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THE BENGUELA ECOSYSTEM. PART VII. MARINE-GEOLOGICAL ASPECTS

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ABSTRACT The Benguela Ecosystem has made an imprint on the underlying sediments on the continental margin since the Late Tertiary and today the Holocene sediments are the product of the modern Benguela Ecosystem and its interaction with the adjacent hinterland. The Orange River still builds a wave-dominated submarine delta, but wave-driven littoral drift sweeps sand equatorwards to be deflated from log-spiral beaches towards the Namib Sand Sea. A poleward undercurrent carries silt and clay polewards towards Cape Columbine along an extensive belt of terrigenous mud. Across the margin, depth-zoned assemblages of benthic foraminiferans and of ostracods are useful markers of oceanic water-masses, while planktonic foraminiferans are found seaward of the major upwell cells. On the equatorward side of the Lüderitz upwell cell, diatoms and organic matter dominate the diatom ooze deposited on the inner shelf. The diatoms are accompanied by a dysaerobic benthic-foraminiferan fauna and fish debris from the mass mortalities that are common in summer as upwelling slackens. This belt of diatom ooze, flanked by quartzose and then micaceous facies along the inner shelf, is one of the only places in the world where concretionary phosphorite is forming today. The landward flank of the ooze is opal-rich, whereas the seaward flank is organic-rich, because more of the highly soluble diatoms dissolve before reaching the greater depths farther out to sea. It is in these organic-rich diatom oozes that varved laminae have been cored. A start has been made in extracting a palaeoclimatic record from the cores by the study of diatoms, foraminiferans (both planktonic and benthic), fish debris, faecal pellets (both planktonic and benthic) and aeolian dust (mica and quartz).

The Benguela Ecosystem thus overlies a fascinating assemblage of marine sediments, which, for such an inherently variable system, has very distinct patterns summarising 'average' conditions, while preserving evidence of rare, but significant events, El Niños, for example.

INTRODUCTION

This review of marine-geological aspects of the Benguela Ecosystem complements earlier papers on aspects of the physical oceanography (Shannon, 1985), the chemical oceanography (Chapman & Shannon, 1985), the plankton (Shannon & Pillar, 1986), the fish and invertebrates (Crawford, Shannon

R

iffiths, 1988) and the
n (1985, pp. 106–112)
Benguela Ecosystem in
find it to be essential

Ocean, based on the
(Legs 71 to 75) of the
ed as *South Atlantic*
An important feature of
the Hydraulic Piston
f undisturbed sediment
ıss (1985) to study the
high opal (diatoms and
e eastern Walvis Ridge
guela Current, whereas
to an equatorward lati-
orthwards to 17°S over
e Quaternary sediments
he & Schrader (1988),
Pleistocene sediments on
& Rothe, 1986). Dean
Meyers *et al.* (1983) and
cal variations of calcium
ediments on the eastern

al data available for the
g on detailed investiga-
rchers, the latter based in
own Marine Geoscience
ncorporated the Geologi-
, which had also been
niversity of Cape Town

F THE MARGIN

la Ecosystem (Fig 1) was
eir magnificient "physio-
The margin was studied
se of H.M.S. HECLA as part
bathymetry betweeen the
mpson (the MGU's foun-
pson & Du Plessis, 1968;
ymetric profiles between
ith a bathymetric chart of
ental margin off southern
the Geological Society of

