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On the Sedimentary Sequence of Langebaanweg «E» Quarry, Cape Province, South Africa

The fossil occurrences of Langebaanweg, in the southwestern Cape Province, may represent some of the oldest deposits of the late Cenozoic Sandveld, an undulating surface that at least in part owes its origin to eolian forces.

The basic geological units, which attain some 50 m above modern sea-level, have been outlined by Hendey (1970, 1973) and Bishop (in Wolff, Singer and Bishop, 1973). The writer visited Langebaanweg's " E " Quarry with Q. B. Hendey in September 1971, collecting a representative suite of sediment samples. Following preliminary examination of some 24 of these, 12 from the late Pliocene Varswater Formation or Cyclothem and 2 from the modern Saldanha littoral were analyzed in further detail; (a) west-sieving, using 37, 63, 210, 595 and 2000 μ sieves, with hydrometer analysis of 2 samples with appreciable clay/silt components; (b) calcium carbonate content by the Chittick gasometric apparatus; (c) pH values, electrometrically in distilled water; and (d) exploratory microscopic examination of sand grain surface texture and mineralogy. These tests were carried out in the Paleo-Ecology Laboratory (Anthropology Department) of the University of Chicago. The results, the first of their kind to be completed from Langebaanweg, helped to narrow the range of interpretative possibiltiies for the strata of the Varswater Formation (see Table 1). However, considerable stratigraphic and sedimentological work will be required to resolve the outstanding problems and the present description and discussion is intended solely to serve as a preliminary position paper.

Description of the strata

The basic sediment data is summarized in fig. 1 with respect to the members of the Varswater Formation, the underlying Basal Clay, and modern littoral samples from Saldanha Bay. Cumulative texture is shown as most conveniently broken down by the 63, 210 and 595 μ sieves, complemented by the median (Md) grain-size for each sample. Sorting (So) is expressed by the Trask coefficient $\sqrt{Q_1/Q_3}$ where Q_1 and Q_3 are the first and third quartiles respectively of the cumulative grade-size spectrum, with $Q_1 > Q_3$. Skewness (Sk) is expressed by the

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formula $Q_1Q_3/(Md)^2$. It is at once apparent from these simple parameters that interesting patterns occur in the textural data, while the chemical results are essentially indicative of post-depositional conditions or alterations.

Basal Clay. Underlying the Varswater Formation *sensu strictu* is a unit of pale yellow (2.5 Y 8/3, dry, in the Munsell notation), clay loam (Sample No. 3202). Sorting is very poor due to a bimodal textural spectrum, with maxima in the clay fraction (under 2 μ) and the medium-sand grade (near 100 μ). A clay content of 34% is reflected in the slickenside structures that obscure any initial bedding characteristics. There is extensive and distinct, yellow (10 YR) mottling of ped faces and sandy pockets, with additional pyrolusite staining and hematitic micro-concretions. Traces of phosphatic sands may be either primary or reworked; the 1% carbonate content is probably secondary.

Bed 1. The basal unit of the Varwater Formation is a rather complex agglomeration of material. Two or more phases of apatite cementation are recorded within 3 generations of consolidated materials, each subsequently reworked and embedded in a matrix of finer deposits. The minimal sequence of development can be synthesized as follows:

(i) Induration of coarse quartz sands with phosphates to form a brown (10 YR 5/3, 6/4), crystalline rock " throughly cemented with apatite giving normal diffractometer peaks " (R. L. Hay).

(ii) Reworking of this oldest phosphatic rock, worn down to well-rounded pebbles and small cobbles, ultimately deposited within a matrix of medium-grade sand.

(iii) Induration of the previous agglomeration with phosphates to form a light yellow brown (10 YR 6/4), crystalline rock, retaining a sand " texture ".

(iv) Reworking of this new generation of " phoscrete " into cobbles and blocks (up to over 75 cm thick), partly embedded in a matrix of medium-grade sand (No. 3203-D).

(v) Partial carbonate cementation and iron-enrichment of the previous agglomerate to a white (2.5 Y 8-9/2), sandstone with large, common and prominent, brown-yellow (10 YR) mottles.

(vi) Reworking of all of the previous products of induration into a matrix of unconsolidated, white (10 YR), medium-to-coarse-grade sands (Nos. 3202A, 3204). These are well-rounded and polished in terms of surface texture, decreasing in sorting with increasing median grain-size. Phosphate grains are limited to grades over 500 μ and are all strongly rolled and clearly reworked. Major fossiliferous occurrence of marine invertebrates and vertebrates (Marine Faunal Unit 2 of Hendey, 1973).

Altogether, Bed 1 maintains an average thickness of a meter or less, forming a discontinuous bed in " E " Quarry that dips noticeably seaward, i.e. to the south and west, attaining a maximum elevation of almost 30 m (Hendey, 1970). The contact to Bed 2 is conformable.

