Event-Stratification in Nummulite Accumulations and in Shell Beds from the Eocene of Egypt

Abstract: The concept of event-stratification may successfully be
         applied to two types of bioclastic deposits in the Eocene
         of Egypt:

   1. Middle Eocene Gizehensis-Bed: physical processes
      ("winnowing events") are significantly involved in
      structuring **and** in**-situ** accumulating nummulitic
      Sediment bodies.

   2. Upper Eocene shell beds: reveal a complex series of
      erosion and colonisation events over a certain time
      interval, each "physical process" being followed by
      a "biological response".

1. Introduction

The Eocene of Egypt comprises shallow-marine **and** marginal **Sediments**
that were deposited in narrow and elongated tectonic basins forming
embayments of the Tethys. Early **and** Middle Eocene were times of car-
bonate **Sedimentation,** but due to regression, **Sediments** became essen-
tially terrigenous from the Late Eocene onwards. Compilations on
stratigraphy **and Sedimentation** patterns are provided by SAID (1962)
and SALEM (1976).

The object of this paper is to apply the concept of "event-stra-
tif ication" to two rather different kinds of shell deposits:

1. Accumulations of nummulites as a very special case of bio-
   clastics.
2. Several prominent and laterally persistent shell beds, that are
   being used for refined stratigraphic correlation (STROUGO 1977).

2. Nummulite Accumulations Structured by Physical Events

2.1. Previous Work

The sedimentological aspects of such bioclastic deposits that con-
tain nummulites in rock-forming quantities have **so** far received
little attention. Generally, nummulites are believed to have formed
autochthonous "banks" or "bioherms" or they are even considered as
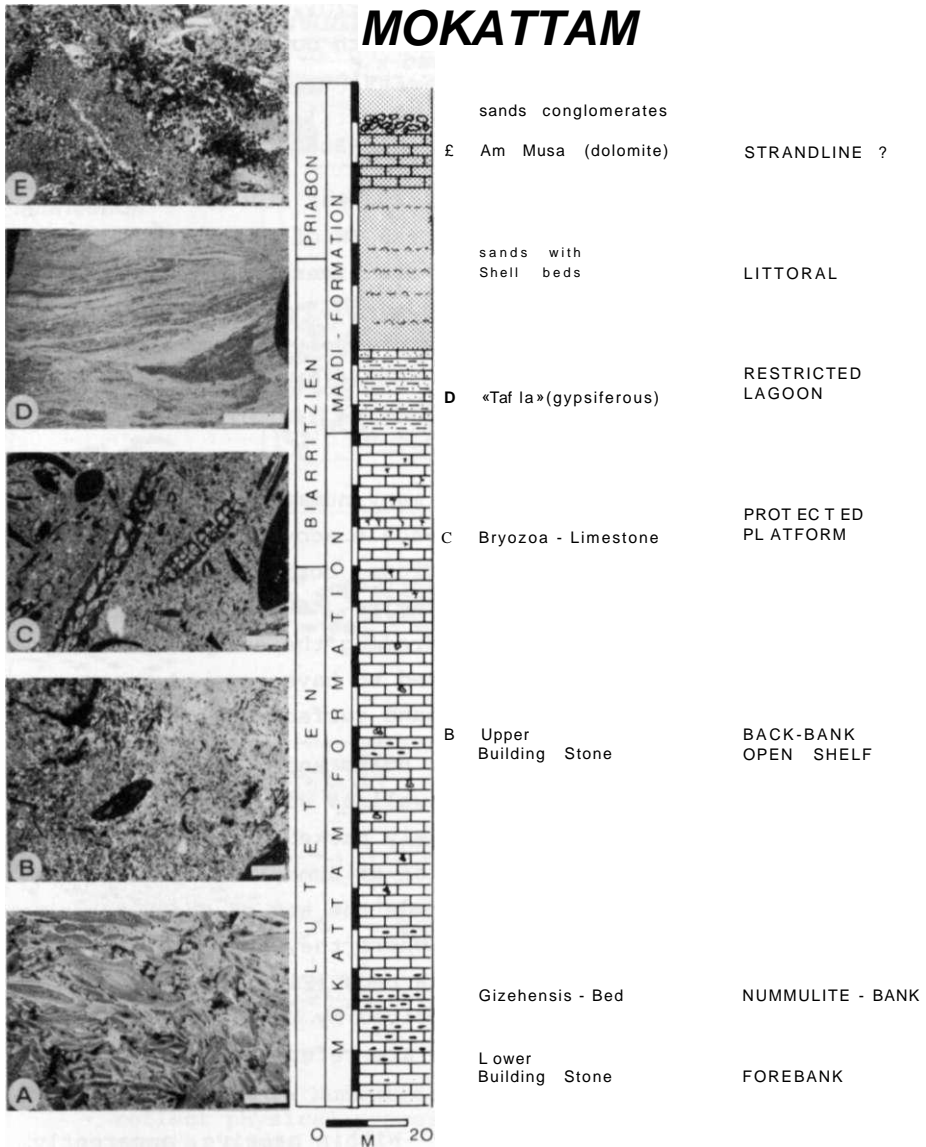reef-builders (ARNI 1965; ARNI & LANTERNO 1972, 1976; DECROUEZ &
LANTERNO 1979).

