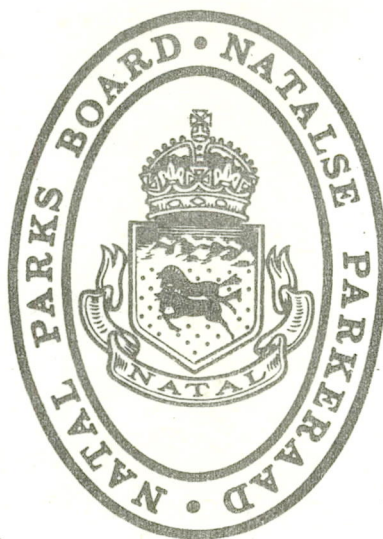


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THE GEOLOGY OF LAKE ST. LUCIA, AND

SOME ASPECTS OF ITS SEDIMENTATION

BY

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ABSTRACT

Lake St. Lucia is a saline lagoon on the Zululand coastal plain. It has a surface of 380 km² and an average depth of less than 1,5 m. The rocks found in and around the immediate surroundings of St. Lucia represent approximately the last 70 million years of the Earth's history. South Africa, until the breakup of Gondwana Land was completely land locked. After the breakup of Gondwana the 1st true marine sediments were deposited. These include the beach and river deposits of the lower Cretaceous and the deep sea marine deposits of the upper Cretaceous. There is scattered evidence of Pliocene/Miocene marine sedimentation. A compound barrier and a series of parallel relict beach-dune ridges record a succession of depositional events related to Pleistocene sea-level fluctuations. Aeolian sandstones of the penultimate glaciation were planed by the Eem transgression, during which three distinct beach deposits accumulated a few metres above the present shoreline. This high stand flooded the back-barrier area and coral reefs developed in False Bay, the western arm of the existing lagoon system. Sea-level lowering concomitant with the last glaciation initiated renewed valley incision. It was then that the high dunes of the modern barrier originated. The smaller river mouths were sealed by littoral processes during the post-glacial transgression and the lagoonal complex became established. This has been substantially reduced in depth and extent. Coring reveals a maximum of 33,5 m of late Pleistocene and Holocene sediment reflecting a change from marine to estuarine and lagoonal conditions.

INTRODUCTION.

Lake St. Lucia is a large saline lagoon on the Zululand coastal plain (Fig 1). It is separated from the Indian Ocean by a compound barrier, the basal portions of which consist of calcareous sandstones bearing raised marine-cut terraces. These are surmounted by semi-consolidated sandstones followed by loose sands of the high coastal dunes which attain elevations of 180 m.

False Bay and the western shores of Lake St. Lucia are incised into Cretaceous strata. These rocks are sporadically overlain by Middle to Upper Tertiary coquina ("pecten bed") and sandstone. Above these are the unconsolidated red, brown and grey sand deposits which mantle the coastal plain. The most conspicuous topographic features of the coastal plain are north-south oriented dune ridges, the larger of which are composed of red sand. To the west of Lake St. Lucia these commonly have a boulder bed at the base.

In False Bay there are fossiliferous late Pleistocene deposits with a fauna indicative of unrestricted marine conditions. These must have accumulated prior to the development of a continuous seaward barrier. At a later stage the barrier was more substantial and had a profound influence on the nature and rate of sedimentation.

A dominant factor in the development of the lagoonal and barrier complexes has been eustatic changes in sea level.

Most of the data were obtained from the study of surface exposures and shallow auger samples. Important information concerning the sediments beneath the Lake bed was provided by seven continuous cores obtained during the latter half of 1973 through the efforts of Mr. T. Blok in charge of St. Lucia Reclamation. The cores extend from the sediment-water interface to Cretaceous bedrock at a maximum depth of over 30 m

Foraminifera, ostracods, diatoms and a variety of microfossils were extracted and set aside for specialist examination.

THE CRETACEOUS

Following the break-up of Gondwana there was rapid erosion of the upgraded continental margin of south-east Africa. The characteristic early Cretaceous deposits of Zululand are non-marine conglomerates, but the influence of the sea is increasingly evident. The gentle seaward dip (2-3 degrees) exposes progressively younger stages from the Neocomian of the upstream Mzinene to the eastern most cliff exposes which probably span the Mesozoic boundary into the Paleocene.

A southerly decrease in thickness is evident. In the Lake Sibayi area there appears to be over 1 800 m of Cretaceous underlying the coastal plain. (Savage, 1975). At False Bay there appears to be only 900 m of Cretaceous material.

The lower Cretaceous (Neocomian) consists of river and beach deposits. These are characterized by boulder beds, fossilized marine fauna and fossilized wood. The opalized fossil wood varies in size from twigs to large tree trunks. These logs would have been carried into the area by rivers during periods of floods and storms.

The Upper Cretaceous (Albian) consists of deep water marine sediments. The rock types present are chalky sandstones, shales, and sandy limestones. These deposits are rich in Ammonite faunas.

TERTIARY.

The Cretaceous rocks are sporadically overlain at an elevation of 10 m by Middle to Upper Tertiary coquina ("Pecten beds") and sandstone.

The two best known outcrops occur in Uloa in the south and Hellgates in the north. The tertiary strata consist of calcareous conglomerates and sandstones developed as sublittoral, beach and coastal dune deposits during marine regression.

These rocks are the richest fossil-bearing deposits of South Africa (King, 1972).

Over 100 different species of marine fauna have been identified. One of the most common species being pecten i.e. the zone fossil Aequipecten Uloa. Teeth of the giant shark Carcharodon meg alodon have also been found.

