3. Most of these forms as seen from the above illustrations can be assigned to one of the standard group of trace fossils, but the ichnospecies of Spongeliomorpha (Thalassinoides) provide some difficulties as the recent counterparts of their producers (decapods) exhibit a variety of feeding habits including plant-eating, predating, scavenging to suspension feeding and even selected deposit feeding (Fursich 1974).

A classification of behaviour, based on the trace fossil morphology alone has resulted in five ethological groups. These have been illustrated for the Washatwa, Kanthkot and Gamdau Formations, in figures 22, 23 and 24. Brief description of the ethological groups is given below.

Cubichnia (Resting traces):- These are shallow depressions made by animals that temporarily settle onto, or dig into the substrate surface. Emphasis is upon reclussion. These structures are found isolated, but sometimes intergrade with crawling traces or escape structures.

Repichnia (Crawling traces):- Repichnia are trackways and epistratal or intrastratal trails made by organisms travelling from one place to another. Emphasis is upon

FIG. 23. Feeding types of Kanthkot trace fossils



locomotion. Repichnia in eastern Kutch are represented by linear or sinous structures some of which show branching. Footprints or continuous grooves are very often observed.

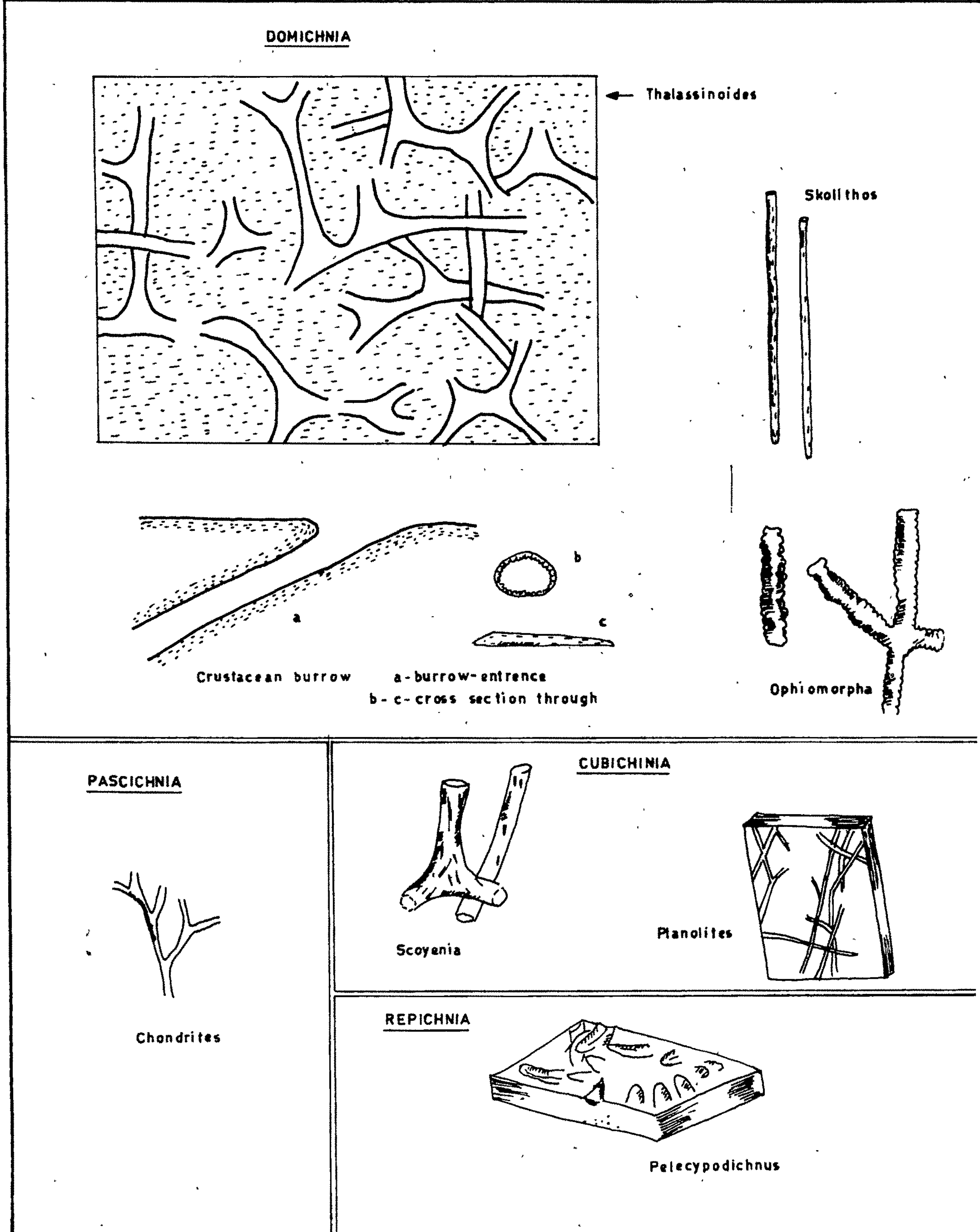
Pasichnia (Grazing trails):- These are the grooves, pits, and furrows, many of them discontinous made by mobile deposit feeders or algal grazers at or near the substrate surface. Emphasis is upon feeding behaviour analogous to "strip mining". The Kutch trails are mostly unbranching, non overlapping curved to slightly coiled patterns, reflecting maximum utilization of surfacial feeding area. Many complete forms are found well preserved.

Fodinichnia (Feeding structures):- Fodinichnia are more or less temporary burrows constructed by deposit feeders. Emphasis is on feeding behaviour analogous to "underground mining". The Kutch representatives include single, branched or unbranched, cylindrical to sinuous shafts or U-shaped burrows, or complex, parallel to concentric burrow repetitions (spreiten structures). Walls of these burrows are usually not lined. Burrows are found oriented at various angles with respect to bedding. Complete forms are found preserved.

Domichnia (Dwelling structures):- These are burrows, borings, or dwelling tubes providing more or less permanent domiciles, mostly to the hemisessile suspension feeders or,

FIG. 24.

Feeding types of Gamadu Formation



in some cases carnivores. Emphasis is upon habitation. The Kutch forms include simple, bifurcated or U-shaped structures perpendicular or inclined at various angles to bedding, or branched burrows having vertical and horizontal components. Walls of these structures are typically lined. Complete forms are very often found preserved.

Ichnocoenoses and Palaeocology:

In the previous Chapter VI different ichnofacies were recognized as valuable paleoenvironmental indicators reflecting the behavioral responses of the distinct depth controlled organisms in relation to the energy conditions at the sediment water interface, substrate types and nutrient distribution regimes. Recently, there has been an argument by Crimes 1970; Frey and Howard 1970; Fursich 1975; and Pickerill, 1978, that although the depth concept of Seilacher (1964, 1967) is a useful working hypothesis it has been oversimplified because other environmental parameters also control the trace fossil distribution. Kern and Warme (1974) also comented that individual ichnotaxa, as previously employed by Seilacher (1964, 1967) may not be always reliable paleoenvironmental indicators and that interpretations must be made utilizing the total available ichnocoenoses.

"Ichnocoenoses" as defined by J. Dorjes and Hertweek (1975) is a palaeontological term meaning "community"

TABLE 14 - Spatial distribution of trace fossils in Wagad Group between Chitrod (East) and Manfara (West).

1 - Chitrod Section
2 - Washatwa Section
3 - Adhoi Section
4 - Halrae Section
5 - Nara Section
6 - Kanthkot Section
7 - Ramwao Section
8 - Tramau Section
9 - Mae Section
10 - Manfara Section.

ICHNOTAXA	LOCATIONS (E) 1	2	3	4	5	6	7	8	9	10 (W)
Rhizocorallium	+	+	+	+	+	+	+	+	+	+
Zoophycos	+	+								+
Palecypodichnus	+	+	+							
Paleophycos	+	+	+	+	+	+	+		+	+
Chondrites	+	+	+	+	+	+	+		+	+
Skolithos	+	+	+					+	+	+
Thalassinoides	+	+	+	+	+	+	+	+	+	+
Enteropneust burrow	+	+								
Box with burrow	+									
Cylindrichnus	+	+	+	+	+		+	+	+	
Spirophyton	+									
Rosselia	+									
Diplocraterion	+	+		+		+				
Planolites	+		+	+		+		+	+	+
Arenicolites	+	+			+	+	+			
Ophiomorpha	+	+	+		+	+	+		+	+
Gyrochorte	+	+	+	+	+	+	+	+	+	+
Muensteria	+	+	+	+		+		+	+	+
Taenidium	+	+	+		+			+	+	+
Teichichnus	+	+	+		+	+		+		+
Scolicia	+	+	+				+	+	+	+
Helminothopsis	+	+		+			+	+	+	+
Crossopodia	+								+	+
Walcottia									+	+
Gyrophyllites										+
Bolonia		+	+							++
Paleodicton										+
Scalarituba										+
Spongeliomorpha	+	+	+			+			+	+
Scoyenia	+					+				+
Lanicodichnus	+									
Holothurian trails		+	+							+
Bioburbation	A-R	A-R	C	C-R	R C R	R C R	R-R	R C R	R C C	A-A

Relative degree of bioturbation at individual location indicated by R = Rare, C = Common and A = Abundent (coenosi) of traces (ichna) that can be recognized and determined as individuals. In accordance with the ethology, use of term "ichnocoenose" is conformable with that of the term "biococenose" i.e. community of organisms on and or in the sediments.