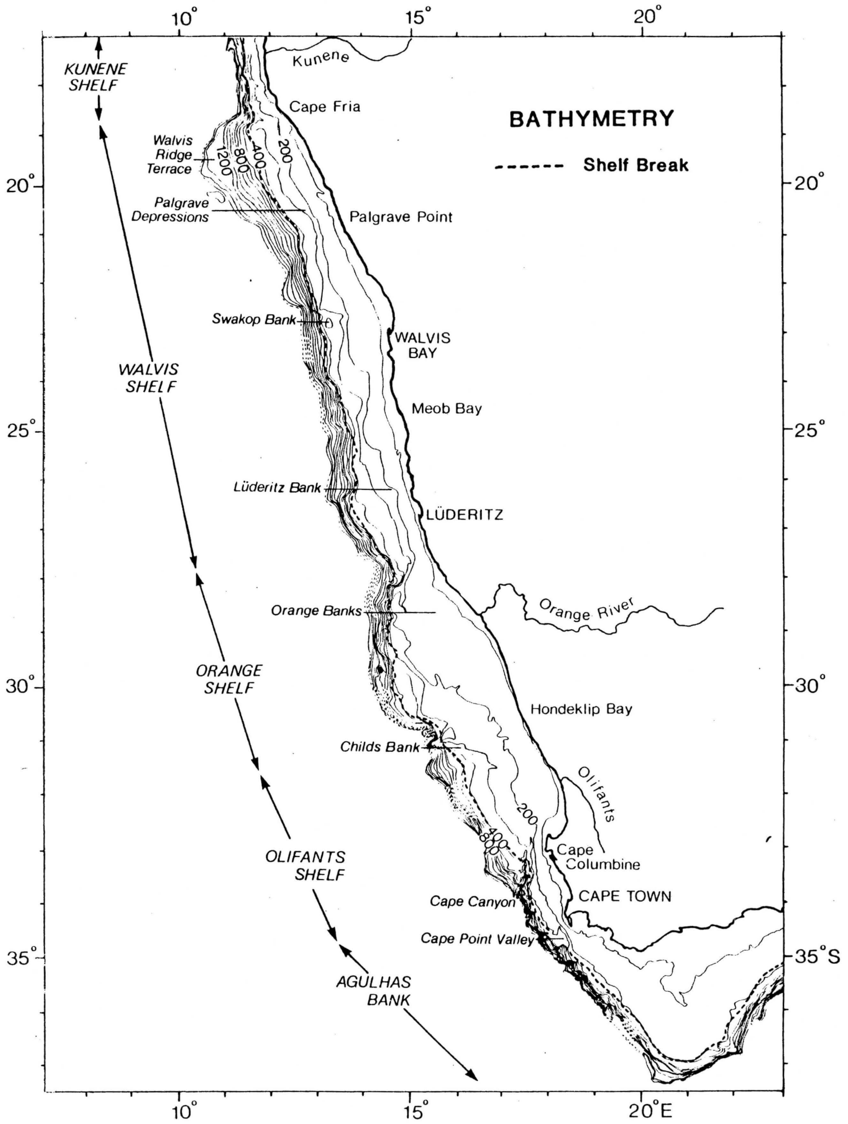

Fig 1.—Bathymetry of the shelf and upper slope from the eastern Agulhas Bank to the Kunene River.

South Africa, Simpson (1968) reproduced the *National Geographic Magazine* versions of Heezen & Tharp's (1961) physiographic diagrams of all the oceans of the world and presented a bathymetry map of the margin and surrounding basins in the southeast Atlantic and southwest Indian Oceans. This map was drawn by his assistants, Erica Forder and Lesley Shackleton.

: summarised by Embley & Morley
hain cruise, contrasting the marine
d the southern Angola Basin. Excel-
racter of the upper 100 m of the slope
g with data from a 16 m-long piston
:. This core (RC 13-229) penetrated
tation rate and an apparent lack of
of pelagic sedimentation for the last
ty epoch. Oxygen-isotopic stages 1 to
he planktonic foraminiferan *Globo-*
e benthic foraminiferan *Uvigerina* sp.
/es a record of palaeoclimatic change
ela Ecosystem throughout the Upper
des a succinct appraisal of the rich
the west coast of southern Africa:
s and processes along the continental
asts. The shelf sediments range from
r beds locally rich in phosphorite
nge River, to organic diatomaceous
high concentrations of metals. The
ed only small amounts of sediment to
time except for the areas off the
ransported sediments from the more
y & Morley, 1980, p. 201).

