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Stratigraphy in the Modern Generation

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STRATIGRAPHY IN THE MODERN GENERATION

Lee C. Gerhard

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When I was young and a freshman, the Earth was two billion years old, the Edsel was just on the drawing board, and conglomerates were deposited nearshore, sandstones just offshore, shales farther offshore, and finally, in the quiet of the deep ocean, limestones were precipitated. Time was measured by fossils, a brand-new radiocarbon system, and Bishop Usher.

Well, the Earth has aged considerably since then, and so have I.

Many believe that stratigraphy has made large strides since Vail and associates expoused their seismic stratigraphic concepts a few years ago, but to make that judgement is to reveal ignorance of geological literature and history. Simply stated, modern stratigraphy is a restatement of long-established principles of stratigraphic practice, whose history can be traced back to Wernerian geognosy, rocks deposited during a fundamental unit of time, giving time correlation of facies. Fundamentally, the "new" stratigraphy is recognition of the roles of unconformities in interpretation of geologic history. The Primitive, Flötz Gebirge, Vulcanisches Gebirge, and Aufgeschwemmte, are all separated by unconformities.

While these concepts are not new, perhaps we can credit Charles Schuchert, Carl Dunbar, Marshall Kay, R.C. Moore, and Larry Sloss with development of the facies and time concepts under which we labor now, recognizing that the first two might well be at odds with the last-named person, and R. C. Moore at odds with all. We will return to these people in a while.

What are the major advances in stratigraphy since 1946? Why did they take place? I submit to you that stratigraphy today comprises the study of geologic processes, rates at which the processes operate, and the sedimentary structures that result, including fossils. What is new is the use of modern sedimentary environments to construct boundary rules for sedimentary facies, sea level motion, and organism-sediment interaction. Oceanography was not a tool of the pre-World War II geologists. Submarines and anti-submarine warfare are the parents of oceanography. The unified field theory of geology, plate tectonics, birthed by union of science and war, has become a part of modern geology since 1965.

There was no field of study called "carbonate geology" in 1958. A handful of Shell scientists, and Krynine's student, Robert Folk (1959), provided the framework for understanding carbonate sedimentology, and finally gave purpose to all those hours of memorizing dreary grey fossils! These studies provided a glimpse into processes and rates; we have built much upon them. Detrital sedimentology followed quickly, and together, during the 1960's, we redeveloped sedimentology - not new concepts of fundamental knowledge, but new ways of validating or testing older theory.

During the early part of this century Schuchert, then Dunbar, carried out one of the great synthesis projects of our science, the first paleogeographic maps of North America, showing distribution of lithologies in various large time increments. This fundamentally provided an unstated but realistic view of facies. Marshall Kay took this knowledge and more, to relate sediment facies to tectonic setting, and recognition of the fundamental differences between cratonic and marginal sedimentation.

Yet, in discussion with Dunbar, the view of unconformity-bounded stratigraphy was not accepted. Attempting to synthesize Paleozoic stratigraphy by packaging unconformity-bounded units across the country resulted in a rather devastating personal review by this master, who claimed all stratigraphic units are somewhere

connected, and thus geographically-restricted stratigraphic terminology was desirable. We precursed Larry Sloss only by months.

Larry Sloss took the science a giant leap forward, by attaching time, and time-interrupts, to facies. His early work was in 1949, but really did not reach many academics until 1963. However, he influenced a generation of geologists, probably including me, by co-authoring a textbook with William Krumbein, Principles of Stratigraphy and Sedimentation (1951, 1963), in which the concepts of unconformity significance and time relationships, and, tectonics and sedimentation, were troweled into the foundations of sequence stratigraphy. I have often argued with Tim Cross about the start of genetic stratigraphy; he taking the view that it was a recent development, and I, that it was a foundation of my undergraduate education at Syracuse. My argument was simply that I am no leader, I think, but my first major published paper using sea level changes for correlation was in 1972, and my first attempt to correlate cycles through sedimentation episodes was 1963 (1967).