THE COMPOUND BARRIER.

Several distinct stratigraphic units are exposed along the seaward side of the coastal barrier, but the sandstones do not outcrop along the landward margin where they are mantled by unconsolidated deposits. Certain units are correlative with outcrops in the Durban area described by a number of authors including Krige (1932), King and Maud (1965), McCarthy (1967) and Maud (1968).

UNIT I

The oldest deposits of the barrier consist of fine to medium-grained sandstone which is best exposed at First Rocks and Bats Cave 2 km to the north of Mission Rocks (Fig 1). This probably equivalent to the "Bluff Beds" of Krige (1932) or the "first aeolianite" of Maud (1968). It extends from an unknown depth below sea-level to a maximum observed elevation of 8 m. The higher parts have been subjected to considerable karst weathering.

Large-scale cross-bedding is a characteristic feature. Dips range from 8 to 36 degrees and are variable in azimuth, although a strong westerly component is evident in most outcrops. Forest laminae commonly display evidence of minor slumping prior to lithification. In thin section the rock is seen to consist predominantly of well sorted sub-angular to rounded quartz grains with diagenetically altered shell fragments and a sparite cement. These attributes together support the interpretation by McCarthy (1967) of an aeolian origin. Sand was presumably piled up as coastal dunes during a stage of eustatically lowered sea-level. Ample sand would have been available from a belt of emergent continental shelf several km wide. Present day prevailing wind directions

are from the northeast and southwest, blowing roughly parallel to the shoreline. During glaciations however, temperature contrasts between land and sea would have been increased, thus leading to a higher frequency of strong onshore winds. This probably accounts for the high proportion of landward inclined forests in unit 1.

At certain localities, such as Bats Cave, these aeolian sandstones are truncated by a flat, horizontal erosion surface at between 4 and 5 m above sea-level. Elsewhere the surface is less regular, ranging from a height of 8 m to below present sea-level.

UNIT 2

The depressions in this undulating surface eroded into unit 1 are overlain between present spring low tide level and an elevation of up to 5 m by coarse-grained, conglomeratic sandstone. These rocks, here referred to as unit 2, are sub-divisible into two distinct facies on the basis of differences in sedimentary structures, and to a lesser extent, in lithology.

The first type consists of low-angle, eastward-inclined planar forests of medium to coarse-grained sandstone with small discoidal and blade-shaped pebbles composed largely of lydianite. Well defined parallel lamination dips seaward at between 4 and 10 degrees. Microscopic examination reveals that these sandstones are less perfectly sorted than the aeolian deposits. They contain in addition to quartz up to 10 per cent feldspar and a variety of Mollusc and echinoderm fragments, foraminifera and algae. These deposits strongly resemble the upper foreshore of modern beaches. The preponderance of flattened pebbles of small size (less than 3 cm maximum diameter) is suggestive of the size-shape sorting processes that operate in the swash zone (Winter 1975), and the eastward dipping stratification records the successive profiles of a prograding beach.

The second facies occurs at a lower level (generally below 2 m a.s.l.) and is gradational into the upper foreshore beds. It consists of trough cross-bedded sandstone, very similar in lithology to the beach deposits, but differing in the shape of the pebbles. Both flat and equant shapes are represented, and many are almost perfect spheres. Furthermore, the maximum size is slightly larger, some pebbles attaining diameters of 15 cm.

Whereas discoidal and blade-shaped pebbles are selectively cast up on a beach, shape sorting results in a larger proportion of equant pebbles being concentrated below low tide level (Bluck, 1967). Thus it appears that this trough cross-bedded sandstone facies originated in a near shore shallow marine environment.

Trough axis azimuths reveal that the currents which deposited these sands flowed in directions which were either sub-parallel or perpendicular to the existing shoreline. Since the late Pleistocene shoreline trend was undoubtedly very similar, these currents were of a semi-permanent longshore variety. Modern day patterns along certain sections of the Natal and Zululand coasts are very similar. Both northward and southward flowing currents are observed at different times of the year. The off-shore directed cross-beds are characteristic components of the near-shore inner trough facies immediately seaward of the swash zone (Clifton et al 1971).

The upper foreshore facies of unit 2 extends to a maximum observed elevation of between 3,5 m and 5 m where they are bevelled by the same seaward-dipping surface that locally truncates the older aeolian deposits of unit 1. Thus the high water level corresponding to the deposition of these beach sands must have been a little more than 5 m above present sea-level and is possibly approximated by a poorly preserved 8 m surface at Bats Cave. Deposition of unit 2 must, therefore, have coincided with an inter-glacial higher sea-level which succeeded the low stand during which the aeolian sandstones (unit 1) accumulated.

During the ensuing marine retreat, probably related to an interstadial of short duration, these shoreline deposits were lithified, and together with the older sandstones, subjected to karst weathering.

UNIT 3

Renewed advance of the sea above its present level planed both aeolian and beach deposits along a seaward-sloping surface at present preserved between 5,3 and 3,4 m. This wave planed surface is mantled by a coarse-grained conglomerate which fills in karst depressions and potholes produced by marine abrasion

The thickness of this conglomerate, designated unit 3, is therefore, highly variable, ranging from a few cm to 2 m. The inclusions consist of locally eroded clasts of calcareous sandstone together with a variety of extrabasinal pebbles. Of the latter quartzite pebbles are most numerous followed by Lydianite and Gneiss. Some of the inclusions are of boulder dimensions, the largest encountered measuring 65 cm in diameter. The mean diameter is approximately four times greater than that of the pebbles in Unit 2. A discoidal shape predominates. Large numbers of oysters and other abraded mollusc fragments are present locally. Some oysters are preserved in living position in potholes. (Hobday, 1975).