The distribution of trace fossils in different stratigraphic sections of the eastern Kutch (Table 14) exhibit a distinct non-random pattern. Some trace fossils are seen occurring together recurrently, whereas the others are never found in the same piece of rock. These relationships are easily recognizable in the field. The groups of trace fossils occurring together constitute the ten ichnocoenoses, shown in figure 25. Each ichnocoenose is named after its most important member.

(1) The *Rhizocorallium* ichnocoenose:

The ichnocoenose consists primarily of *Rhizocorallium irregularia*, and *R. jenesia* with other characteristic elements including *Spongeliomorpha suevica*, *Chondrites* sp., *Cylindrichnus concentirchnus*, *Planolites* and *Skolithos* sp. Most elements of this association are shallow, burrowing deposit-feeders, found in fine or medium-grained sandstone-siltstone alternations of the Washatwa Formation and the lower and upper Kanthkot Formations. Sediments in these Formations wherever, the *Rhizocorallium* ichnocoenoses are located do not

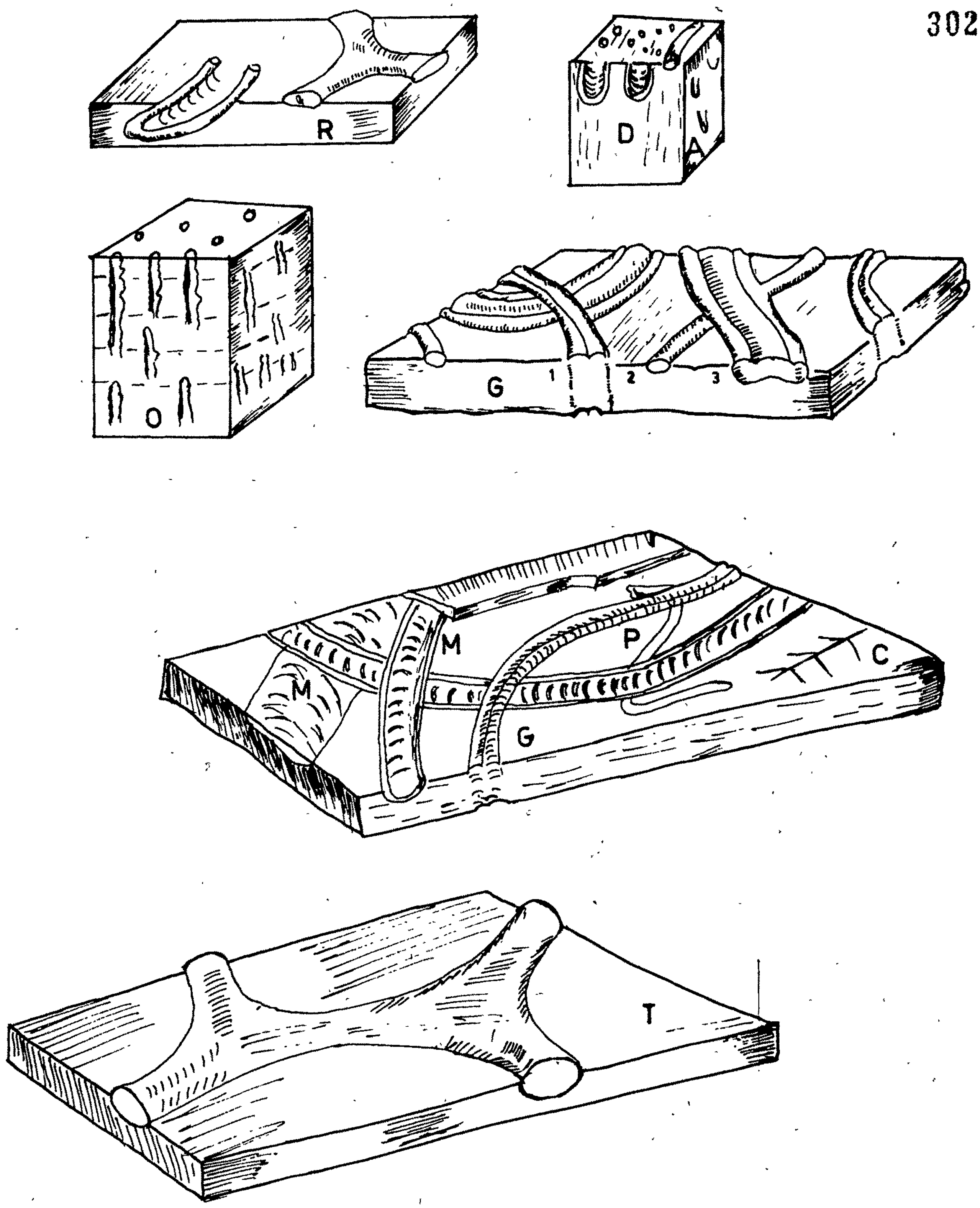


FIG. 25 - Ichnocoenoses in eastern Kutch
R - Rhizocorallium ; D - Diplocraterion
A - Arenicoltes O - Ophiomorpha
G - Gyrochorte (1) Gyrochorte (2) Planolites (3) Curvolithes
M - Muensteria; C - Chondrites
T - Thalassinoides

exhibit any sedimentary structures as a result of extensive bioturbation, which in turn indicate very low rate of deposition. Rhizocorallium association is thought to be low-energy subtidal areas at greater depth although perhaps less protected than those of the Teichichnus association, with intermittent currents sweeping the sea floor (Fursich 1974).

(2) The Diplocraterion ichnocoenose :

Characteristic members of this ichnocoenose are Diplocraterion habichi and D. parallelum. The other trace fossils associations include Spongeliomorpha suevica, Spongeliomorpha saxonica, Planolites sp., Arenicolites sp., Ophiomorpha nodosa and Spyrophyton sp.

The Diplocraterion ichnocoenose observed in Chitrod and Washatwa sections is mainly composed of different dwelling tubes of suspension feeders (domichnia). This ichnocoenose can be interpreted as indicative of a relatively high energy environment, with insufficient sedimentation of fine-grained particles to support deposit feeders. Thus, suspension feeding is believed to have been predominant. Physical reworking appears to have been frequent, as indicated by the presence of their numerous horizons. The long tubes at Chitrod and Washatwa are interpreted as a protective shelter against unstable conditions in the sea floor with high water agitation, but low rate of sedimentation.

(3) *The Arenicolites* ichnocoenose

This is the simplest assemblage of two or three ichnotaxa. The assemblage is dominated by the vertical shafts of slender U-burrows, commonly very closely spaced. At places (in Chitrod and Washatwa) the connecting U-bents are visible less commonly because these require a favourable direction of fracture to reveal them in longitidinal section. Slender *Skolithos* sp. accompany these and on certain beding planes, sole surfaces are found covered with "small stuffed burrows".

(4) *The Ophiomorpha* ichnocoenose

This ichnocoenose consists exclusively of *Ophiomorpha* and can be observed in the Chitrod and Washatwa sections in Fort Sandstone Member and in Mae and Manfara sections and in the lower parts of the Gamdau Formation. In Chitrod the density is highest and can be interpreted to indicate conditions of moderate to high sediment influx. Furthermore, these accumulating sediments appears to have protected older sedimentary structures from physical disturbance. A low rate of reworking seems to be a precondition for the construction of structures as the clay-ball lined walls in *Ophiomorpha* indicate. On the other hand, the regular nature of the tube swellings along certain bedding planes reveals that these were brought by some events effecting all the burrows individuals at the same time. Periodic additions of new layer of sediments causing successive upward extensions of the shafts as suggested by Howard, Valentine and Warme (1971) seems to be a reasonable explanation.

(5) The *Gyrochorte* ichnocoenose

This ichnocoenose is dominated by the ichnospecies of *Gyrochorte*, *Comosa* and *Curvolithos* or both with associated Planolites and the pelecypod trails. The ichnocoenose generally shows a high degree of bioturbation indicating relatively slow sedimentation and little physical reworking. The small-scale, ripple laminated sandstone with *Gyrochorte* very often found in the Washatwa, Adhoi, and Manfara sections indicates increase water agitation with concomitent increase in sediment transport, but not necessarily increase of sediment influx.

The *Gyrochorte* ichnocoenose represent the activity of sediment feeding (*Gyrochorte*, *Planolites*) or carnivorous (*Curvilithos*) animals. The later requiring other infaunal animals as food sources (Heinberg, 1973). The pelecypod tracks which are included in this ichnocoenose are the only representatives of filter feeders (siphonal bivalves). Most of the other infaunal sediment feeders are therefore interpreted to be an important faunal element indicating an environment of relatively low-energy where fine-grained detritus of nutritional value to sediment feeders was allowed to settle.