R.C. Moore prominently figures into our consideration through his understanding of the midcontinent Pennsylvanian sedimentary cycles, and the need to study sea level changes to understand shallow marine sedimentary rocks. Besides, this talk is being given in the house that Moore built, and I can do no less. Moore's Historical Geology (1958) is still "must reading" for every graduate student.

There are some basic concepts which I would like to mention to you. Consider the inter-related construction, transportation and degradation processes of the shallow marine setting most carefully. Consider subaerial exposure and processes carefully. And pay particular attention to rates of change, especially the rates of change of sea level, and their sedimentary significance.

For example, comparison of Moore's sea level curve with that of Heckel, and of my own interpretation for a typical cyclothem of the

western midcontinent, shows complete mirroring of interpretation between Moore and Heckel, and a return to a more Moore-like shape with my own interpretation. My interpretation is based upon a sea level/sedimentation model developed from theoretical considerations, and reinforced by field data about the last 5000 years of rise.

Today our topic is "Predictive Stratigraphic Analysis". Nice term, old concept. Those of us from petroleum exploration backgrounds have been attempting predictive geology for many years. We are pleased to welcome you all to our chase. Seriously, we do understand that prediction is the "Holy Grail" of geology.

You are in the house of R. C. Moore, and I know he will be amused, and perhaps enlightened, by our deliberations. If you hear a low growling rumble, pay no attention. That's Ray listening to you all, but registering his own view.

Illustrations:

1. Ternary diagram showing the three major carbonate processes that determine reef architecture. Connecting plotted points representing individual samples will trace the evolution of process influence on the reef.

2. Time-depth sea-level curve for St. Croix, U.S. Virgin Islands (based on Adey and Burke, 1976).

3. Hypothetical sea level curve for Oread cyclothem, eastern Kansas.

4. Comparison of Pennsylvanian cyclothem sea level curves by Moore (1958), Heckel (1990) and Gerhard, this paper (1991). Curves are redrawn to comparable vertical scales.

5. Kansas Geological Survey coring operation on the San Juan River, Utah. Photograph shows portable drilling apparatus used in obtaining a 45 foot-long continuous core of an Ismay reef.

6. Stacking geometries and sea level curve for the KGS Ismay core from the San Juan River Canyon. Column A represents the interpreted major stacking geometry for the region. Column B is the interpreted local stacking geometry, which could also include changes in reef geometry as well as sea level changes. Column C is the interpreted sea level changes that resulted in the stacking geometry. S is shallow, including subaerial exposure, D is deep, including basinal. Steepness of curve represents rate of change.

7. Hypothetical lithologic sequence predicted from analysis of the KGS Ismay core and from outcrop studies, compared to sea level stage.

8. Schematic diagram showing the relationships of sea-level change to absolute water depth, detritus generation, sedimentation and reef architecture. Left portion shows reef classes plotted against sea level (air-water interface)and the sediment-water interface. At lowstand a hydromechanical reef initiates reef development in very shallow water. Absolute water depth increases as rapid sea-level rise takes place, where biodetrital reef growth is initiated. When the biodetrital reef growth rate exceeds rate of sea-level rise, absolute water depth decreases. Finally, when the reef grows sufficiently shallow to permit rapid-growing reef framework organisms to thrive, a framework reef architecture is developed and reaches surface. On left, schematic shows the abundance of detritus in the reef decreases upward with change in reef architectural class.