Unit 3 is ascribed to transgressive shoreline processes which characteristically deposit coarse shingle. The fact that the coarsest material is preserved in the potholes suggested that these pebbles and boulders were responsible for their abrasion. The sides of some potholes are distinctly undercut. Vigorous surf action broke off blocks of sandstone which were later incorporated in the pebbly matrix.

The superabundance of pebbles derived from the Precambrian hinterland suggests that in addition to the Mfolozi other large rivers with outlets further north may have been providing this material. There is however a northward decrease in the maximum dimension of these inclusions suggesting that the competence of the Mfolozi considerably exceeded other rivers in the area. Larger pebbles are encountered to the north of the Mfolozi than to the south, indicating that beach drift patterns were probably the same as they are today. (Hobday, 1975).

Maximum high water mark corresponding to this episode was a little more than 5 m above present sea-level, but could not be determined precisely. It was nevertheless distinctly lower than the previous transgression which had been accompanied by the deposition of unit 2.

UNIT 4

An aeolian sandstone very similar to unit 1 in terms of its composition, texture and sedimentary structures overlies

a 4,4 m pebble veneered (unit 3), eroded surface at Bats Cave. The foresets are inclined westward at angles of 35 degrees. This sandstone was apparently not deposited to any great thickness, extending to an elevation of only 10 m at this locality. Nevertheless, the karst and decalcified upper portions suggest that some of the overlying sands were derived by leaching of this unit.

The limited distribution and thickness of this deposit suggests accumulation during a brief marine regression. A narrow belt of exposed sand would thus have been subjected to deflation, the sand accumulating against the older deposits of the barrier.

UNIT 5

Evidence for at least one further rise in sea-level above the present shoreline comes from a second generation of potholes incised through unit 3 and commonly extending into unit 2. These potholes differ from the older variety associated with unit 3 in the preservation of outflow channels produced by seaward runoff. Oysters occur most abundantly in these potholes within 1,5 m of modern spring high water mark. Many adhere to the sides or to one another in living position and there are few reworked fragments. Potholes related to this episode at elevations of up to 4,5 m contain reworked oysters and discoidal pebbles.

COASTAL DUNES.

Practically continuous high coastal dunes extend from Mtunzini northward into Mozambique. They consist of light coloured, almost pure quartz sand with local concentrations of heavy minerals such as ilmenite, rutile, Zircon and Magnetite. Grain size analysis reveals a normal distribution with a median diameter in the medium sand range. (Hobday, 1975).

In places the coastal dunes overlap landward onto an older ridge of red sand. Dune peaks attain an elevation of 188 m to the south of St. Lucia Estuary. Between the Estuary and First Rocks to the north they are low and insignificant. Beyond First Rocks two lines of high dunes are separated by a narrow depression.

Deep augering revealed an increasing percentage of heavy minerals, but the absence of a core of older consolidated deposits. The sands have been weakly calcified in places. There is no evidence of the lignite-bearing Port Durnford Formation except to the south of St. Lucia Estuary (Hobday, 1975). Excavation of the seaward dune flanks reveals multidirectional cross-bedding. Occasional cross-bedding on a large scale, in sets of 10 m thick, is reflected in places by patterns in the vegetation growing on the flanks. This, together with the topography of the dune crests, suggests that winds from the north-east and south west have been equally effective.

As with the older aeolian deposits sand would have been carried landward across the exposed sandflat. The pre-existing ridge of older cemented sands coincident with the modern shoreline would have localised accumulation as an almost continuous dune belt, broken only by river outlets. Stabilisation by vegetation would have occurred during the subsequent climatic amelioration. Further limited accretion of wind-blown sand along the seaward margins has been accompanied by local erosion of the dune base elsewhere depending upon differences in shoreline trend and offshore topography.

POSSIBLE RELATIONSHIP OF BARRIER DEVELOPMENT TO PLEISTOCENE SEA-LEVEL FLUCTUATIONS.

Changes in the relative level of land and sea, such as are evident in the Lake St. Lucia barrier, are attributable to two possible basic mechanisms, tectonic or eustatic. Monoclinical warping (King & King 1959), although demonstrable on a large scale involving seaward tilting of land surfaces, does not account for the wide extent of low terraces at comparable elevations along much of the east coast of southern Africa (Kriger 1927, Davies 1970, 1971). A eustatic origin appears to be the more likely.

There are marked differences of opinion as to world-wide sea-levels during early and middle Pleistocene times, and also with regard to the validity of Holocene levels higher than the present (Curry 1969). Nevertheless, there appears to be general agreement that during the late Pleistocene, between approximately 75,000 and 130 000 years ago, there were times when sea-level stood several m higher than at present. It is also accepted

by a number of investigators that this Eemian (Sangamon) high was not a single event, but consisted of three peaks separate by slightly lower levels (Fairbridge 1960, Mesolella et al 1969, Emiliani 1970, among others).

It is possible that the stratigraphic units 2, 3 and 5 of the St. Lucia barrier correspond with these three Eemian peaks (Hobday 1975). Unit 1 which is widely developed along the Mozambique, Natal and probably much of the south eastern Cape coast, is therefore interpreted as originating during the preceding Saalian glaciation.

FOSSILIFEROUS LIMESTONES OF FALSE BAY.