TEXTURE

; this margin is found in the unpub-
, which was reproduced in Simpson
k sediments appeared in Rogers
the addition of textural data, as far
973). The texture was also reviewed
: was extended northwards to Walvis

a map of sediment texture based on
ntire margin off South Africa and
ture, as well as of the distribution of
ntly published by Birch *et al.* (1986)
between Moçambique and Angola.
s (1985) Figure 6 and will be more
erences.
ilt, and clay were determined on
cron sieve to separate the sand and
ction. The dried coarse fraction was
nicron (2 mm) gravel fraction from
n Andreasen pipette (Anonymous,

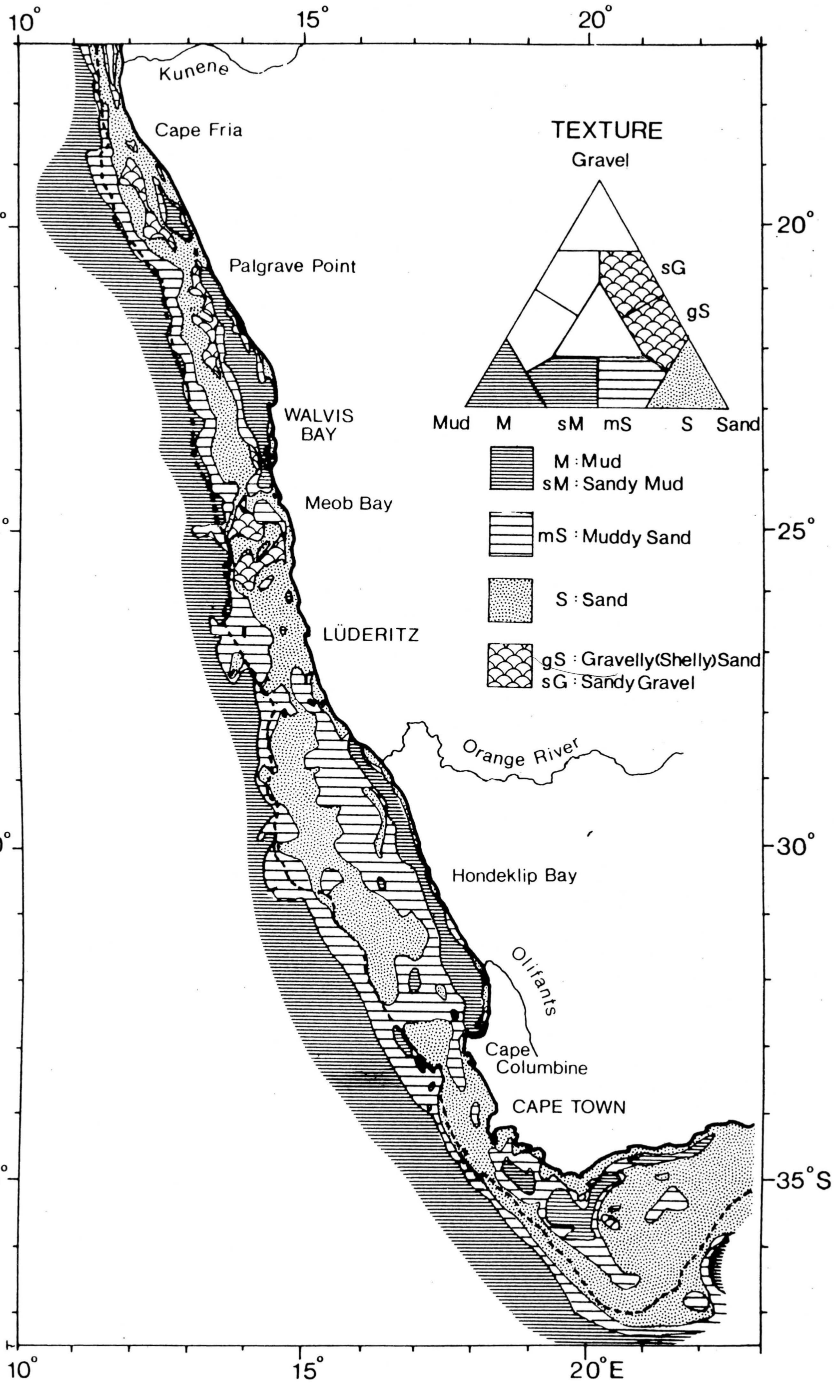

Fig 3.—Texture of unconsolidated surficial sediments on the shelf and upper slope from the eastern Agulhas Bank to the Kunene River. Dashed line marks the shelf break. Compare with Shannon (1985, Fig 6).