MOKATTAM

	sands conglomerates	
£ Am Musa (dolomite)		STRANDLINE ?
	sands with Shell beds	LITTORAL
D «Taf la»(gypsiferous)		RESTRICTED LAGOON
C Bryozoa - Limestone		PROTECTED PLATFORM
B Upper Building Stone		BACK-BANK OPEN SHELF
Gizehensis - Bed		NUMMULITE - BANK
Lower Building Stone		FOREBANK

PRIABON · BIARRITZIEN · LUTETIEN

MAADI - FORMATION · MOKATTAM - FORMATION

0   M   20

Fig. 1. Stratigraphic summary log of Middle and Upper Eocene in
the Mokattam-Hills (E of Cairo) and tentative environmental
Interpretation. The Gizehensis-Bed (Mokattam-Formation) and
several shell beds (Maadi-Formation) are discussed here

However, nummulites have also been recognised to occur wave-affected
(ARNI & LANTERNO 1972), reworked in shoals and fore-reef **Channels**
(SANTISTEBAN & TABERNER 1980), in cross-bedded littoral series

(RONIEWICZ 1969) and in turbidites (ENGEL 1970). FOURNIE (1975)
compared certain nummulite accumulations with ooids shoals and re-
lated them to an analogous hydrodynamic regime.

2.2. Stratification Types in the Gizehensis-Bed

The Middle Eocene *Nummulites gizehensis-Beä* was studied in classi-
cal exposures at the Giza Pyramids Plateau (W of Cairo) and in the
Mokattam Hills (E of Cairo, Fig. 1), where limestones appear ge-
nerally massive or relatively thick-bedded (0.5 - 1.5 m) with 1 -
50 cm marly intercalations. They consist largely of nummulite-bio-
micrites showing wackestone/packstone depositional textures (Fig. 4),
but grainstones may also occur. The following features bear on their
origin (Fig. 2):

(1) <u>Firmground Horizons</u>. The bases of many nummulite beds are
    Sharp and erosional, showing large-scale scours and small-scale
    pockets (pot holes), as well as burrows, both typical for firm-
    ground conditions *(Gloasifungites* -facies, SEILACHER 1967). Major
    hydrodynamic events (hurricanes?) eroding the seafloor down to
    already compacted levels are inferred to have exposed these
    laterally fairly persistant firmground surfaces.

(2) <u>Erosive Pockets and Pot Holes.</u> Pot holes and pockets occur
    in association with firmgrounds as well as within nummulite beds
    (Fig. 3). They commonly show a densely packed grainstone fill with
    edgewise imbrication and fan position of nummulites and are most
    common in the shallowest parts towards the top of the Gizehensis-
    Bed (probably a "Nummulite Bank"), where they indicate the com-
    posite and amalgamated nature of the beds (Fig. 3). These
    pockets resemble the pot holes described by DORR & KAUFFMAN (1963)
    and AIGNER & FUTTERER (1978), which are referred to strong vor-
    tex currents during storm events.

(3) <u>Scour-and-Fill Structures</u> (Fig. 2). Within massive, apparently
    unstratified beds, scour-and-fill structures occur in various
    Orders of magnitude. They are much broader (up to several dm)
    and filled with nummulite-packstones. Their lower boundary is
    commonly shallow channel-like or sinusoidal but normally non-
    erosive.