Highly fossiliferous limestones containing a variety of corals and molluscs, together with local concentrations of brachiopods and cirripeds, are exposed in very small outcrops at Listers Point and Picnic Point on the western shores of False Bay.

The faunal characteristics of the limestones are similar at all localities, but there are differences in the relative abundance of various coral types. At Listers Point several large colonial corals are preserved in growth position together with scattered solitary forms. Maier (1975) tentively identified these are Favia, Goniporas, Anomastrea and Babanophyllia annae.

Large bivalves such as Hyotissa Hyotis, with a maximum observed length of 23 cm have been obtained along with large specimens of the gastropod Tonna. Other commonly occurring moluscs include Circe scripta, Decatopecten sp., Polinices sebae, Rapana rapiformis, and Ostrea. The barnacle Balanus is abundant, along with a small brachiopod of the family Kraussinidae also present are echinoderm fragments and possible crab remains. Trace fossils are mainly large (1 - 4 cm diameter) vertical tubes with horizontal offshoots and probably include both Ophiomorpha and Thalassinoides. (Hobday 1975, Maier 1975).

Petrographic examination reveals that the bulk of the allochems are biogenic, consisting of mollusc fragments, foraminifera and

red algae, with a variable proportions of lithoclast, mainly quartz. According to Folks's (1959) classification this rock is a biosparite, a well sorted, moderately high energy deposit, with a sparry calcite cement.

During times of very low lake level the lower parts of the formation are seen to contain concentrations of spherical to discoidal pebbles of rhyolite, basalt, jasper, chert and lydianite along with many oysters, mainly broken. This merges upward into fossiliferous biosparite with a great variety of fossils, followed by a coral rich zone with a matrix of broken shells. There are conspicuous differences between one outcrop and another in the proportion of articulated to disarticulated bivalves and also in the degree of alignment of the fossils. South of Listers Point up to 50 percent of the bivalves are articulated and there is a tendency toward upward convexity of individual valves. No preferred disposition is apparent in the predominantly disarticulated valves at Picnic Point.

Along the shores of False Bay the limestones overlie an eastward dipping surface eroded into Cretaceous siltstones. The basal contact is undulatory in a direction parallel to the lake shore. In places there is evidence of intense boring of the Cretaceous surface by marine organisms prior to deposition of the pebble and shell debris. The upper surface extends to a maximum observed elevation of 3,4 m a.s.l. Probing beneath the submerged shelf suggests that the base extends to a maximum of 1 m below sea-level.

These deposits have been radiometrically dated as older than 50,000 years (Orme 1973). This, together with their elevation and geomorphic situation, suggests deposition during the Eemian high stand concomitant with planation of the barrier terraces. The lithology and faunal content point to an unrestricted, high energy shallow marine situation in close proximity to the shore. Sea-level was at least 3 m above the present, and the water temperature possible a few degrees warmer. It appears that False Bay was at this time a marine embayment with Hells Gate opening directly to the sea. This would have been contemporaneous with one of the stages of bevelling of the barrier sandstones to seaward. These at this stage would have resembled some of the shallowly submerged "reefs" off the present day

Natal Coast, e.g. Aliwal Shoal and Glenton Reef. Living corals were restricted to areas of free circulation in the vicinity of Hells Gate, and have not been encountered as fossils in those areas of False Bay which would have been very sheltered or periodically diluted by fresh water inflow. (Hobday 1975).

The upper surface of the limestone slopes gently eastward and was possibly wave-planed. This was very likely a consequence of the Eem sea-level oscillations postulated above. On the other hand the surface may have been eroded during a Holocene transgression above the present sea-level. This is believed to be unlikely however in view of the apparent antiquity of some of the sands which overlap the landward margins of the limestone surface.

The approximate position of the Hluhluwe River outlet at this stage was probably in the vicinity of a patch of fluviatile or estuarine conglomerate some 2 m a.s.l. which is situated 2 km south west of the present mouth.

SANDS OF THE COASTAL PLAIN.

Several distinct varieties of unconsolidated sand mantle the coastal plain. Prominent north-south trending dune ridges consist largely of homogeneous red sand with pebbles and boulders towards the base. Six dune cordons, decreasing in age from west to east, have been mapped by Davies (1975).

A thick basal boulder bed occurs in the lowermost parts of the western corcons, e.g. at Bushlands Halt inland of the present study area. This is replaced eastward by scattered pebble bands at all elevations. A kilometre inland from Fannies Island Rest Camp pebbly coarse-grained sand attains a maximum thickness of 8 m. Heavy mineral laminae, containing up to 60 per cent zircon, rutile, magnetite, garnet and ilmenite, occur interlayered with quartz sand, which itself contains prominent textural banding. Pebbly coarse-grained beds 1 - 15 cm thick alternate with finer material in approximately the same proportion. These layers commonly display opposed (herringbone) cross-lamination. The pebbles are discoidal and of physically resistant lithologies, mainly vein quartz and quartzite. Further south near Charters Creek and in the Makakatana plantation area are similar deposits displaying low angle cross-bedding of variable azimuth.

These deposits are interpreted as of estuarine or shore zone origin, with indications of tidal reversal in flow. The presence of numerous westward inclined cross-beds precludes a normal fluvial origin. The moderately mature composition and texture and the predominantly discoidal pebble shape suggest energetic processes with shape-sorting such as occurs on beaches or estuarine shoals. (Hobday, 1975).