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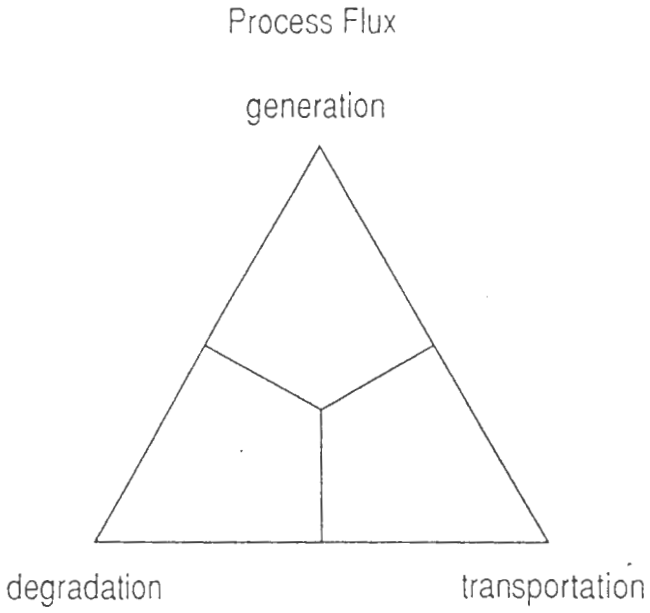
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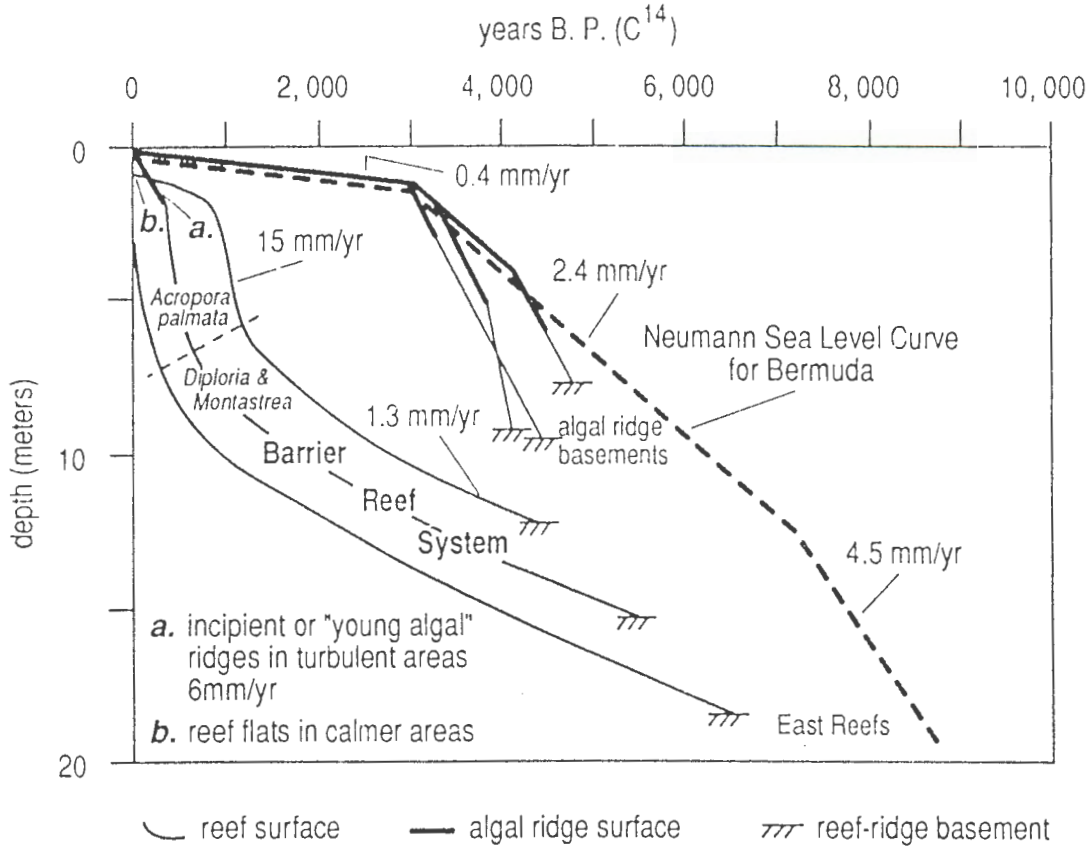
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