(4) <u>Planar Lags.</u> (Fig. 2). Thin planar layers of nummulite packsto-
    ne are also common and may almost exclusively consist of the
    larger B-forms of *Nummulites gizehensis,* which are often Imbri-

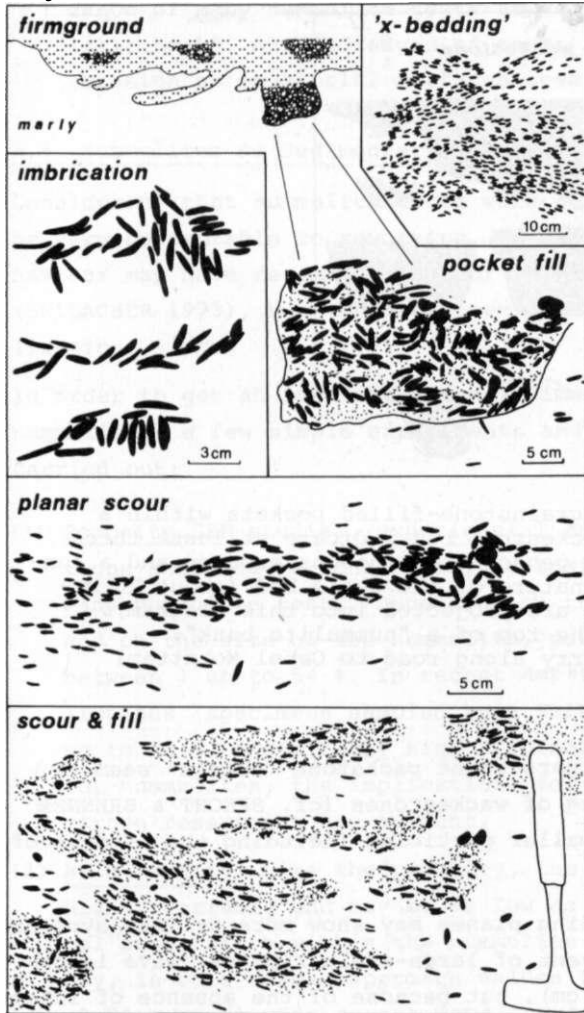## *Physical Events in Nummulite-Banks*

Fig. 2. Biofabrics in Nummulite-accumulations ("Gizehensis Bed")
reflect physical processes as structuring and stratifying
agents. Note:

- extensively bürrowed firmgrounds with erosive relief,
- erosive pockets filled with biosparite,
- imbrication,
- stratification reminiscent of cross-bedding,
- Nummulite-concentrations on planar scours,
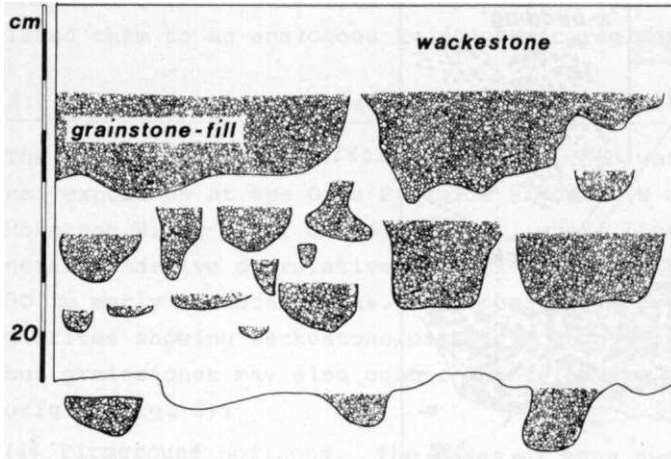- small-scale scour and fill structures

Composite Bed

Fig. 3. Levels with erosive grainstone-filled pockets within a
massive Nummulite-wackestone bed indicate at least three
discrete episodes of penecontemporaneous erosion and a com-
posite, amalgamated nature of the whole bed (about 20 me-
tres lateral outcrop are projected into this diagram).
This is a bed from the top of a "nummulite bank".
(Gizehensis-Bed, quarry along road to Gebel Mokattam)

cated. These laterally persistent packstone-"sheets" seem to
have formed by winnowing of wackestones (cf. SPECHT & BRENNER
1979) and removal of smaller particles including the A-forms of
the nummulites.

(5) Erosive Ripples.   Bedding planes may show more or less symmetri-
cal undulations reminiscent of large-scale ripples (wave length
60-100 cm, height 10-25 cm), but because of the absence of inter-
nal structures typical for ripples and due to the highly variable
shape, these undulations more likely represent "erosive ripples"
(cf. REINECK & SINGH 1975, Fig. 8; GOLDRING 1971, Fig. 15) or
"scour ripples" (BAILEY 1966, Fig. 1) rather than normal ripples.