The homogeneous red sand, which in most dune ridges overlies the boulder and pebble bearing deposits, has a median diameter in the fine-grained sand range and displays little regional variation in texture. Subangular to rounded quartz grains make up between 70 and 95 per cent. The heavy mineral content decreases eastward from a maximum of 8 per cent near Bushlands. In most samples clays constitute between 6 and 18 per cent, occasionally more. These appear to have originated by the kaolinisation of feldspar, which is almost entirely absent. The red sand has a maximum thickness of 50 m immediately to the west of False Bay. (Hobday 1965)

The innermost dune ridge, which passes through Hluhluwe village, is probably related to a very high early Pleistocene sea-level. The dune bases become progressively lower eastward concomitant with an increase in topographic relief and dune continuity. This is suggestive of decreasing antiquity, a conclusion which is supported by east-west differences in soil profiles. Indurated ferruginous zones, a product of advanced podsolisation, are well developed in the west.

Although present 4 km inland from St. Lucia Estuary this soil horizon has not been recognised seaward of Lake St. Lucia (Hobday 1975.)

The red sands of the dune ridges are attributed to aeolian processes which accompanied marine regressions. Together with the coarser estuarine or beach deposits at the base each probably constitutes a transgressive-regressive couplet, but the details are masked by advanced diagenesis, which has destroyed most primary structures, plus the obscuring effects of younger sands and dense vegetation.

Very fine-grained light coloured sand is intermittently exposed in a dune ridge adjacent to the western shores of Lake St. Lucia and The Narrows. It rests on the Cretaceous at an elevation of 7 - 12m, and varies between 3 and 9 m in thickness. It is abruptly overlain by pebbly coarse-grained sands. Over 90 per cent of the sand is quartz with about 8 per cent calcite. It is well sorted, and unlike other sands in the area, displays marked positive skewness. This, in combination with other textural and compositional attributes, is suggestive of deposition by wind. An absence of internal structures and the weathering characteristics both resemble loess (Hobday 1965).

The Coastal plain is veneered with coversands which are generally between 0,5 and 3 m thick. Some have undoubtedly been derived by leaching of red sands, as evidence by white sand tongues which extend down into the red sand. There is nevertheless textural evidence of local redistribution, probably during Holocene times. Ventifacts have been recovered from this deposit at the top of a quarry to the west of Fannies Island Rest Camp. (Hobday 1965).

Near Charters Creek a discontinuous thin layer of reworked hardpan is encountered between the red sand and overlying light grey sand. This gravel layer confirms that the upper sands are not simply the leached counterpart of the red sands but are substantially younger.

This is further supported by marked textural contrasts. The median grain size of the coversands coincides closely with the homogeneous red sands, but some samples are slightly better sorted.

Low dunes and hummocky topography are present over much of the eastern half of the coastal plain. These are quite distinct from the larger red sand ridges from which they have been derived by local deflation. A north-south alignment is once more evident but is less consistent. Augering reveals that these dunes consist entirely of Holocene coversands.

LAKE ST. LUCIA CORES.

A coring programme conducted by the Provincial Roads Department established that sediment thicknesses are considerably greater than had previously been suspected (Kriel 1965). Seven continuous cores, extending from the sediment-water interface to Cretaceous bedrock, were obtained from a floating rig. Their locations are indicated in Fig 1. The depth to bedrock and the salient lithological and faunal characteristics are depicted in Fig 3. This diagram illustrates the variability in thickness of the Quaternary fill, ranging from a minimum of 7,8 m to a maximum of 33,5 m. Fig 3 also demonstrates a lack of stratigraphic similarity between the various cores apart from a general tendency for the coarser sediment grades to occur in the lower parts. Carbonaceous mud and silt, such as dominate much of the present bed of the lake, constitute the bulk of the upper part of the cores.

The preliminary radio carbon age determinations, together with those reported by Kriel (1965), indicate a Holocene age apart from the deeper parts of some cores which extend into the late Pleistocene (Hobday, 1975).

Core 1 from northern False Bay extended to a depth of 33,5 m. Below a depth of 19 m silt and shelly sand predominate and contain a variety of molluscs, some of which are of marine affinity, (Hobday, 1975). Sedimentological evidence for high energy processes comes from 50 cm of reworked Cretaceous at the base, but this is overlain by deposits of sand and mud suggesting rapid reduction in energy as a result of deepening or the sheltering effect of a barrier.

Core 2 struck Cretaceous bedrock at a depth of 13,7 m. Between 10 m and the base are poorly sorted sand and oxidised silt containing calcareous and ferruginous concretions. These are interpreted as fluvial deposits. (Van Heerden, 1975). They are overlain by 2,5 m of sand containing broken shells, apparently of changing estuarine origin. Above these are typical lagoonal

muds with abundant Eumarscia pauperscula giving way upward to Solen corneus. Foraminifera are abundant in these lagoonal muds. These were tentatively identified as Ammonia beccarii (Linné). Phleger (1960) associated these with inner lagoon, lower lagoon, beach and fluvial marine environments.

Scattered sand-size quartz grains with a red oxide coating were probably blown in from the Pleistocene red sand cordons. (Van Heerden 1975).

Bioturbated mud containing broken, thin shelled molluscs makes up all but the basal 3 m of Core 3. Gypsum crystals occur at depths of between 18,5 and 25,5 m. This indicates that even during the early Holocene there were periods of intense dessication initiated by effective lagoonal confinement and lack of appreciable inflow of fresh water.