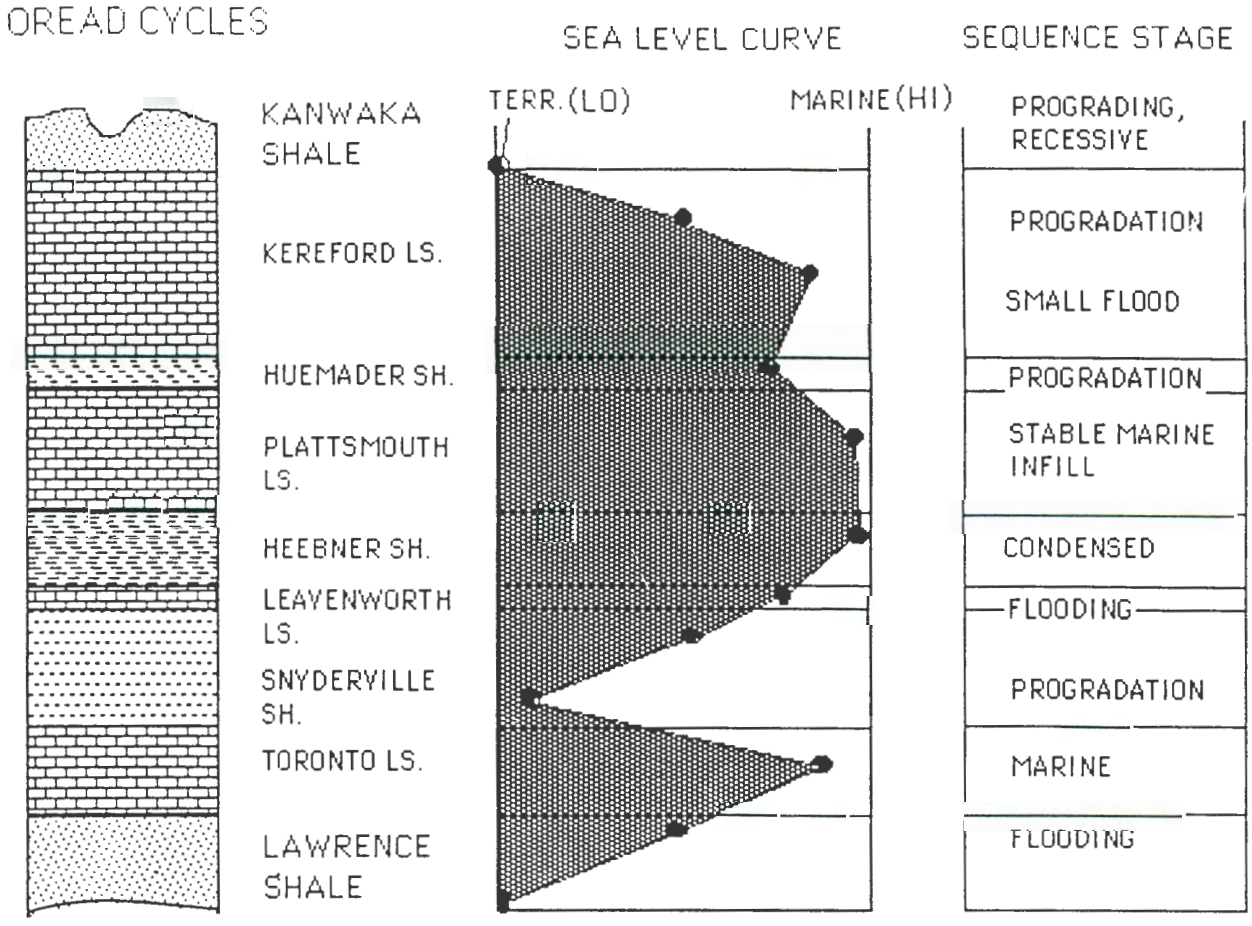
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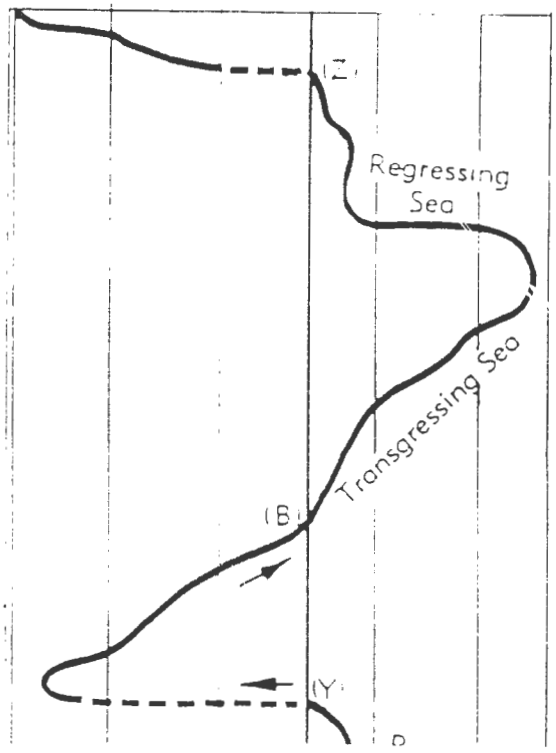
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Process Flux
generation
degradation
transportation