(6) Imbrication.   Both "contact" and "isolate" imbrication (LAMING
1966) is common, especially in local concentrations of the
larger and flatter B-forms of *n. cjizehensis* (Fig. 2), while edge-
wise imbrication was only occasionally observed. Current action
thus seems to have been more important than pure wave action.

(7) Sorting and Fragmentation.   Sorting is normally poor, expressed
by the association of small A-forms and larger B-forms of *s.*

gizehensia. Thin-sections reveal the worn and fragmented appea-
rance of many nummulite tests as well as the abundance of "nummu-
litic hash". Abraded edges of tests are most conspicuous, while
abrasion on equatorial surfaces seem to be less common.

2.4. iMummulites as Sedimentary Particles

Considering that nummulite tests were extremely porous, they should
be very susceptible to reworking, so that their sedimentological be-
haviour may have resembled that of crinoid remains originally
(SEILACHER 1973), but may have been drastically altered by prefossi-
lization.

In order to get an idea about the sedimentological behaviour of
nummulites, a few simple experiments and calculations have been
carried out:

(1) <u>Porosity</u>.SKM-studies, experimental and mathematical determina-
tions show that a considerable porosity is still preserved in
many nummulite tests. Depending on the surrounding rock type
and on the size of the nummulite, porosity was found to ränge
between 1 up to 54 8. In recent *Amphisorus* tests from the Phi-
lippines (specimens sampled by A.SEILACHER), porosity reached
up to 72 %. A similarly high original porosity can be inferred
for nummulites; the implications for their potential as hydro-
carbon reservoirs are evident.

(2) Bulk Density. Like the porosity, the bulk density values are
highly variable and may be as low as 1.28 g cm^{-3}. Due to inter-
nal cementation within the nummulite test, however, bulk density
may, in some cases, approach values typical for pure calcite
(2.71 g cm^{-3}). For recent *Amphisorus,* only 0.305 g cm^{-3} has been
found.

(3) <u>Settling Velocity</u>. Determination of the settling velocity allows
to deduce the diameter of hydraulically equivalent quartz grains
(e.g. FUTTERER 1977, Fig. 10). In this way, nummulites with a dia-
meter of 7 - 24 mm were found to be equivalent to 1.0 - 1.85 mm
sand grains ("very coarse sand").

(4) <u>Critical Transport Velocity</u>. Firstly, hydraulic equivalents de-
rived from settling experiments were used in the HJULSTRÖM-dia-
gram: here, values for the critical transport velocity are most-
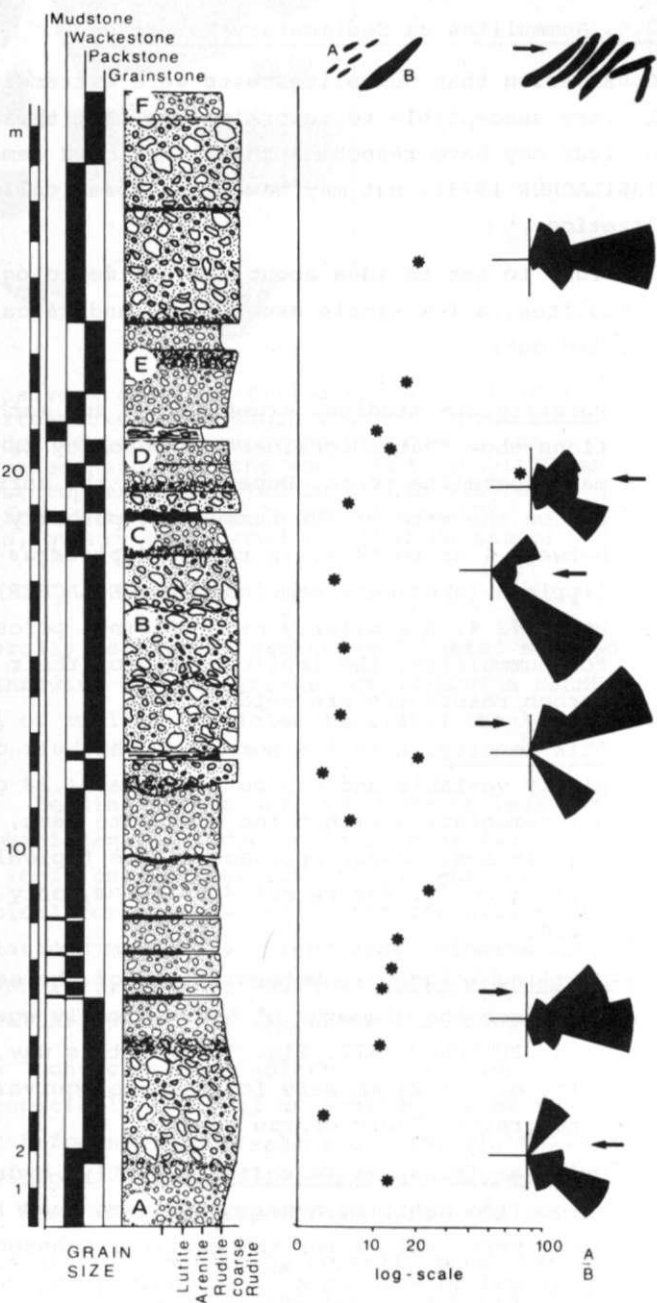ly around 30 - 40 cm s^{-1}. Secondly , the critical transport ve-