The basal sediments of Core 4, situated in the north-east, consist of 20 cm of aeolian sand. This is followed by 1,5 m of very shelly sand with shallow water estuarine or lagoonal macrofauna such as Solen and Balanus. The upper parts of the core are characterized by a large number of foraminifera, indicating a plentiful nutrient supply by tidal incursions or river inflow.

Core 5 to the south of Bird Island indicates a thin basal layer of aeolian sand. This is followed by 40 cm of relatively poorly sorted sand containing articulated bivalves suggestive of a sheltered environment. The remainder of the core consists of rapid alternations of silt and mud, a textural contrast which characterises the floor of the Lake in this area at the present day. The included fauna are essentially estuarine or lagoonal forms.

Core 6 in the southern portion of the Lake struck bedrock at a comparatively shallow depth of 7,8 m. White sand at the base is overlain by 50 cm of highly oxidised medium-grained red sand identical to the wind-blown red dune deposits of the modern coastal plain. A metre of estuarine mud which overlies the red sand is followed by fine-grained brown sand with Solen

and mud clasts. The latter are indicative of periods of subaerial exposure followed by inundation such as occur in a tidal mudflat, or in a non-tidal situation such as Lake St. Lucia today where the level is subject to fluctuation. The uppermost deposits consist of 4,5 m of black mud.

The Narrows (Core 7) display a sequence which is conspicuously different from any other, Whereas shells are generally absent finely disseminated vegetal detritus is common throughout. Mud at a depth of 15 m coarsens upward through silt with ferruginous concretions into silty sand, a typical lacustrine or "bay fill" pattern produced by lake shore encroachment over lake floor muds. Below a level of 15 m there appears to be a complete absence of foraminifera, which is suggestive of a fresh water marsh deposit.

DISCUSSION AND CONCLUSIONS

Despite controversy over the degree and timing of Quaternary sea-level changes it is generally accepted that early Pleistocene levels were considerably higher than at present. Because glacio-eustatic oscillations were superimposed on this non-glacial regression, retreat of the sea from the Zululand coastal plain was undoubtedly erratic and accompanied by several reversals. North-south aligned dunes ridges, whose positions are related to former shorelines, are conspicuously younger eastward. Many of these ridges comprise a basal transgressive beach deposit overlain by aeolian sands. Unfortunately the details of these early to middle Pleistocene events have for the most part been masked by reworking, vegetation and advanced diagenesis.

The drainage pattern was profoundly influenced by these dune ridges. The Mzinene River was deflected first northward and then southward to unite with the Nyalazi and Hluhluwe Rivers, which had been confined behind the same ridge. River valleys became deeply entrenched during stages of sea-level lowering. Northern False Bay and Hells Gate were both incised to depths greater than 30 m. Shorelines corresponding to these low stands were situated near the outer edge of the continental shelf. The combined discharge through Hells Gate probably joined with the Mkuze River to extend across the emergent shelf and erode the deep canyon which is present off Leven Point. Hopefully further coring in the northern lake will document this hypothetical confluence.

Unlike most barrier-lagoon systems which were initiated in response to a deceleration in the rate of sea-level rise during the period approximately 7,000 to 5,000 years ago (Curray 1969, Phleger 1969), the St. Lucia barrier had an earlier origin. A spine of aeolian sandstones, thought to be related to the penultimate or Saalian glaciation, was truncated during the Eem transgression. There were probably three distinct peaks of sea-level advance during which beach and nearshore sand and gravel accumulated. The two intervening stadials are marked by a karst erosion surface and a younger aeolian sandstone respectively.

Planation and inundation of the ancestral barrier sandstones during the sea-level maxima would have permitted free marine circulation in the area now occupied by Lake St. Lucia. Hells Gate opened directly to the sea, with small islands protruding above the barrier, which otherwise was shallowly submergent and breached by a number of channels. The western shores of Lake St Lucia were sea-cliffs at this time, thus possibly accounting for their present linearity. Unimpeded oceanic incursion in those areas of False Bay adjacent to Hells Gate permitted the growth of coral reefs. A variety of molluscs flourished and accumulated in situ as oyster beds and as bioclastic deposits. Other commonly occurring organisms were brachiopods, barnacles, sponges and echinoderms.

During the last glacial retreat the bulk of the earlier valley-fill deposits were eroded. Onshore winds crossing the emergent shelf blew sand against the sandstone barrier core. A prominent submarine ridge near the outer margin of the continental shelf may be a relict barrier marking the maximum extent of the Weichsel regression. Lower ridges to landward possibly represent ridges developed and subsequently flooded during the Flandrian transgression.

Sedimentological and faunal evidence from the Lake St Lucia cores indicates that lagoonal confinement was established at an early stage during the post-glacial transgression. Nevertheless, marine conditions were periodically reintroduced by the breaching of outlets. Progressive reduction of river gradients resulted in the blocking of river mouths in the north, presumably by littoral drift followed by dune formation. Only the Mfolozi River was sufficiently large to maintain an exit.

The combined waters of the northern rivers became impounded behind the barrier thus formed. As the lagoon level rose the margins overflowed the adjacent depressions between the coastal barrier and older ridges inland. This ancestral Lake St Lucia system occupied an area of 1165 km² (Orme 1973), covering the existing Mkuze swamps. Between St. Lucia and the drowned Mfolozi valley to the south was a relatively shallow spillway where the

waters were deflected over older alluvium to the only outlet at the mouth of the Mfolozi.