the silt+clay fraction (mud) and the clay
g then calculated by subtraction. For the
Gravel-Sand-Mud triangle (Shepard, 1964)
ments texturally (Fig 3).
y mud represent areas of low energy and
In general, the upper slope is underlain by
e middle to outer shelf is mainly mantled by
nding to the smooth firm bottom seen on
nsparent belts near the coast consist of mud
Lüderitz, on the Walvis Shelf are gravelly
t, mainly on the middle shelf, and most of the
isc detritus (Bremner, 1978a, 1981a).

OSITION AND DOMINANT MPONENTS

lidated surficial sediment has been examined
of individual samples and the mapping of
classes of sediment were determined, namely
enous (Fig 4). Unlike terrestrial sediments,
omposed of a wide variety of components,
biogenic components, only those grains that
te to the sea floor. Where possible quantitat-
ugh, in the case of calcareous components,
etons contributed to the detritus, so that
is a relatively crude measure of biogenic
idual sand-size components were estimated
nocular microscope using the method of
oportions of dominant, subordinate, minor,
ermined. Only the distribution of the domi-
action is shown in Figure 5.

lated by summing the percentages obtained
d organic matter. Calcium carbonate was
hods after carbon dioxide was evolved by
ric acid to samples of dried sediment
stner, 1971; Birch, 1981). Biogenic silica was
by point-counting sand-fractions to obtain
and assuming that these percentages were
ges of biogenic silica in the total sample
1983). The method was used by Van Andel
Gulf of California and assessed by Calvert
ically determined opal values of the total
ed estimates. A significant correlation was