GIZEHENSIS - BED
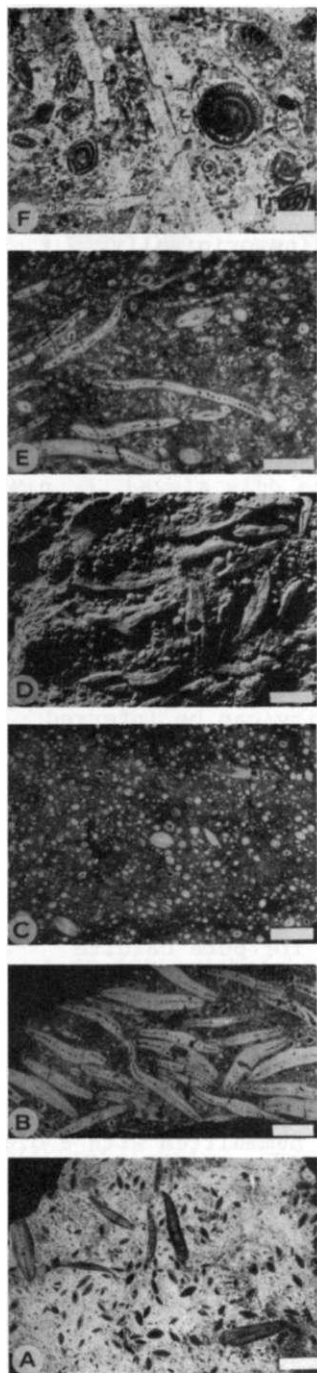
LITHOLOGY   A/B-RATIO   IMBRICATION

locity was directly determined by flume experiments carried out
by Dr. E. FUTTERER (Kiel). Here, velocities ränge between 18 -
77 cm s^{-1}, which is in the same order of magnitude as the values
derived from settling experiments. Dr. FUTTERER also observed,
that nummulites are transported by sliding, saltation and rolling.

2.5. Conclusions

(1) Stratification types and biofabrics in nummulite accumulation
show that physical sedimentary events were responsible for their
structure. The smaller A-forms of *N.gizehensia* largely dominate
the assemblages (Fig. 4), as BLONDEAU (1972) has postulated for
their original communities. Therefore nummulites seem to have
mainly accumulated in situ through winnowing events and thus
have formed extensive Sediment bodies (Fig. 5).

There is no evidence for reef-like buildup in the "Nummulite
Banks" of the "*Gizehensis-Bed. Du*e to the mechanisms involved,
this type of buildup may be called "nummulite teils".

(2) Simple experiments indicate that nummulites must have been very light
and susceptible to reworking at current velocities as low as 20
- 80 cm s^{-1}. According to LOGAN et al. (1969, Fig. 3), storm-
induced wave-current velocities of this order of magnitude occur
in waters as much as 100 m deep.

(3) Physical processes involved in the formation of "Nummulite Banks"
may be comparable to the role of physical storm-related Sedimen-
tation in molding the character of present-day carbonate mud
banks around Florida (WANLESS 1979).