(6) The *Muensteria* ichnocoenose

This ichnocoenose is dominated by various backfilled tunnels (*Muensteria* sensu lato) with occassional occurrence of *Gyrochorte*. All these traces can be interpreted as traces of deposit feeders. This ichnocoenose is located in the fine-grained sandstones and shales of Patasar and Adhoi Members, indicating dominance of deposit feeders that lived in a low energy environment an interpretation supported by the fine-grained nature of the enclosing sediments.

(7) The *Teichichnus* ichnocoenose

The characteristic member of this ichnocoenose is *Teichichnus rectus*. Other elements included in the association are *Cylindrichnus concentrichnus*, *Spongeliomorpha suevica*, *Chondrites* sp., *Planolites* sp., *Muensteria* and occassional *Gyrochorta comosa*.

The ichnocoenose consists of shallow burrows, mainly of deposit feeders. The preference of these burrows is usually to the argillaceous sediment in the Fort Sandstone Member and and the Adhoi Member. Physical structures are mostly destroyed by bioturbation of this ichnocoenose. The association as a whole represents a low-energy regime with lower rates of deposition and fairly stable substrate conditions which allowed extensive bioturbation. Food particles obviously accumulated in the sediments rather than remained in suspension. The Teichichnus association as suggested by Fursich (1974) is characteristic of subtidal areas of reduced turbalance and current activity as well as of quiet water lagoons.

(8) The Chondrites ichnocoenose

This association is characterized by Chondrites and Planolites with minor Skolithos and is found usually in shales and fine-grained sandstones. It is exhibited practically in every stratigraphic unit of the eastern Kutch. The association appears to be related to sediments formed in shallow subtidal to intertidal and lagoonal environments and represents a low energy regime as suggested by the ichnogenra Chondrites and Planolites, with low rates of deposition and a fairly stable substrate which allowed extensive bioturbation.

(9) The Thalassinoides ichnocoenose

It only involves a single ichnospecies Thalassinoides suevica. It is usually found with interbedded sandstones and mudstones. The large, semi-permanent horizontal tunnel system indicate quiet environment with little reworking. This ichnocoenose probably represents the lowest energy levels (Fursich and Heinberg, 1983).

(10) The Scoyenia ichnocoenose

This ichnocoenose consists of shallow burrows of crustaceans. The preference of the burrows is usually to poorly sorted, thinly laminated, cross-bedded red and grey sandstones and dark grey to red clayey siltstone of delta plain deposits. The other members of this ichnocoenose include Planolites, Ophiomorpha, Chondrites and Pelecypodichnus.

TRACE FOSSIL DISTRIBUTION

In the recent ecological research it is a general practice to express distribution of benthic forms in terms of "Taxonomic diversity", "faunal diversity" and "trophic structure".

"Taxonomic diversity" is a fundamental ecologic parameter that denotes the number of individuals per taxon per unit of sea floor. This parameter is usually expressed as a diversity index and is used to characterized the taxonomic structure and temporal stability of a benthic community (Frey 1975).

"Faunal density" means absolute abundance of trace or body fossils, in terms of the abundance of living organisms at any particular time (standing crop). This is, however, elusive so far trace fossils are considered. For this reason, measures of biotic density (number of individuals per taxon) are usually not calculated for trace fossil assemblage. However, relative abundances can be used to estimate common and rare species during life of the assemblage (Rhoads,1975). Studies by Rhoads,(1967) also indicate that the rate of bioturbation is generally poorly correlated with faunal density but is closely related to the mobility of the burrowing or grazing organisms.

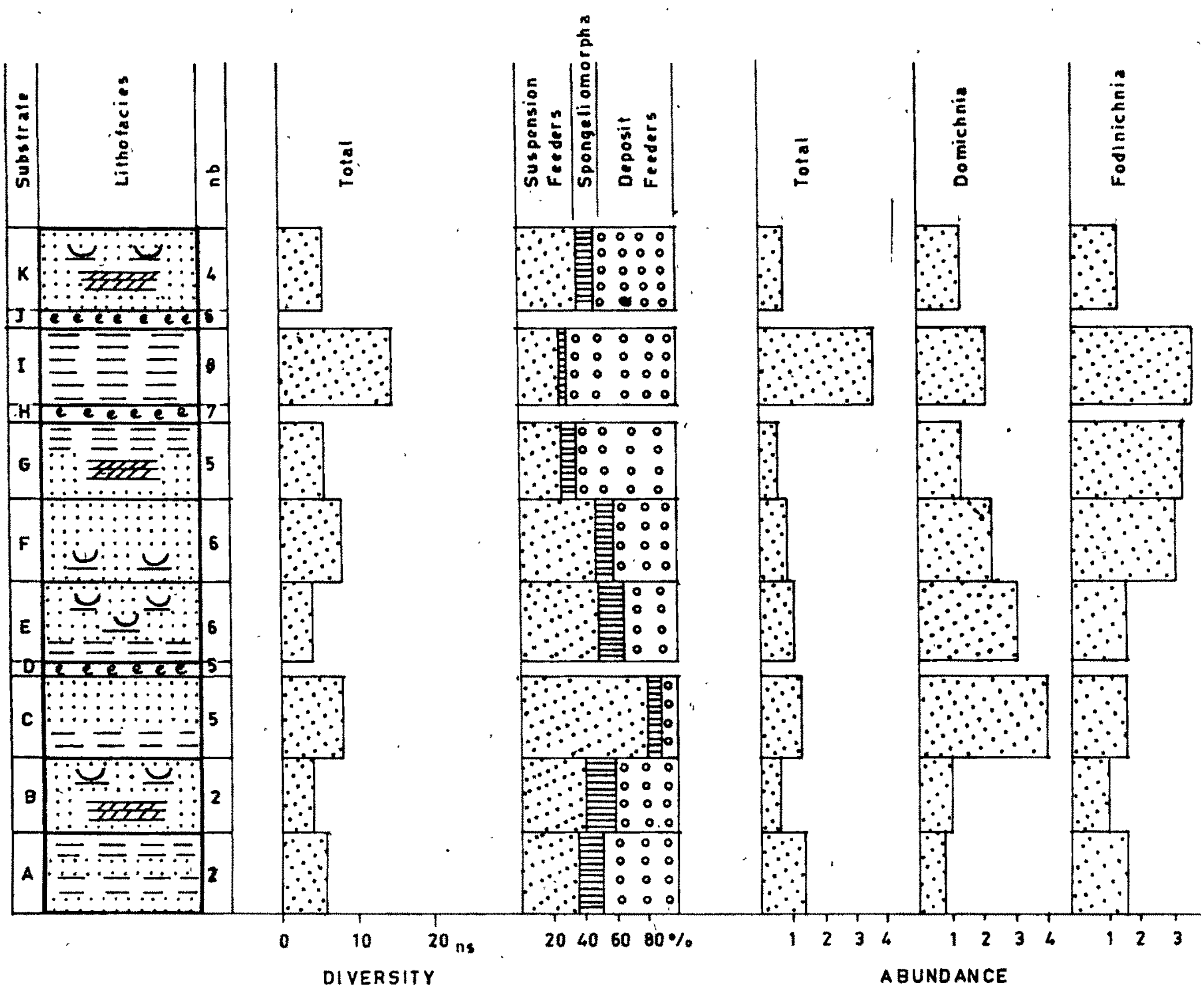
"Trophic diversity" is another important ecologic parameter in the benthic work and is the proportionating of feeding types amongst the constituent species (Walkar, 1972; Rhoads et al. 1972; Walkar and Bambach, 1974). According to these authors the distribution of herbivours, carnivorous or scanvengers, especially suspension feeding and deposit feeding benthos provide useful information about the feeding resources, relative sedimentation rates, water turbidity and sea floor stability (Rhoads et al., 1972).

As regards the rocks of the study area are concerned they contain a variety of lithofacies and as such several factors which operated differently in each environment must have exerted control on the preservation of trace fossils in these rocks. Although, preservations biases do affect the body fossils, such effects are especially marked with trace fossils, which are merely arrangements of sedimentary particles that comprise the host lithology. Bearing all these points in mind, the distribution of various groups and genera of trace fossils found in different lithofacies (substrate types) has been plotted in Figures 26 and 27.

As seen from these figures the diversity of genera seems to be fairly constant throughout the Wagad depositional cycle, except in the argillaceous sediments of facies "I" where it is maximum. This is probably due to the suitability of majority of the sediments types to the suspension feeders and the deposit feeders both. Generally speaking the suspension feeders show a slight preference for the coarser grained sediments (as in facies "C" and "F") whilst deposit feeders are abundant in argillaceous sediments (units "G" and "I"). Members of the Spongeliomorpha group are less common in argillaceous sediments (unit "I").