Bed 2. Some 2 m of white (10 YR-2.1 Y), well-sorted (So indices 1.4-1.7), medium-grade (Md values 117-159 μ) sands (Nos. 3205-3208), with no conspicuous bedding structures. Sand grains are polished, but increasingly more angular, with an admixture of reworked phosphate grains and very fine, mineralized bone debris. This is the major faunal unit (Estuarine Faunal Unit 1 of Hendey, 1973). Locally, near the top, Bed 2 has been indurated into a gray (5 Y 7/1.5) " silcrete ", as much as 50 cm thick; Hay noted nothing but quartz on the diffractogram and describes this material as a " sandy quartzose chert ".

Bed 3a. After the presumed interruption indicated by the terminal induration of Bed 2, sedimentation resumed along identical lines (No. 3210), although intensive oxidation has produced large, common and prominent, red-yellow (7.5 YR) mottles. About midway there are a number of lenticles of compact, laminated, gray to very dark gray (10 YR 3-6/1), clay with sandy pockets (No. 3209). Sorting is poor in a bimodal distribution with a secondary grade maximum near 175 μ. These lenticles are seldom over 1 cm thick and possibly include rootlet or worm structures. At this point the main sedimentary body becomes noticeably coarser changing to an oxidized, yellow (10 YR 7/6), coarse sand with good sorting (So. 1.6) and a median size of 275 μ (No. 3211). There also are abundant phosphatic sand grains that are subangular, " frosted ", and quite possibly authigenic. Locally there may be unweathered feldspar crystals as well as feldspar and quartz pebbles, with some fragmentary fossils (Estuarine Faunal Unit 2 of Hendey, 1973). The contact with Bed 3b is poorly defined and as yet inadequately understood.

Bed 3b. The subsequent trend of sedimentation was fined and more uniform, with the dominant material a white (10 YR), moderately-sorted (So 1.8-1.9), medium-to-coarse-grade sand (Md 178-184 μ). (Nos. 3212, 3213A, B). Pebbles and bone are absent. Proportions of phosphatic sand grains increase upwards and a meter or so beneath the top suggest a zone of primary phosphate enrichment-a compact, light yellow-brown (10 YR 6/4) horizon. This is in turn altered by a younger, 30 cm-thick carbonate horizon, over 40% soluble in cold HCl and containing quantities of amorphous silica (No. 3213B). The combined thickness of Beds 3a and 3b is well in excess of 7.5 m, and the nature of the bedding structures, if any, is at present obscure.

The thick, overlying sequence of sands and carbonate horizons, presumably marking eolian deposition and paleosol formation, has not yet been sampled. The primary relevance of these younger, Pleistocene cover sediments is for an understanding of the Elandsfontein fossil occurrences, some 20 km to the southeast (Butzer, 1973).

Some points of interpretation

By way of comparison, sand samples were collected from a sandy beach at Langebaan, on a low wave-energy sector of Saldanha Bay: No. 3200 comes from the watermark, No. 3201 from wind-reworked beach sand in the spray zone. It is readily apparent (fig. 1) that median size, sotring, and skewness of these 2 samples is almost identical to that of the Langebaanweg sediment column between the top

of Bed 1 and the base of 3a (Nos. 3204-3208, 3210). No local analogues were obtained for other parts of the sequence, although the high-wave energy coast of False Bay, at Swartklip, provides points of comparison for the coarser sands of Bed 1 (Nos. 3203A, D). This suggests that further collection from more, exposed intertidal zones, and from the Great Berg River and its estuary, might provide close analogues to other, problematical parts of the sediment column.

With these severe limitations in mind, the following discussion is intended simply to explore some of the possibilities and limitations of interpretation.

Basal Clay. The gleyed, bimodal clay loam underlying Bed 1 could reflect on an estuarine, a lagoonal, or even an alluvial environment. Without more extensive exposures, comparative material, and an intensive geochemical study of the phosphatic component, it will be impossible to arrive at any firm conclusions. The available data suggest subaqueous deposition in an environment subject to strong, possible periodic alternations of transport energy.

Bed 1. The repeated reworking of phosphatic rock into gravelly sands, as well as the bedding properties and a highly littoral faunal assemblage, all point to a beach environment. Specifically, a moderate to high wave-energy intertidal zone is indicated. By contrast, the phosphatic induration of beach sands finds no