Fig. 4. Detailed log showing variations of microfacies, depositional
fabrics, grain size and nummulite A/B-ratio within the "Nummulites
gizehensis-Bed" (northern escarpment of Giza Pyramids Plateau, along
Fayum road). A-forms dominate throughout most of the sequence, but
layers with relative enrichment of B-forms often correspond to pack-
stone textures, indicating winnowing and removal of the fine parti-
cles including the A-forms. Note also abundance of imbricated fa-
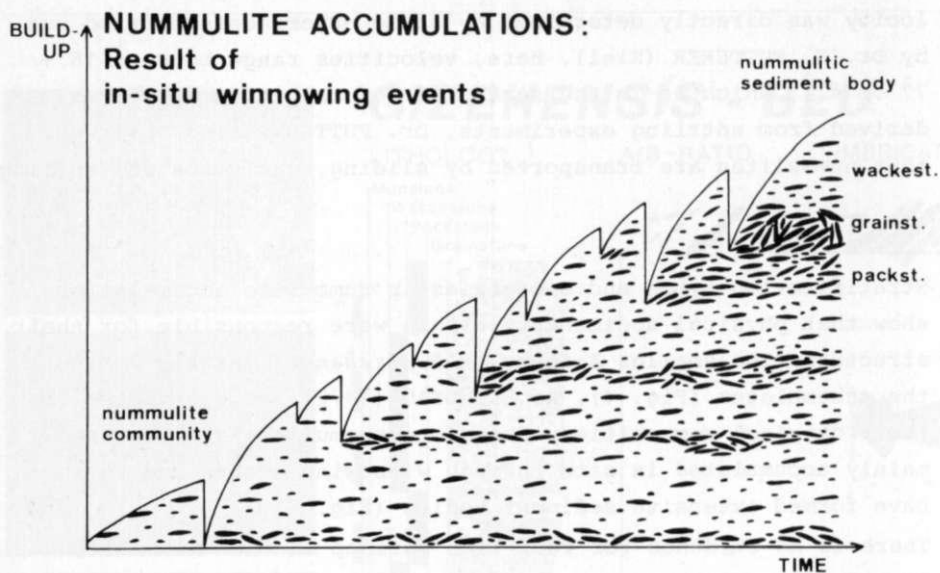brics (each measurements based on about 100 nummulites)

Fig.   The time-buildup diagram suggests that episodic winnowing
        (probably storm-generated) is responsible for structure,
        depositional fabrics and growth of nummulite accumulations.
        Repeated winnowing events of varying intensity have washed
        away substantial amounts of lime-mud that probably represen-
        ted the original Substrate of nummulites (according to
        BLONDEAU 1972). Thus, the resulting bioclastic accumulation
        is slowly growing upwards like an archaeological "tell-
        structure" ("nummulite teil") and consists to a large extent
        of event-generated in-situ lag deposits, but does not repre-
        sent the actual habitat conditions of the nummulites. Due to
        gradual shallowing, winnowed fabrics become more abundant
        towards the top of nummulitic Sediment bodies

3. Shell Beds: Interplay Between Physical Processes and Biological
Responses

3.1. General Problems

Shell beds have been widely used for Community reconstructions (e.g.
McKERROW 1978). It has also been debated whether detailed and even
quantitative reconstructions concerning mortality rates, diversity,
trophic structure etc. can be derived from such accumulations of
biologic hard particles. After all, they may have suffered consi-
derable taphonomic distortion. Apart from postmortal transport, fau-
nal changes due to minor environmental fluctuations may have obli-
terated the original faunal spectrum of a "Community" (cf. WILSON
1967, FÜRSICH 1978, BOUCOT 1975).

In general, Shell beds should not be viewed indiscriminately as paleoecological portraits of paleocommunities, but should rather be analysed in their taphonomic details in order to appreciate their füll sedimentary history.

3.2. Taphonomy and Stratification in Upper Eocene Shell Beds

Upper Eocene shell beds, usually 0.5 tp 1.5 m thick, have been studied in the Mokattam Hills (cf. Fig. 1), the Giza Pyramids area, and in Quasi"-el-Sagha (Fayum Oasis) . Generalised they show the following attributes (Fig. 6):

(1) Shell beds develop on scoured surfaces which are commonly burrowed by *Spongeliomorpha* , indicating firm **Substrate** conditions ("firmgrounds").

(2) In most cases, these firmground horizons were colonised by *Carolia* as a pioneer. Similar pioneer colonisations by this epibyssate bivalve usually take place repeatedly on internal erosion surfaces within shell beds.