To obtain more information about substrate preference of trace fossils, their abundance has been observed by recording in each unit presence or absence of the traces

FIG.26. Diversity (number of species, ns) & abundance (expressed by the index of abundance) of ecologically grouped trace fossils in various Substrate (nb; number of beds investigated). Legend in fig. 14.

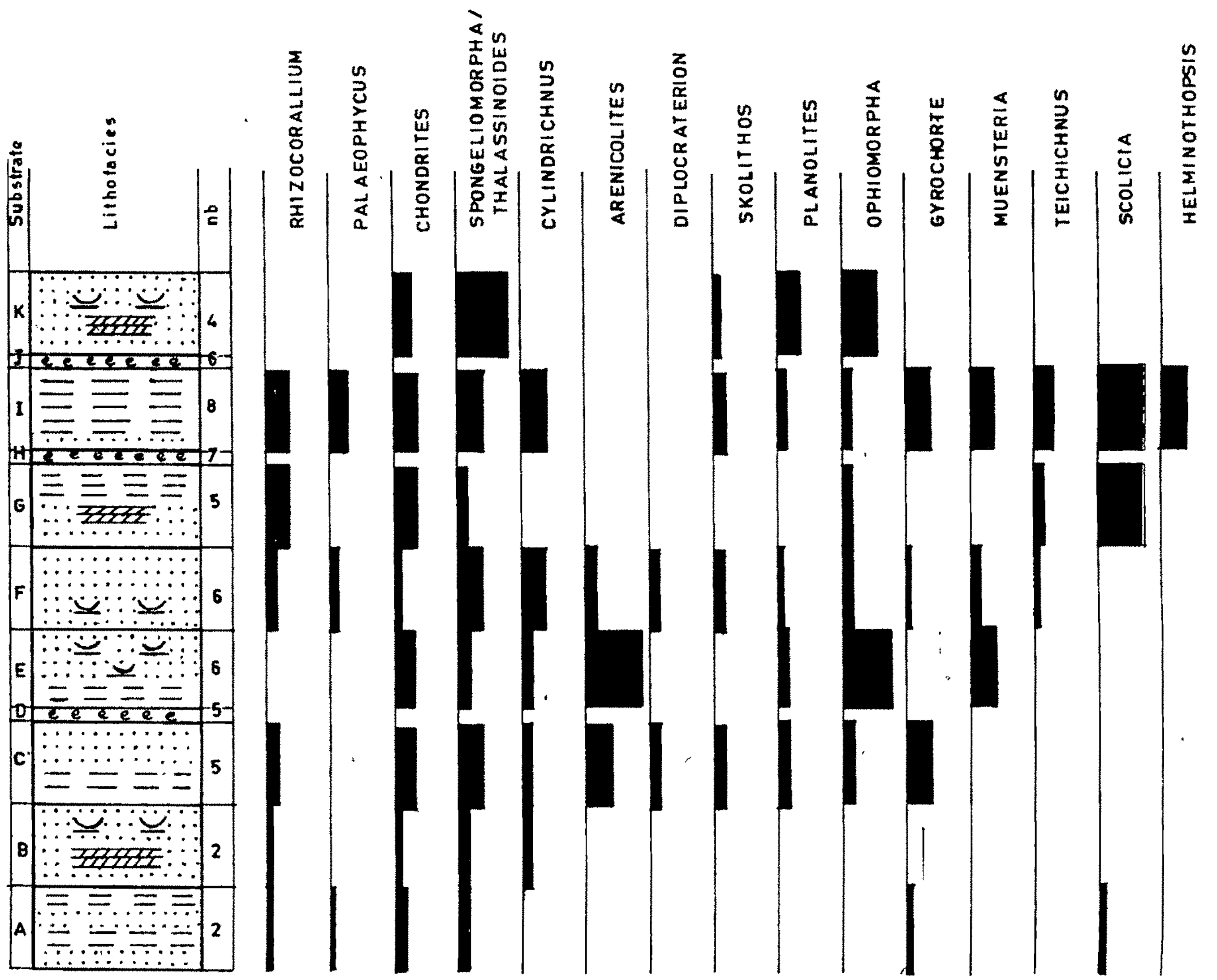


(Table 14) and classifying them according to their occurrences into four groups (1) rare; (2) sparse; (3) common and (4) abundant. The abundance of all traces in each substrate type then represents the total of ichnogenera for all beds of this substrate type multiplied by their index of occurrence. Finally, the index of abundance was calculated by dividing the abundance of all traces in each substrate type by the number of beds (n_b) investigated.

The index of abundance (Figure 26) show that in most of the substrate (except "I") the trace fossils are of low abundance. The abundance of main ecological groups (domichnia and fodinichnia) when compared, reveals that the domichnia and the fodinichnia both more or less vary in the various substrate types and no clear preference to any particular substrate type is indicated by them.

The abundance of individual trace fossils in various substrate type (Figure 27) also does not give a clear picture. Many forms including Rhizocorallium, Chondrites, Spongeliomorpha, Ophiomorpha, are found in a variety of sediments. Abundance of Diplocraterion, Arenicolites, Ophiomorpha and Spongeliomorpha is especially found in arenaceous sediments. On the other hand Gyrochorte, Muensteria, Helminothopsis and Scolicia are well preserved in the argillaceous sediments (fine sands and shales).

FIG. 27. Abundance of indiviual ichnogenra in various types of substrate (units and Legend as in fig. 14.)



In general the results obtained from figures 26 and 27 suggests that most of the Wagad trace fossils are related to the substrate only in a very limited way. This indicates that there are too many other factors that influence the distribution of Wagad trace fossils and no clear picture was obtained when only one of such factors (substrate) was considered by the author in his above studies.

Figure 28, drawn after Fursich (1974) illustrates in a simplified way the relationship between trace fossils and their environment. The diagram indicates that their substrate is only one factor besides distribution of available food below or above the depositional interface, whilst both in turn depend mainly on the hydrodynamic condition and food production. The hydrodynamic conditions are ultimately governed by depth and paleogeographic setting.

Interpretation of sediments in terms of lithofacies sometimes indicate relationships between the trace fossils and the environments. Diplocraterion for example is found associated with trough cross-bedding and ripple surface in Chitrod and Washatwa sections indicating a high energy environment. Muensteria and Scolicia especially in the Manfara, Mae, and Washatwa sections occur in shaly facies in low energy environments. As confirmed earlier the suspension-feeders as expected show higher diversity in the finner sediments also reflect the

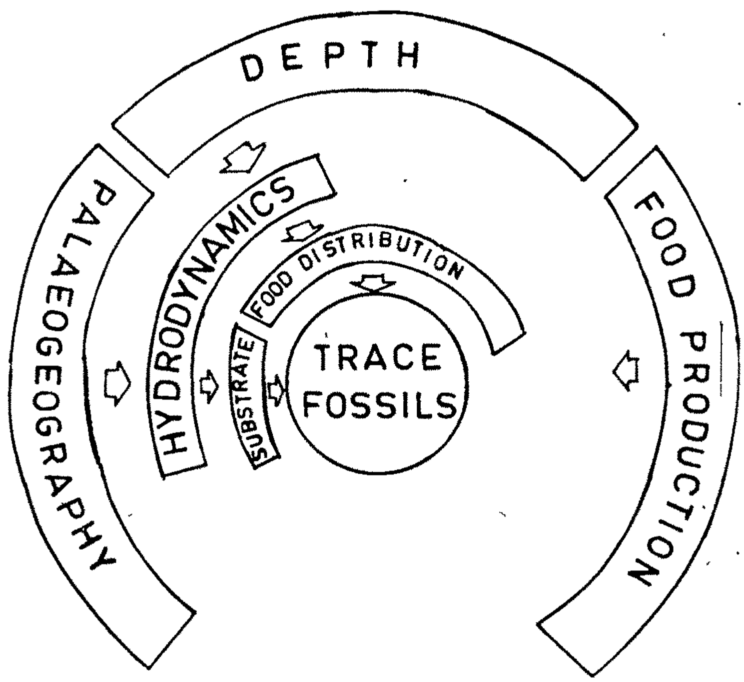


FIG. 28 Simplified model of the relationship between trace fossils and their environments More important relations are indicated by arrows (after Fursich 1974)

energy conditions. In the higher energy conditions food particles are held in suspension and are, therefore, more easily available for suspension feeders. Whilst in low-energy environment food particles tend to accumulate within the sediment which can be exploited by the deposit feeders. In general, the comparison of the abundance of the two feeding types represented by Domichnia and Fondinichnia indicate that there is a decrease of suspension feeders in low energy environment and a particular increase of deposit feeders. Some deposit feeders present in all sediments and environments seems to have found equally suitable conditions everywhere while suspension-feeders are found strongly dependent on turbulance or current for their food intake.

It may, therefore, be concluded that the hydrodynamic conditions together governed by depth and paleogeography played the most important role into the distribution of the Wagad Group of trace fossils. High energy environments favoured deep burrowing and suspension feeding and low-energy environments shallow burrowing and deposit feeding.