Subsequent changes in the configuration of the Lake St. Lucia system were accomplished by delta infilling, sedimentation, swamp encroachment and local shoreline erosion (Hobday 1965, Orme 1973). Pronounced accumulation of mud in the immediate vicinity of rivers entering the Lake is probably due to flocculation of clays in saline water. As noted by Phleger (1969) a marked reduction in the salinity during flood stages allowed clay to become more widely distributed over a lagoon. At the present day the entire floor of the Lake is above effective wave base. As a consequence wind-induced waves and associated currents are the most effective sediment transport mechanisms.

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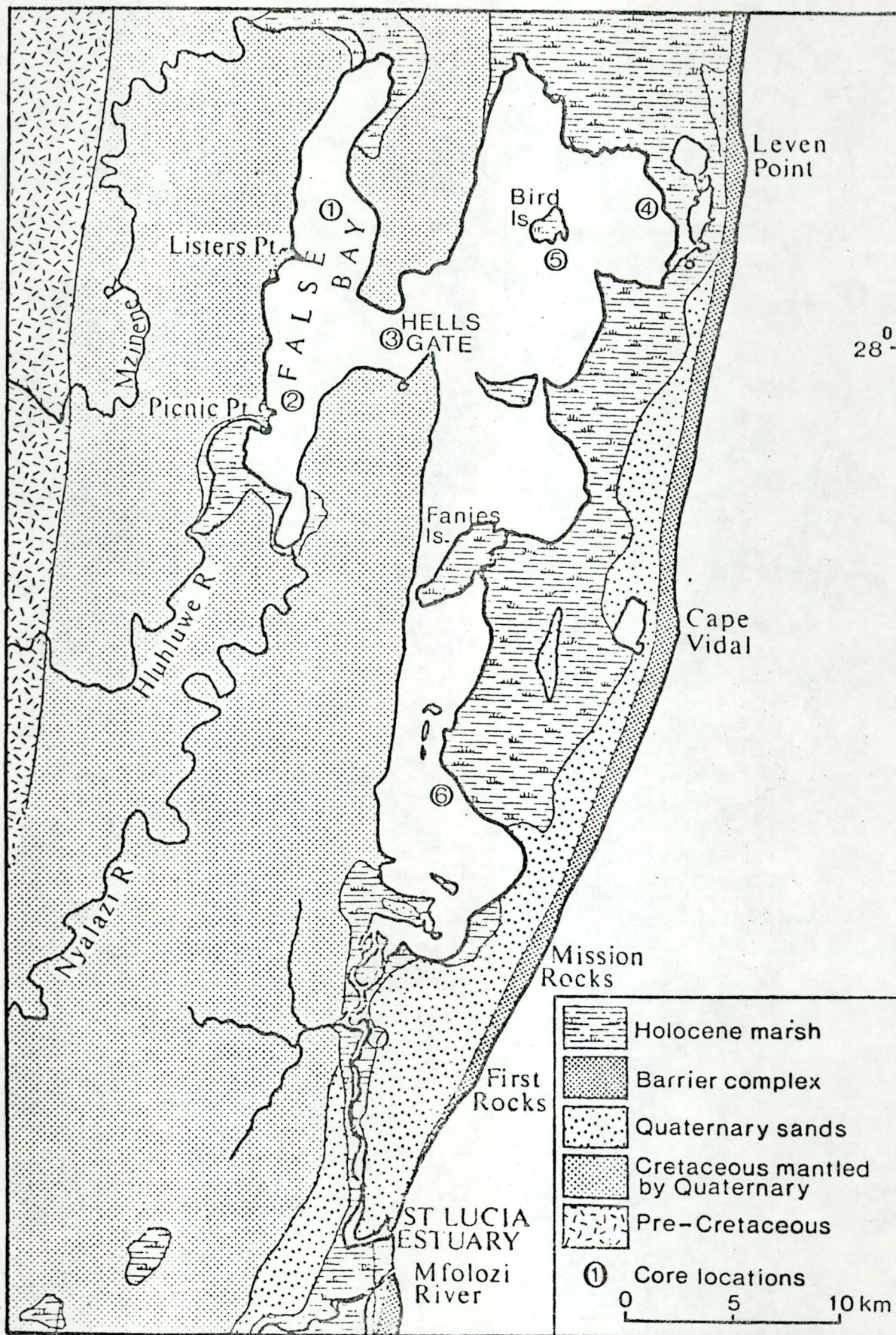


Fig. 1 - Generalised distribution of the main geological and geomorphological elements of the Lake St Lucia area. Core sites and other important localities are indicated.