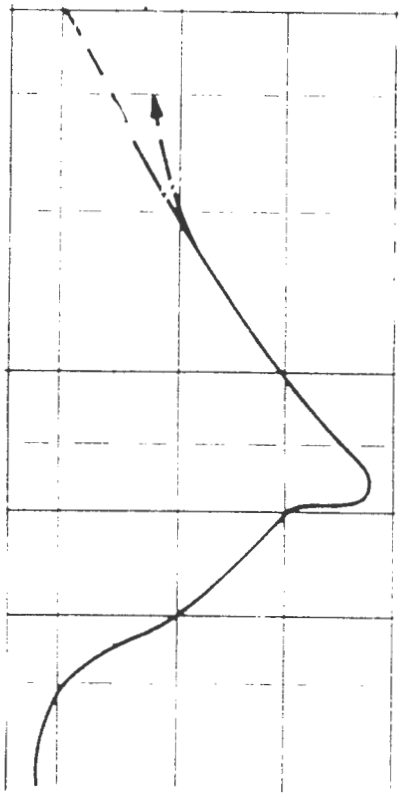

years B. P. (C^{14})
0
2, 000
4, 000
6, 000
8, 000
10, 000
depth (meters)
0
10
20
0.4 mm/yr
b.
a.
15 mm/yr
2.4 mm/yr
Neumann Sea Level Curve
for Bermuda
Acropora
palmata
Diploria &
Montastrea
1.3 mm/yr
algal ridge
basements
Barrier
Reef
System
4.5 mm/yr
a. incipient or "young algal"
ridges in turbulent areas
6mm/yr
b. reef flats in calmer areas
East Reefs
reef surface
algal ridge surface
reef-ridge basement


OREAD CYCLES
SEA LEVEL CURVE
SEQUENCE STAGE
KANWAKA SHALE
KEREFORD LS.
HUEMADER SH.
PLATTSMOUTH LS.
HEEBNER SH.
LEAVENWORTH LS.
SNYDERVILLE SH.
TORONTO LS.
LAWRENCE SHALE
TERR.(LO)
MARINE(HI)
PROGRADING, RECESSIVE
PROGRADATION
SMALL FLOOD
PROGRADATION
STABLE MARINE INFILL
CONDENSED
FLOODING
PROGRADATION
MARINE
FLOODING