FIG. 29. STRATIGRAPHIC SECTION, TRACE FOSSILS AND DEPOSITIONAL ENVIRONMENT IN CHITROD

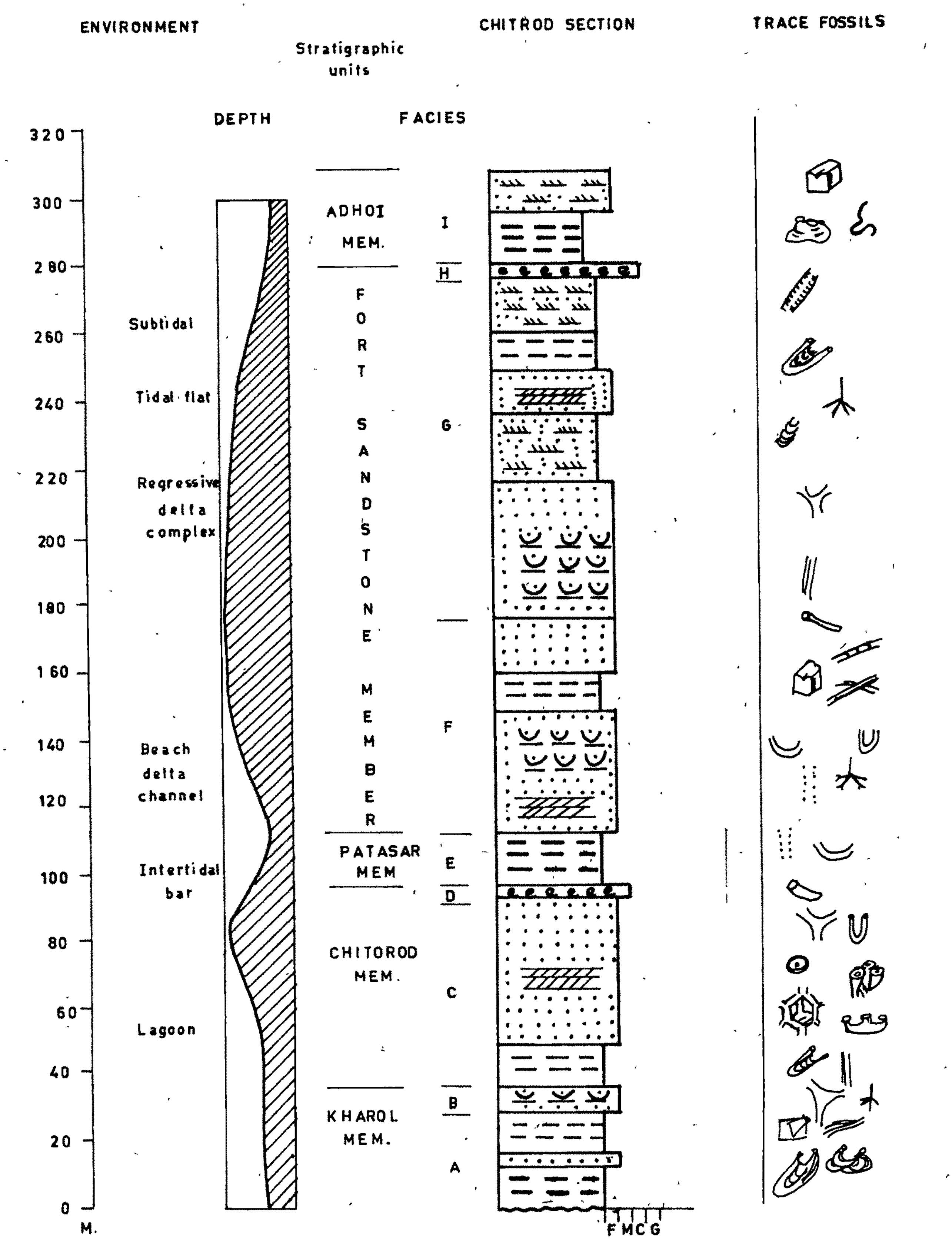


FIG. 30. STRATIGRAPHIC SECTION, TRACE FOSSILS AND DEPOSITIONAL ENVIRONMENT IN WASHATWA

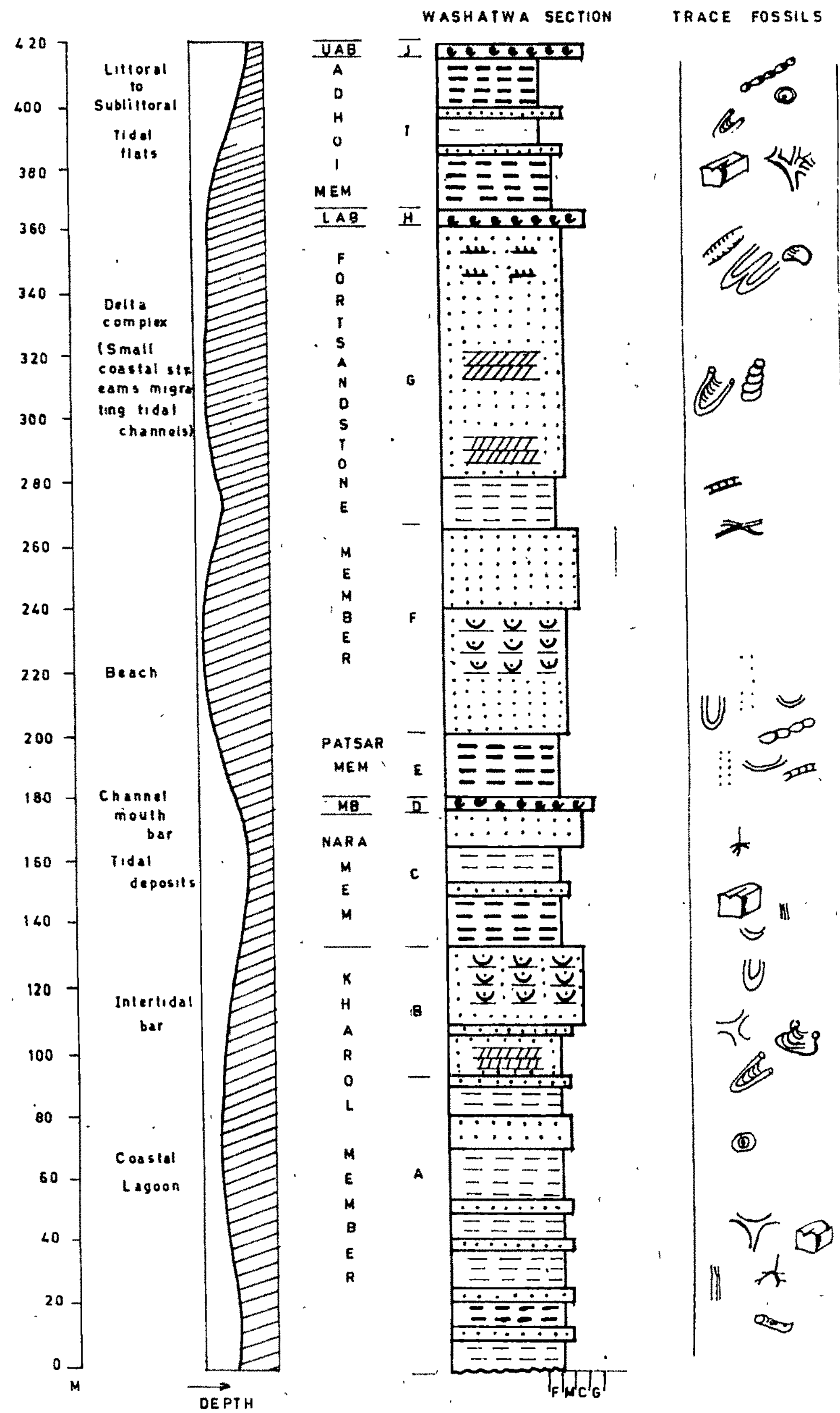


FIG. 31. STRATIGRAPHIC SECTION, TRACE FOSSILS AND DEPOSITIONAL ENVIRONMENT IN HALRAE