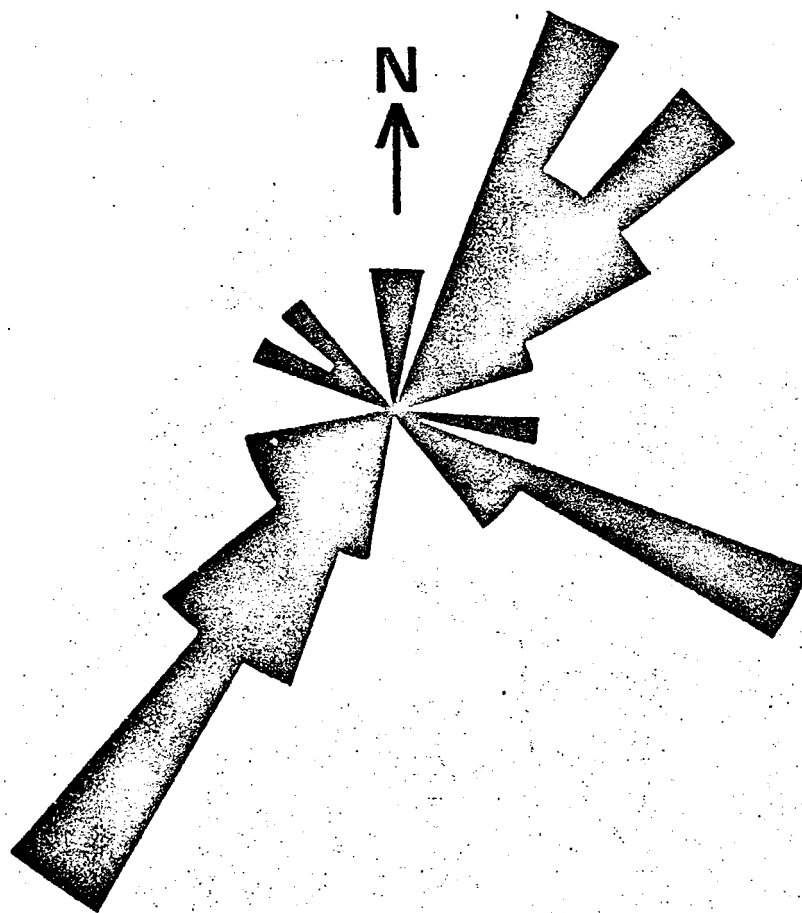


Fig. 2 - Distribution of cross-bed azimuths in the lower nearshore facies of unit 2 (34 readings).

see plate 20

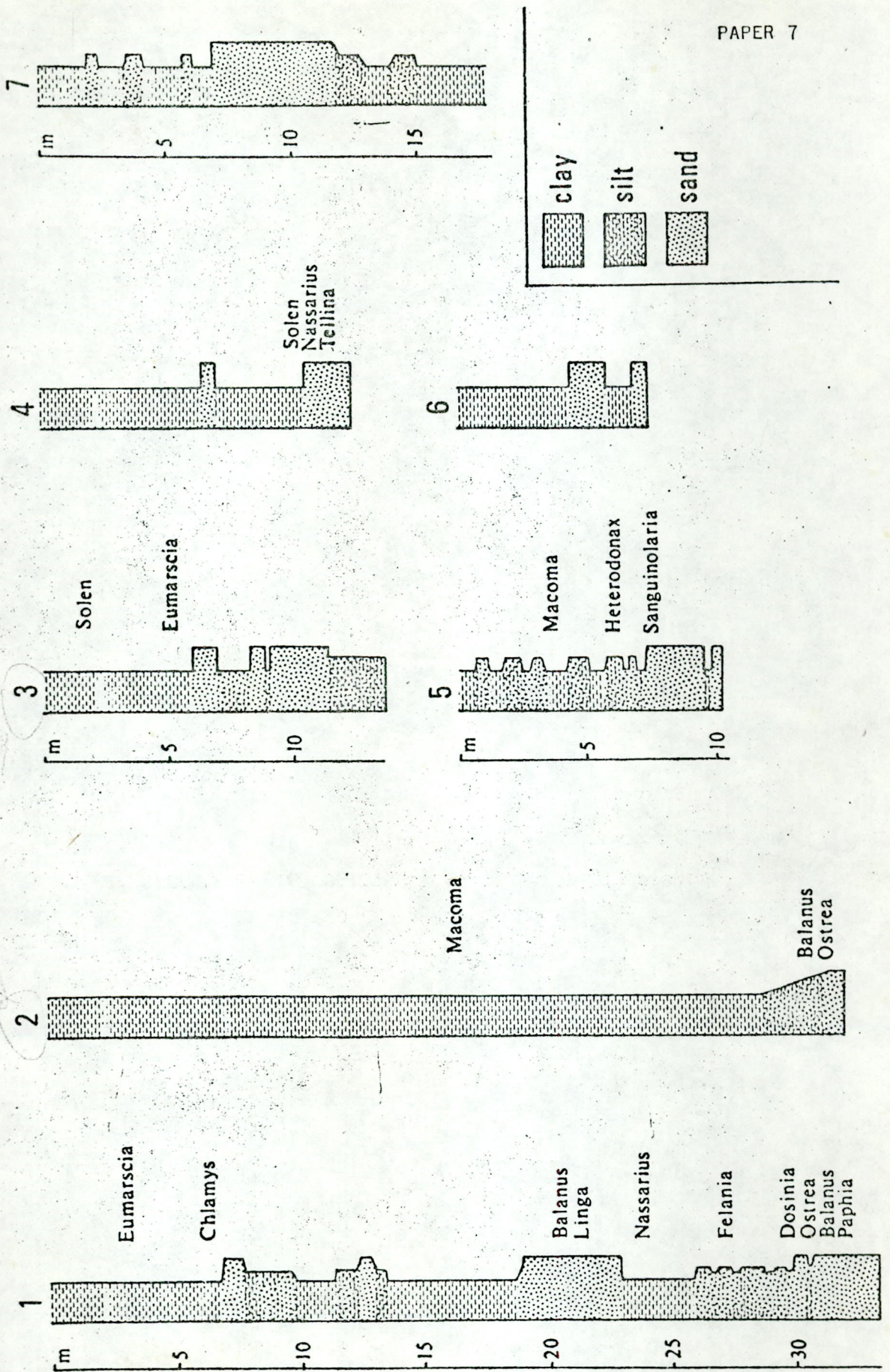


Fig. 3 - Schematic representation of lake cores indicating dominant grain size and generalised distribution of commonly encountered macrofaunal genera.