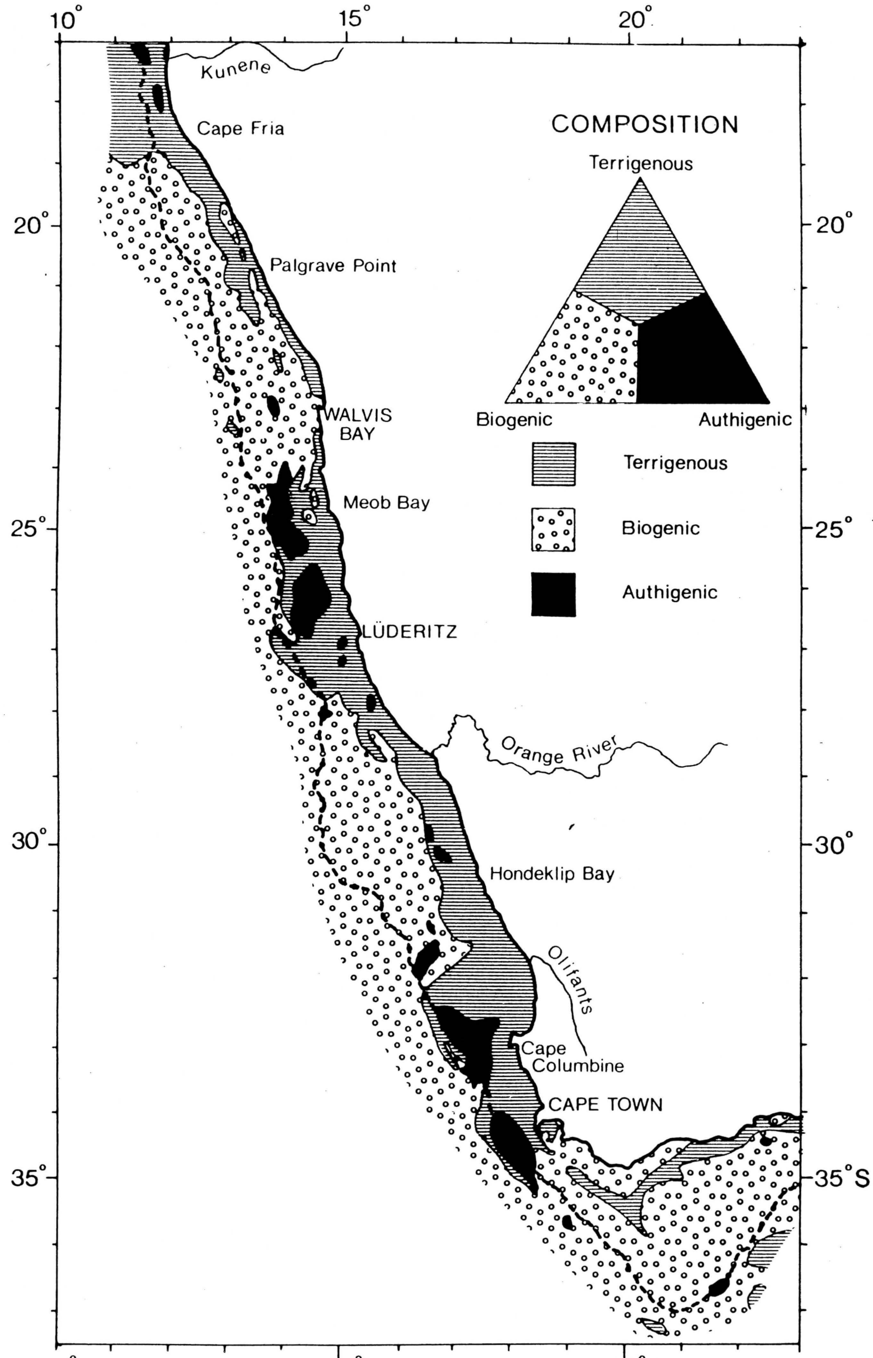

Fig 4.—Composition of unconsolidated surficial sediments on the shelf and upper slope from the eastern Agulhas Bank to the Kunene River. Dashed line marks the shelf break.