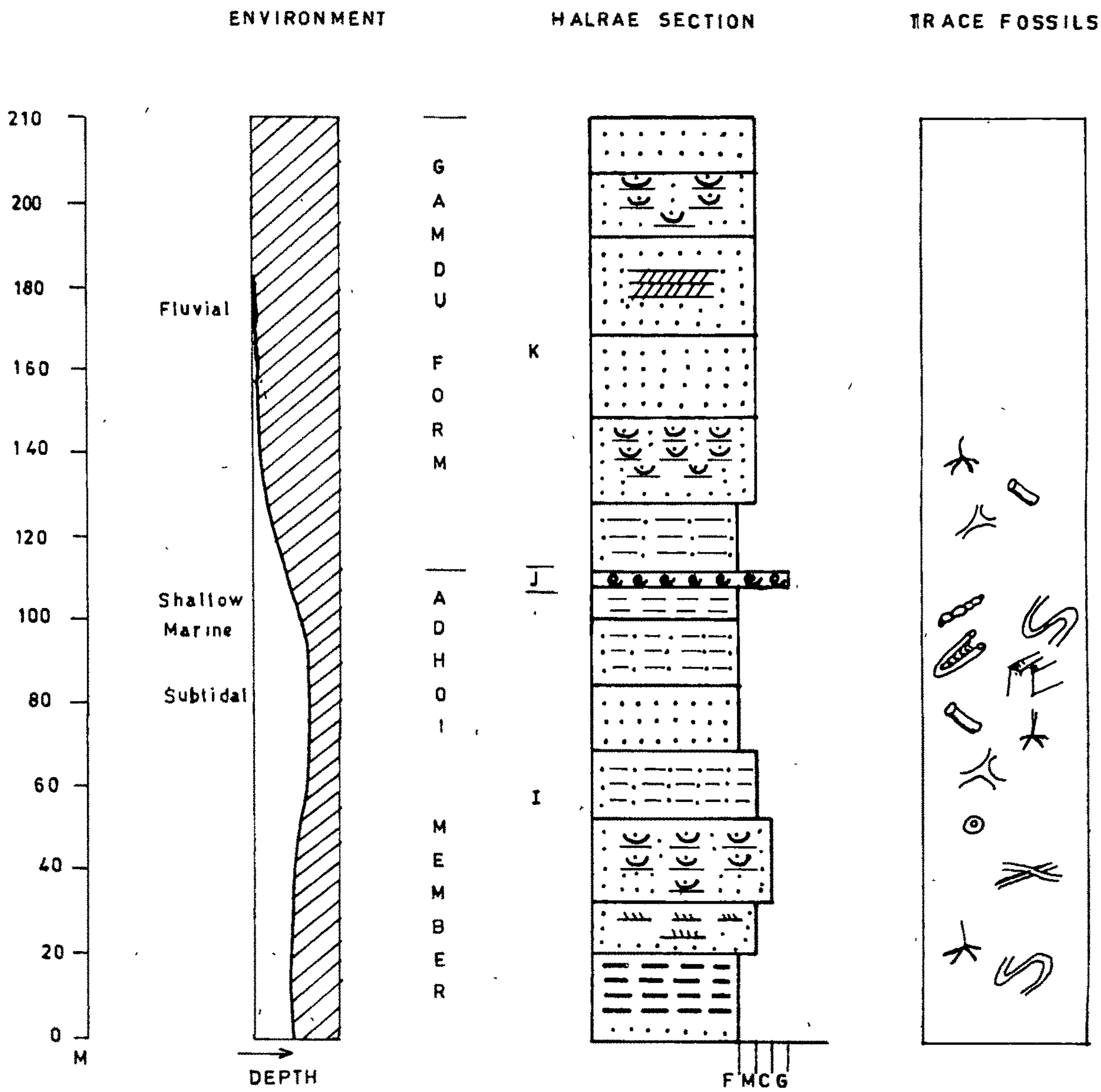


FIG. 32. STRATIGRAPHIC SECTION, TRACE FOSSILS AND DEPOSITIONAL ENVIRONMENT IN ADHOI

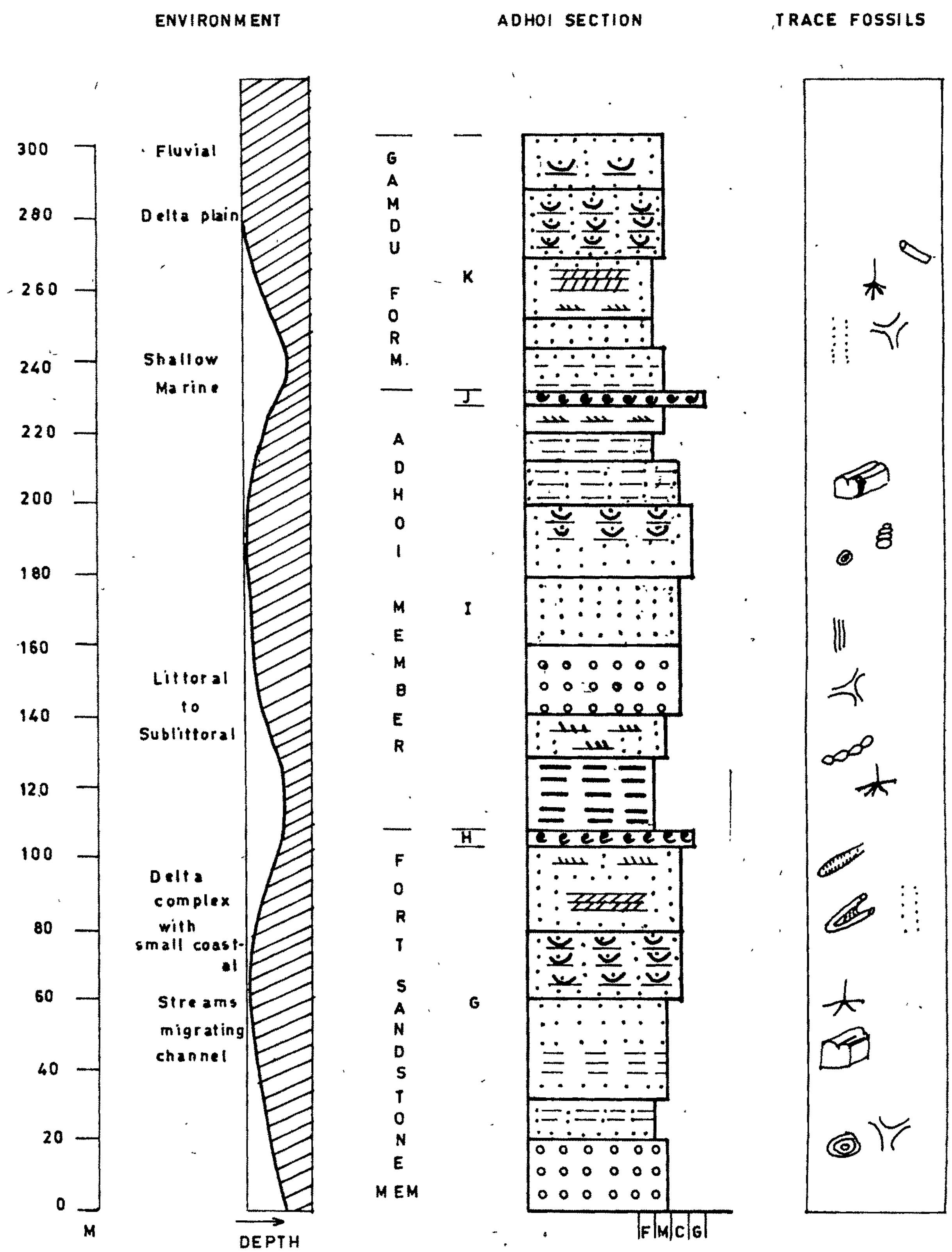


FIG. 33. STRATIGRAPHIC SECTION, TRACE FOSSILS AND DEPOSITIONAL ENVIRONMENT IN KANTHKOT