(3) Shell bed development is characterised by (often repeated) changes in faunal composition and Sediment fabrics. Thus, *Carolia* colonies become frequently replaced by ostreids or by *Plicatula* , the former being in many cases cemented onto *Carolia* Shells. The oysters in turn may later be encrusted by corals, eventually leading to small-scale coral banks.

(4) Subsequent erosion may have led to partial or complete reworking of original epibenthic assemblages and to the production of shell debris. This shelly Substrate in turn became inhabited by specific organisms (e.g. *Ophiomorpha* with pellet-ligned walls for stabilisation).

(5) Intercalations of endobenthic organisms (Spatangids,*Turritella*) indicate phases of intermittent mud-sedimentation and softground conditions. Since the fine Sediment itself has later became reworked and winnowed away, these shell lags represent the only "memory" (SEILACHER, this volume) of softground intervals within mostly epifaunal shell beds.

3.3. Conclusions

(1) Shell bed initiation in the Upper Eocene requires strong erosion (major storm event?) to create a firmground Substrate, which could be used by *Carolia* as a post-event pioneer colonizer.

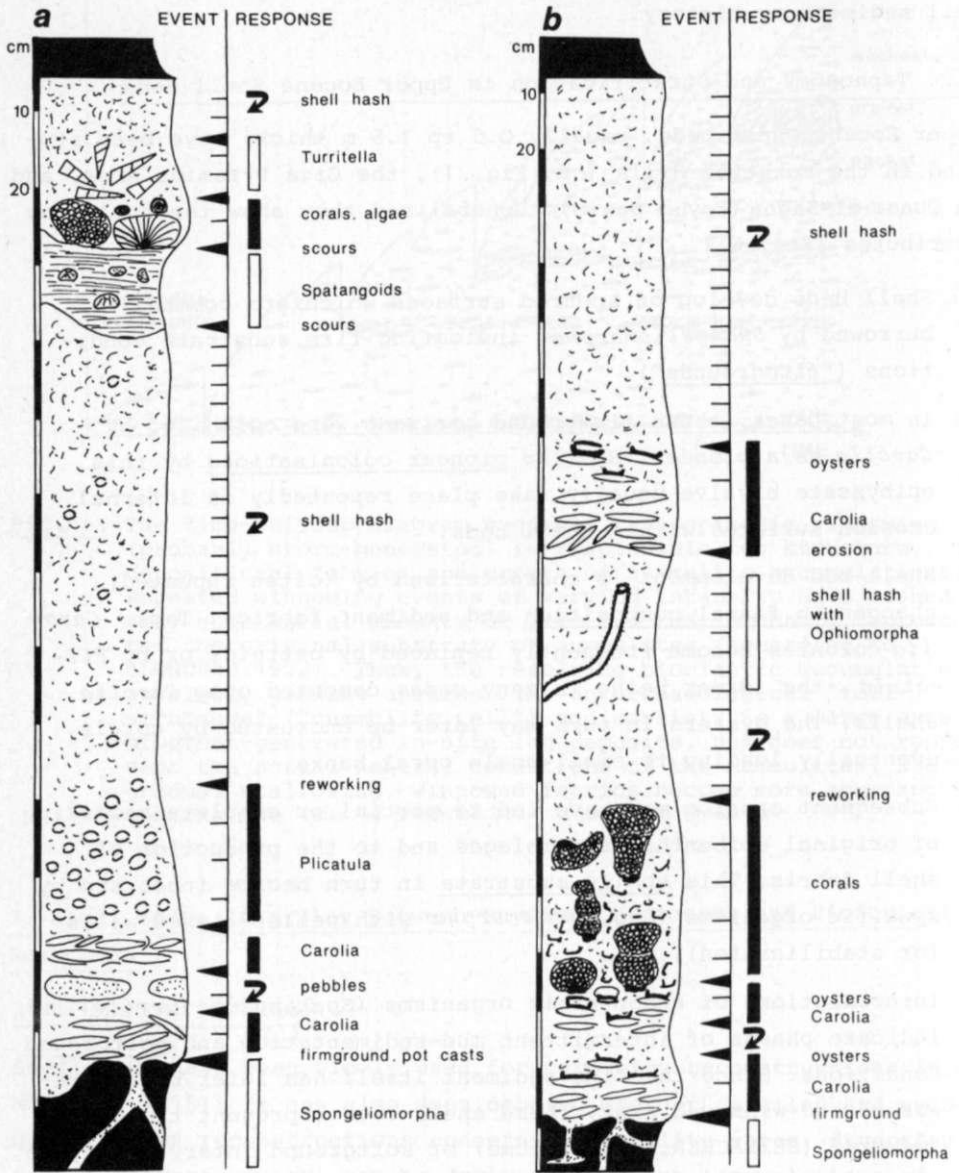# SHELL BEDS: events, successions, pseudo-successions