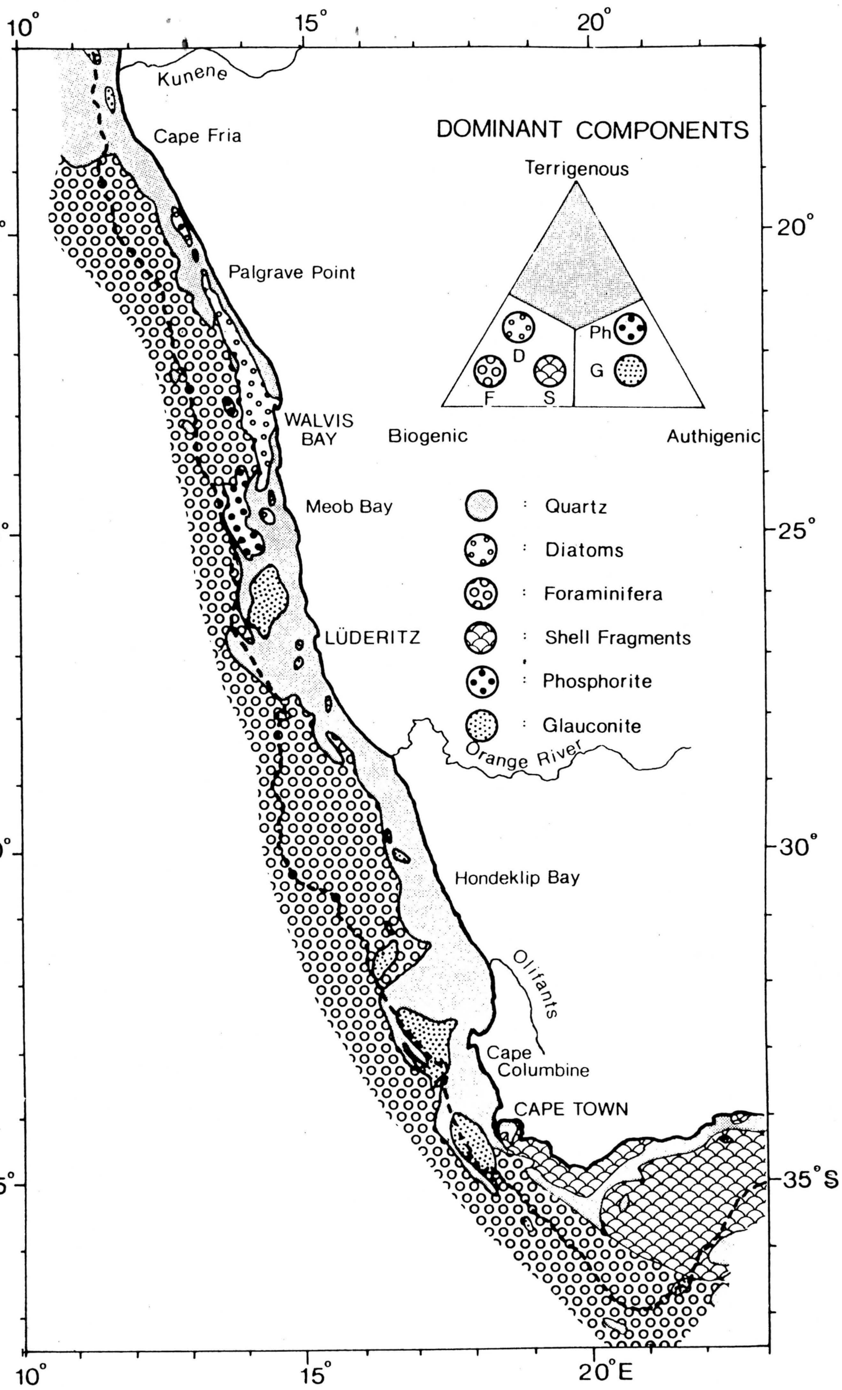

Fig 5.—Dominant sand-size components of unconsolidated surficial sediments on the shelf and upper slope from the eastern Agulhas Bank to the Kunene River. Dashed line marks the shelf break.

found. Organic matter was measured by
a dried subsample was oxidised by hot chr
against ferrous sulphate (Morgans, 1956). T
was then multiplied by a factor of 1.8 to o
The abundance of very fine sand-size ovoi
weighing the dried sand-fraction, disintegr
peroxide, wet-sieving, drying, and reweig
pellets was then added to the initial percen
obtain the original mud content of the sed

The authigenic fraction (Fig 4) was dete
ages of glauconite and phosphorite in the t
in the sand fraction and is slightly magnetic
a Franz Isodynamic Separator using set
Fortunately, glauconite normally occurs o
intermixed with non-magnetic calcareous g
was the norm. On the inner shelf glauco
magnetic terrigenous minerals and a separat
Spectrophotometry (ammonium-vanadate-
determine the content of phosphate as P_2O_5
then calculated by multiplying by a factor o
pure phosphorite (the carbonate fluorapatit

The terrigenous fraction (Fig 4) was mea
sum of the weight percentages of the bioge
100%.

BIOGENIC SEDIMENTS

The Agulhas Bank is clearly dominated by b
southern sedimentological boundary of t
& Rogers, 1973; Birch *et al.*, 1976a) betwee
Agulhas Bank and foraminiferal oozes on t
apparent in Figure 5. The northern sed
Benguela Ecosystem (Avilov & Gershano
1970) shows up clearly in both Figures 4
biogenic foraminiferal ooze on the Walvis
sediment on the Kunene Shelf. These sedim
the physical oceanographic boundaries defi
as the Agulhas Bank Divide and the Angola
Walvis Shelf do we find a deposit of diato
main focus of this review. The landward
swings seaward of the shelf-break off Cape
again off Lüderitz and Meob Bay (Fig 5).
westward swings to active zones of upwelli
correlated with the Cape Peninsula and C
ward swinging Good Hope Jet in the so
sive Lüderitz upwell cell farther north
The Hondeklip and the northern Namib
Bay and Cape Fria seem to have little e
boundary.