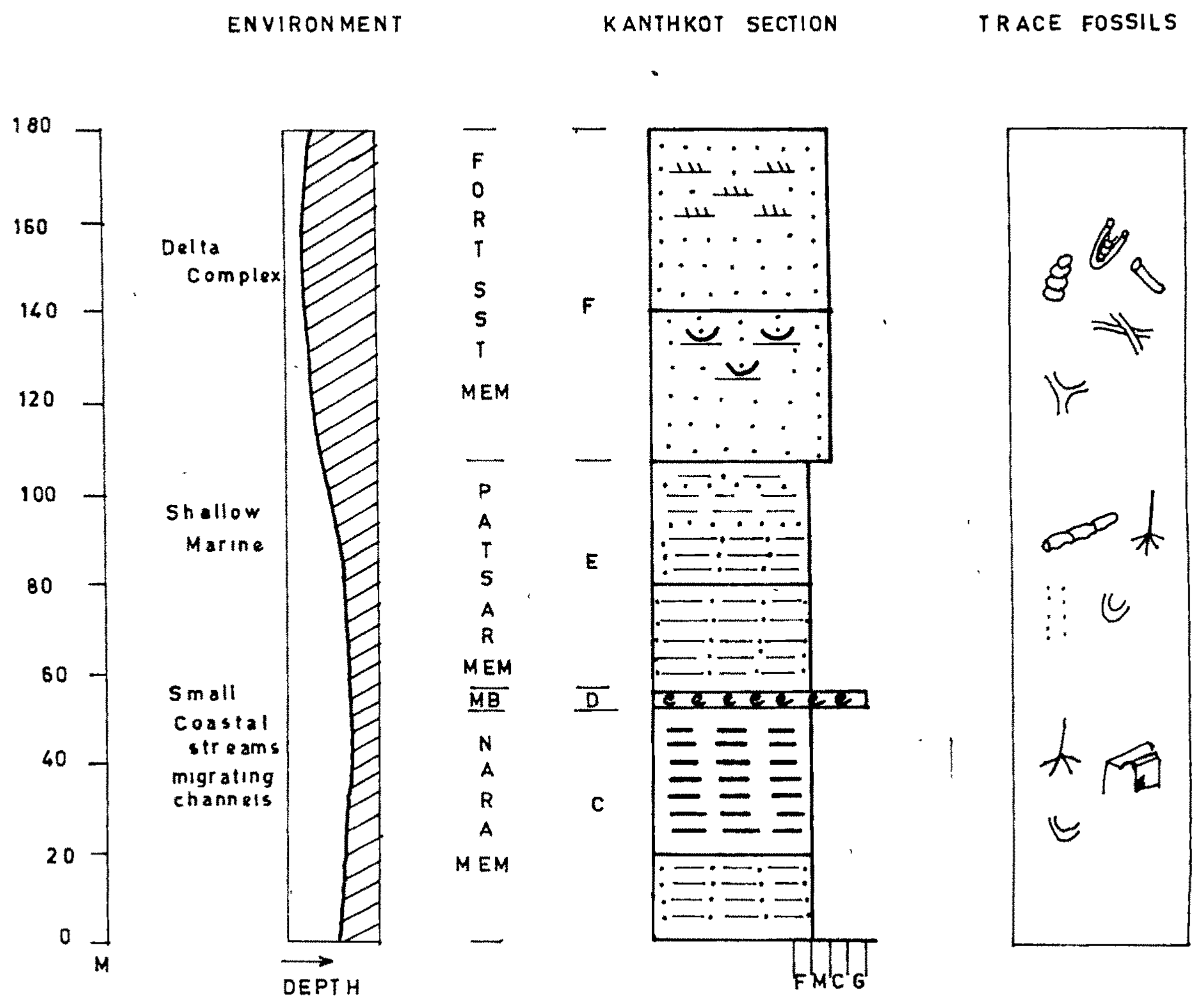


FIG. 34. STRATIGRAPHIC SECTION, TRACE FOSSILS AND DIPOSITIONAL ENVIRONMENT IN RAMWAO

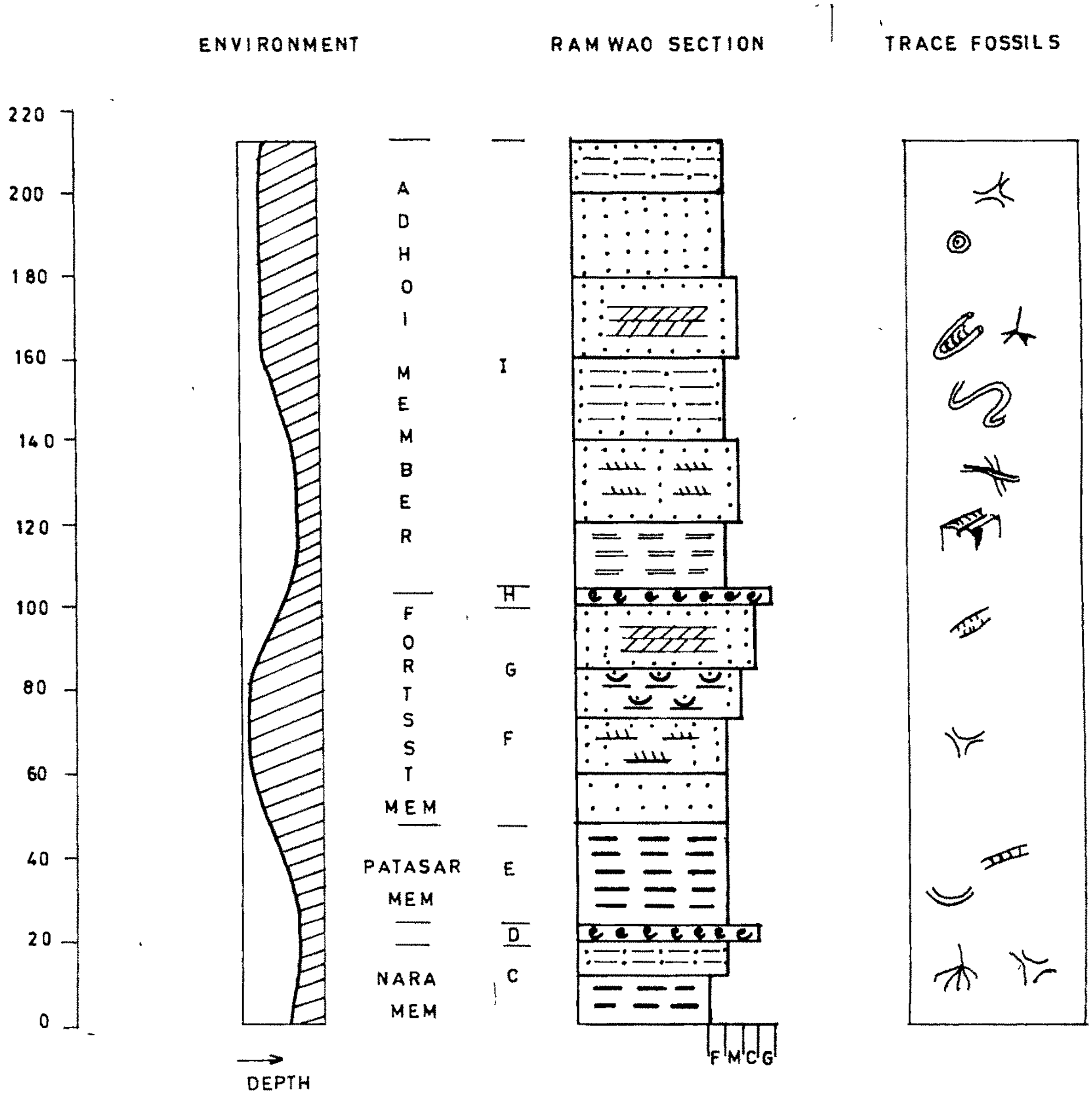


FIG. 35. STRATIGRAPHIC SECTION, TRACE FOSSILS AND DEPOSITIONAL ENVIRONMENT IN TRAMAU

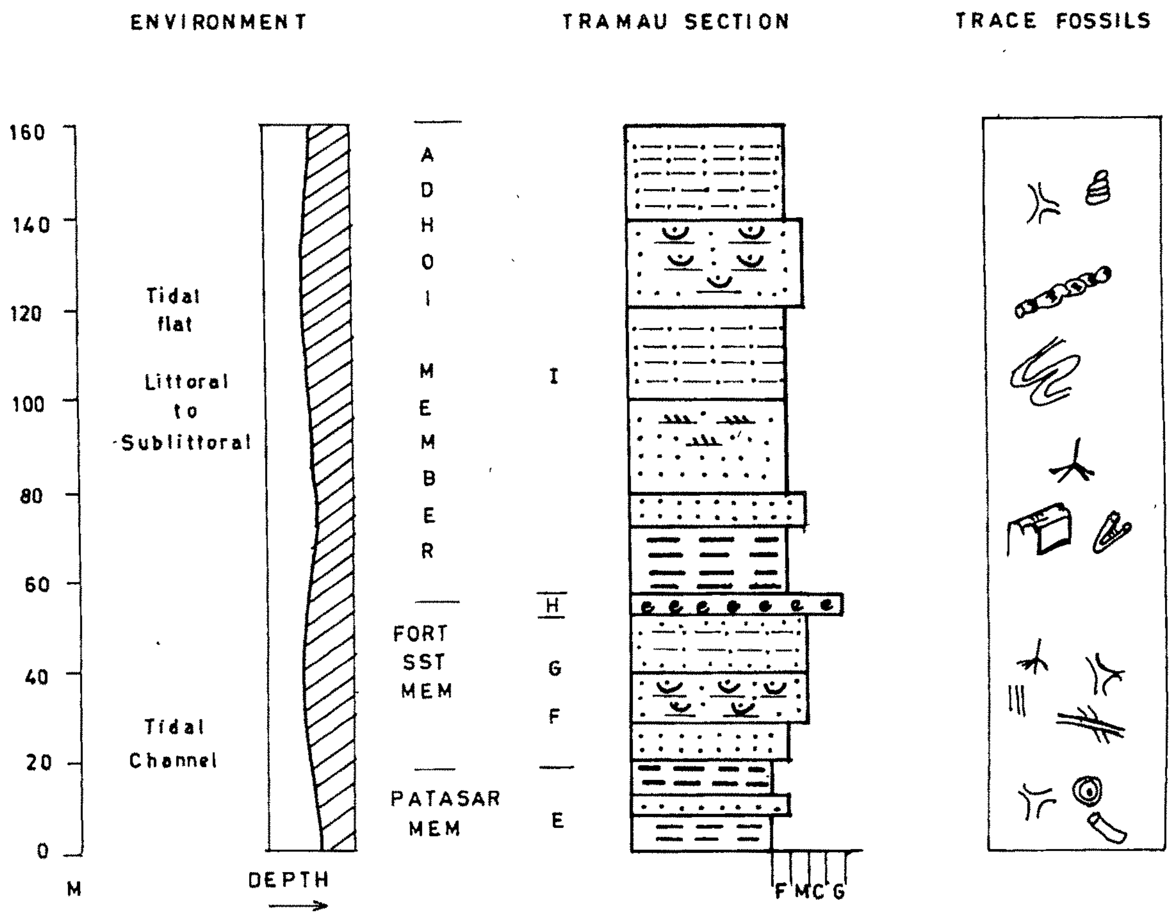