a

EVENT | RESPONSE

cm	
10	shell hash
20	Turritella
	corals. algae
	scours
	Spatangoids
	scours
	shell hash
	reworking
	Plicatula
	Carolia
	pebbles
	Carolia
	firmground. pot casts
	Spongeliomorpha

b

EVENT | RESPONSE

cm	
10	
20	shell hash
	oysters
	Carolia
	erosion
	shell hash with Ophiomorpha
	reworking
	corals
	oysters Carolia
	oysters
	Carolia
	firmground
	Spongeliomorpha

Fig. 6. Shell beds revealing a complex series of erosional/depositional events, followed by specific biological responses. Some appear to be true ecological successions, other are merely "pseudo-successions". (Black bar = epifaunal response, clear bar = endofaunal response, a = "Plicatula-Bed", b = "Ostrea-Bed", Mokattam-Casino section, Maadi-Formation)

(2) Shell bed development: shell beds accumulated on such firmgrounds are essentially autochthonous, but they record a series of sedimentary events (erosion/deposition), each of which may be followed by a specific biological response (epi/endobenthic colonisation of soft, shelly or firm Substrate, see Fig. 7). Although some of the resulting sequences resemble "community successions", faunal changes within shell beds seem to be primarily controlled by environmental fluctuations ("community replacement", BOUCOT 1975, HOFFMAN & NARKIEWICZ 1977), rather than by biologically induced changes. Thus they represent only "pseudo-successions".

(3) Biostratinomy: The mechanism responsible for shell bed development can be described as a quantum-like accumulation of a larger number of "process-response **Couplets**" (physical event - biological response) over a certain time interval. Firmground/ shell bed complexes have acted as "reference horizons", recording the **interplay** between ecological and **sedimentary** events during longer **time** periods.

(4) Stratigraphy: Due to their large geographic distribution and their isochronous character major shell beds are useful for high-resolution stratigraphy on a regional scale.
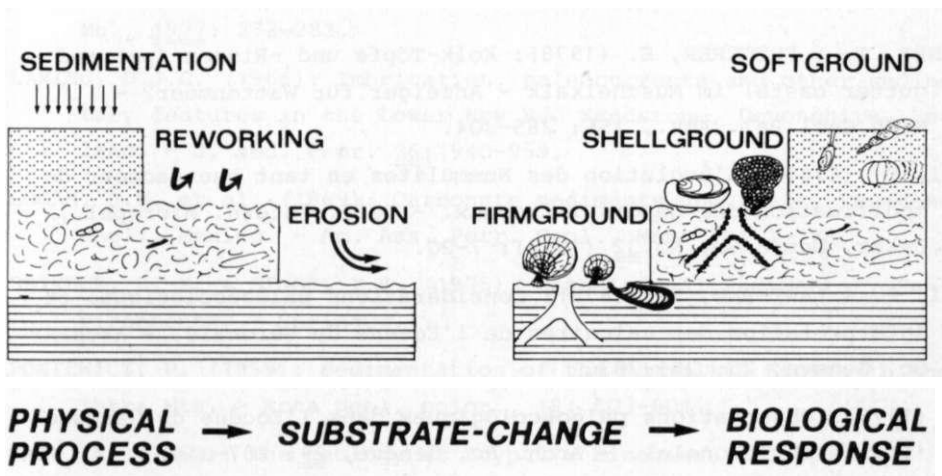

Fig. 7. Different sedimentary events or "physical processes" (sedimentation/reworking/erosion) alter **Substrate** conditions on the sea floor and are followed by specific "biological responses" on the newly created soft-, **Shell-** or firmgrounds. Repetition and accumulation of such "process-response **Couplets**" represent the baslc mechanism responsible for the development of the complex shell beds described here

(5) Evolution: Since many similar shell beds with analogous but
    morphologically different faunas occur at different levels,
    they might provide the opportunity to study the tempo and mode
    of evolutionary changes in the "post-event fauna" as compared
    to the "background fauna" (SEILACHER 1981).

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