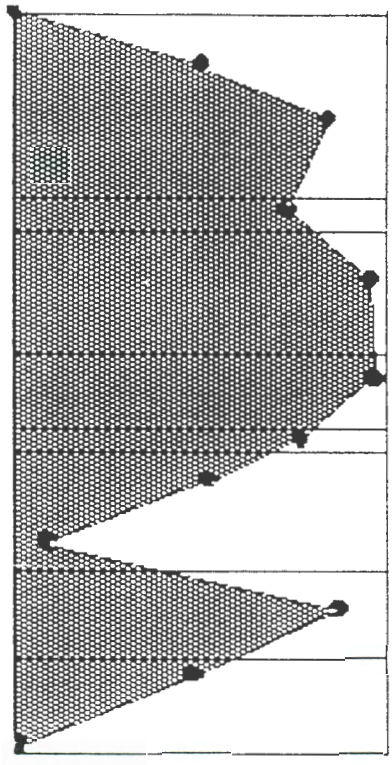
MOORE
1958

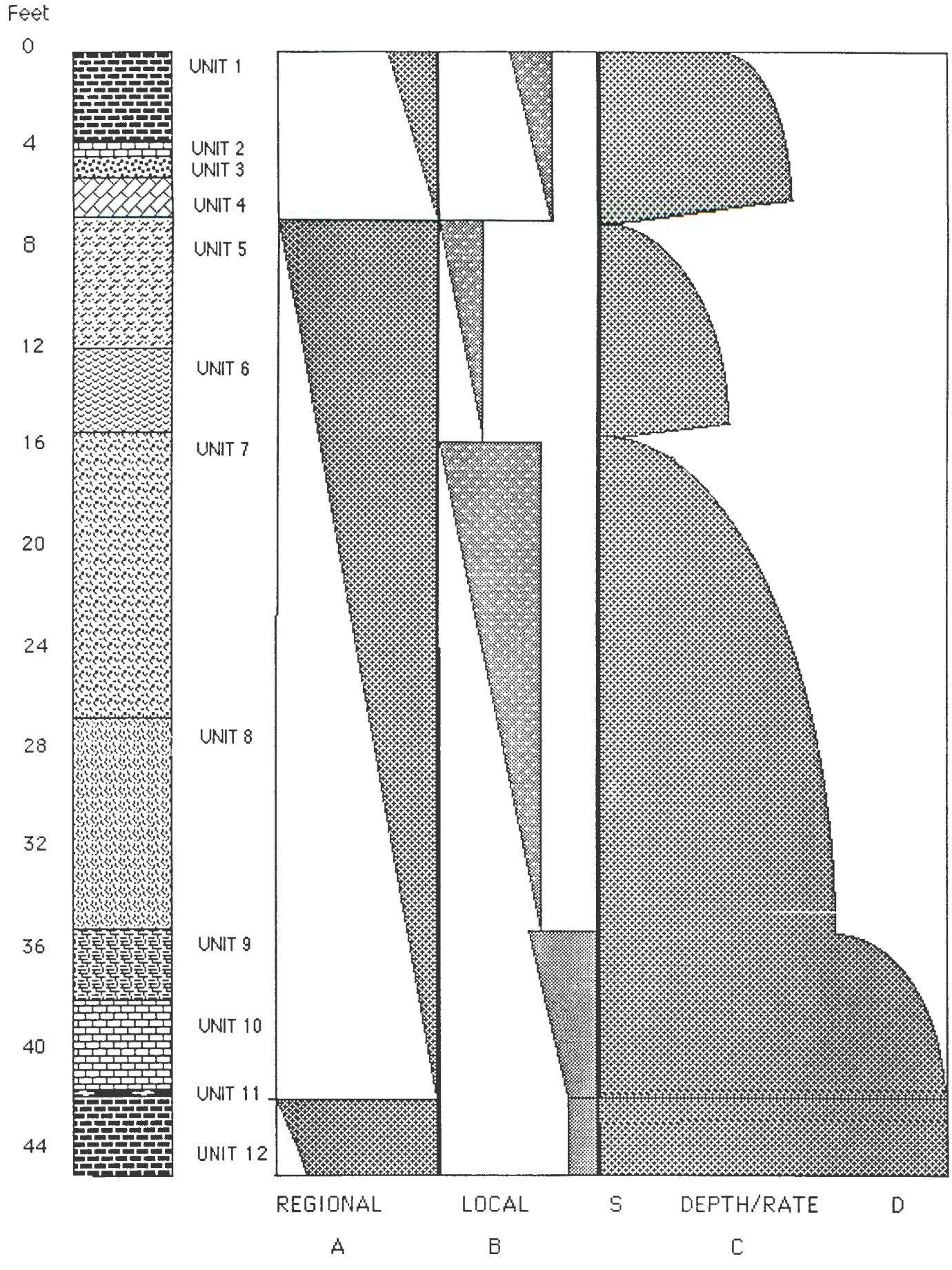


HECKEL
1990

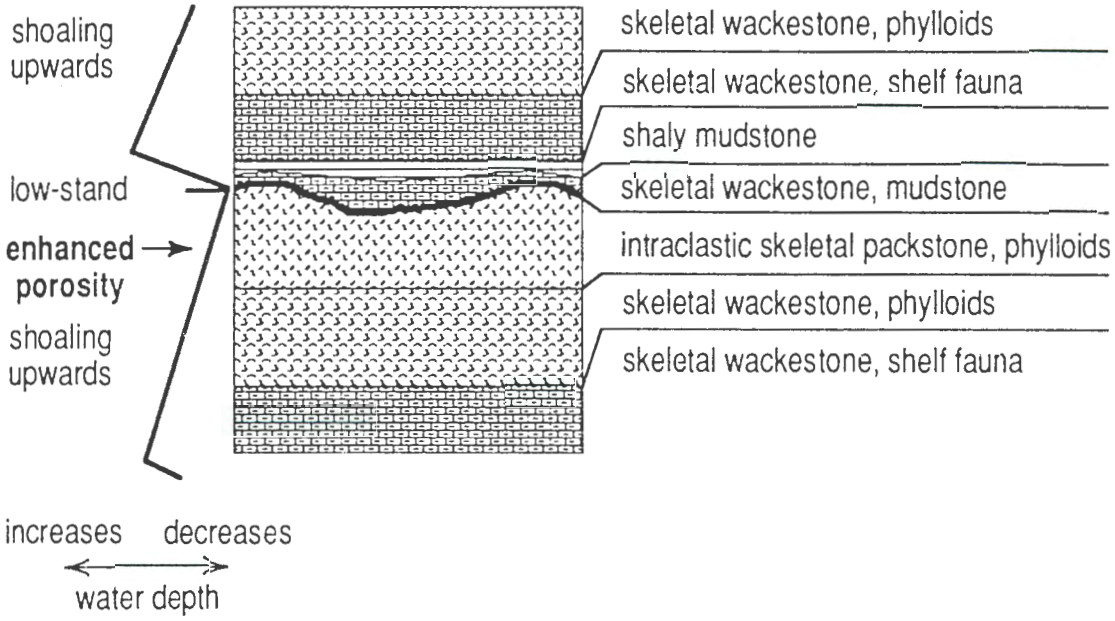


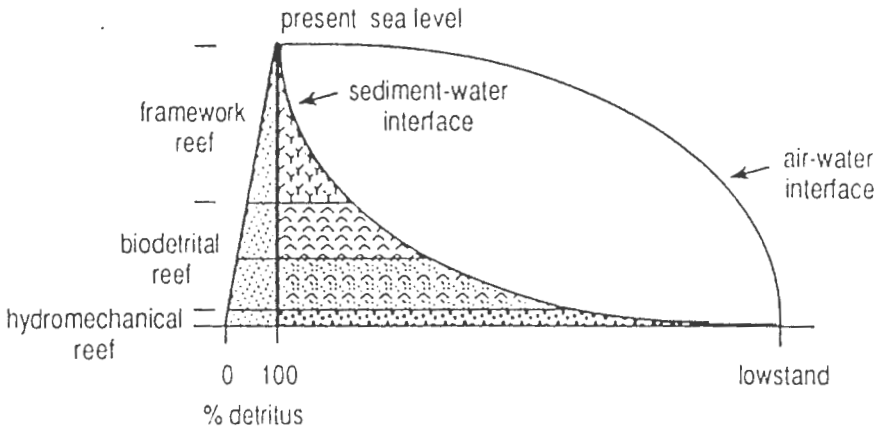
GERHARD
1991




Feet
0
4
8
12
16
20
24
28
32
36
40
44
UNIT 1
UNIT 2
UNIT 3
UNIT 4
UNIT 5
UNIT 6
UNIT 7
UNIT 8
UNIT 9
UNIT 10
UNIT 11
UNIT 12
REGIONAL
LOCAL
S
DEPTH/RATE
D
A
B
C

Conceptual Ismay Phylloid Reef Development




present sea level
framework reef
sediment-water interface
air-water interface
biodetrital reef
hydromechanical reef
0 100
% detritus
lowstand