FIG. 36. STRATIGRAPHIC SECTION, TRACE FOSSILS AND DEPOSITIONAL ENVIRONMENT IN MAE

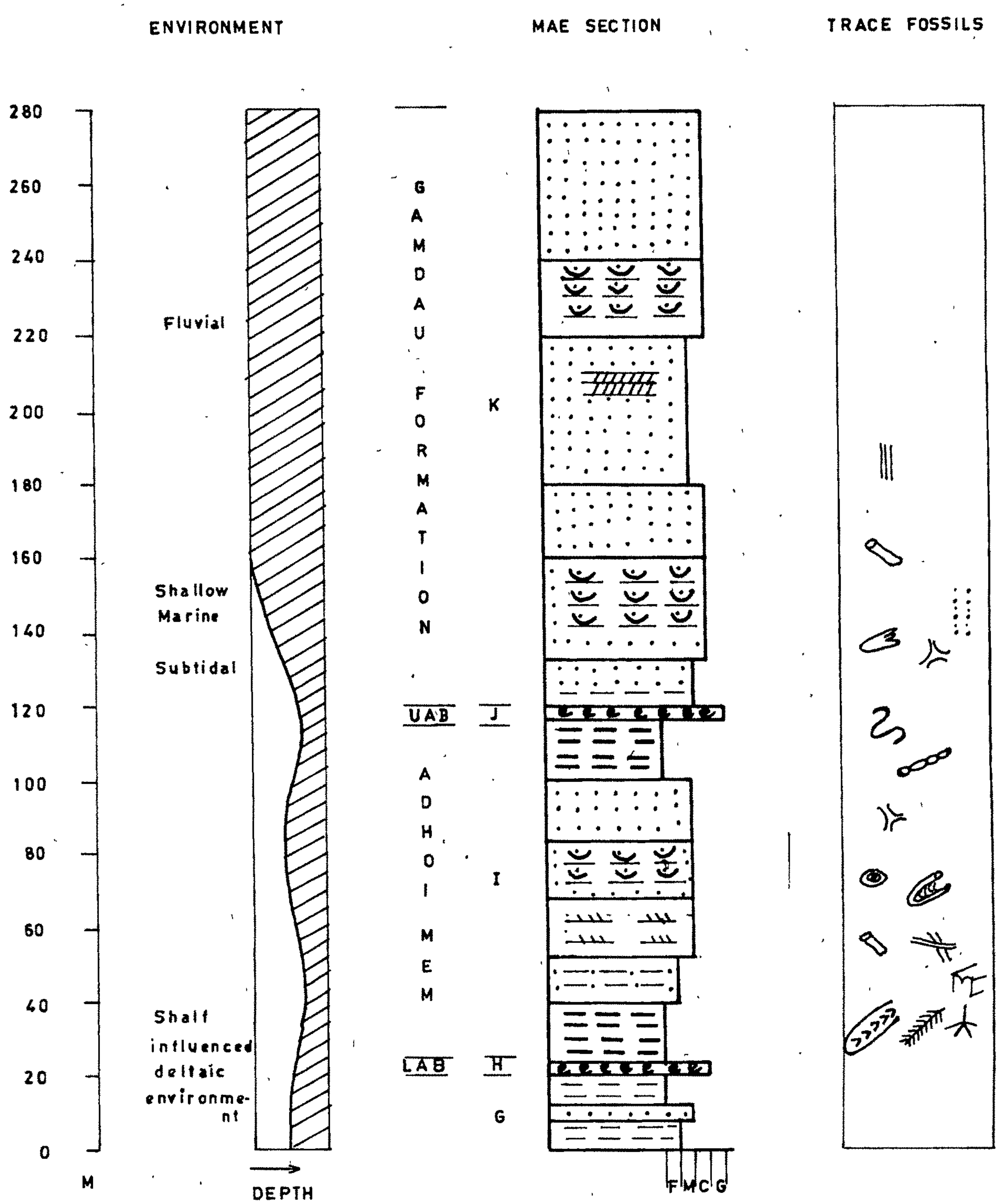


FIG. 37. STRATIGRAPHIC SECTION, TRACE FOSSILS AND DEPOSITIONAL ENVIRONMENT IN NARA

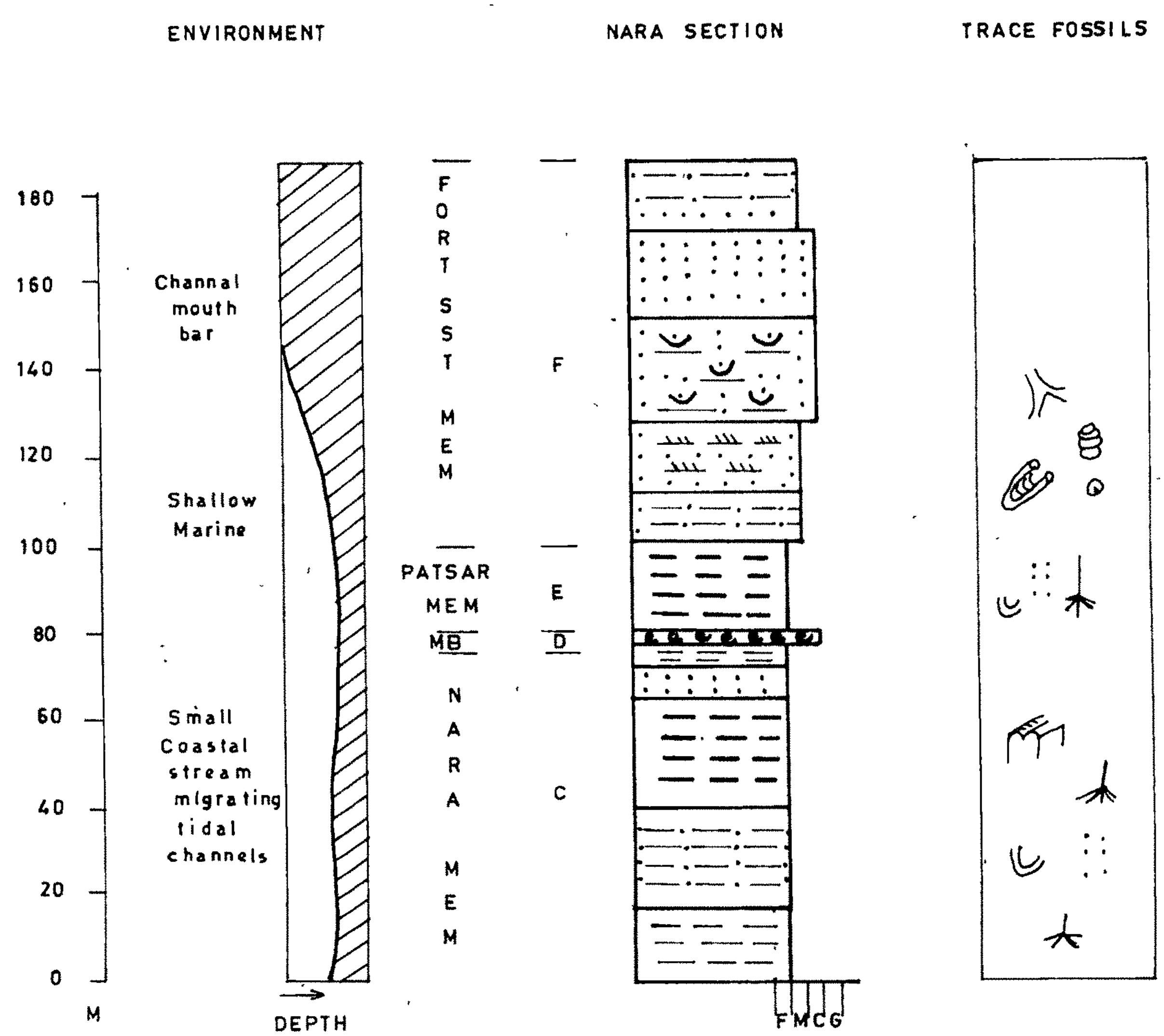


FIG. 38. STRATIGRAPHIC SECTION, TRACE FOSSILS AND DEPOSITIONAL ENVIRONMENTS IN MANFARA