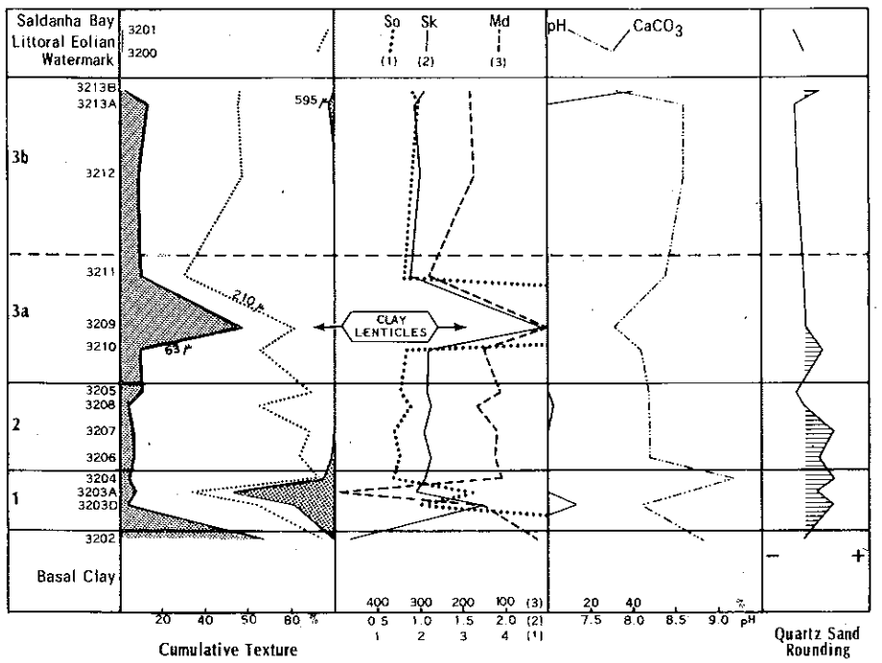

FIG. 1. - Analytical data from Langebaanweg "E" Quarry with comparative texture in the 63, 210 and 595 μ grades; median grades and coefficients of sorting and skewness; relative degree of quartz rounding, as estimated from plates of Shepard and Young (1961); as well as $CaCO_3$ and pH values.

TABLE 1. - A TENTATIVE STRATIGRAPHY OF "E" QUARRY, LANGEBAANWEG

(based in part on Hendey, 1973)

Geological Age	Rock-Stratigraphic Unit		Lithology	Depositional Environments	Faunal Unit
Pleistocene (to Holocene?)	(Cover Sands)		Sands, Calcretes, etc. (2-40 m)	Subaerial (eolian, pedogenetic)	—
Pliocene Upper	VARSWATER FORMATION	Bed 3b	Phosphate enrichment	?	
		Bed 3a	Medium-grade sands with clay lenticles, followed by medium- to coarse-grade sands (over 7.5 m)	Initially marine-littoral, then possibly estuarine (? channel bars of intertidal zone)	— ..... Estuarine Faunal Unit 2
		Bed 2	Silcrete development Medium-grade sands (2 m)	? Marine-littoral (foreshore or longshore bar?)	Estuarine Faunal Unit 1
		Bed 1	Medium-to-coarse-grade sands and pebbles Carbonate cementation Medium-grade sands/ pebbles Apatite cementation Medium-grade sands/ pebbles Apatite cementation Coarse-grade sand	Marine-littoral (3 transgressive beaches alternating with phosphate enrichment under indeterminate conditions)	Marine Faunal Unit 2 Marine Faunal Unit 1 —
		(Basal Clay)	Clay loam (thickness unknown)	?	—

immediate explanation other than the occurrence of long, intervening phases with low-energy conditions. The terminal beach sands of Bed 1 — with their hyperlittoral fauna — continue conformably and without perceptible chance of facies into the base of Bed 3a.

Bed 2. The good sorting and homogeneous character of the Bed 2 sediments speaks against a fluvial environment. Instead, the modern analogues, the well-rounded and polished sand grains, as well as the presence of abraded faunal remains, all argue for intertidal deposits on or just offshore of a low wave-energy beach. The fossils may have been transported by beach or longshore drifting, and

were probably deposited in very shallow water. The composition of " Estuarine Faunal Unit 1 " would suggest a river-mouth at no great distance, although the immediate depositional environment would not appear to have been estuarine. No explanation can presently be provided for the siliceous cementation at the top of Bed 2.

Bed 3. The lenticular changes of facies mid-way in Bed 3 introduce a significant change of depositional environment. Clay lenticles of this kind could have been laid down in subaerial, muddy pools, in certain estuarine settings; or in shallow, offshore depressions able to trap suspended sediment. However, the equally sudden influx of coarser sands that remained characteristic thereafter, as well as the subtly decreasing degree of sorting, rule out an offshore environment. At the same time, the sediment sequence is too homogeneous and still too well-sorted to allow a good case for fluvial sedimentation. We are therefore inclined to favor a river-mouth setting, possibly channel-bars within the intertidal zone.

The phosphate enrichment of Bed 3 appears to be at least in part primary. The phosphate is of the concretionary rather than oolithic variety and would therefore seem to infer post-depositional accummulation by colloidal apatite in existing, permeable sandy sediments. Such phosphoritic metasomatosis may have destroyed any bone in at least the upper subunit of Bed 3. Although submergence is suggested by the phosphate enrichment, the nature of the superposed body of water cannot be deduced from the available evidence. On the other hand, the calcrete cap of 3b must be a much younger phenomenon, related to subaerial pedogenesis broadly contemporaneous with the cover sands.

The preceding data are summarized in a highly provisional manner in Table 1.

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ZUSAMMENFASSUNG

Geologische Untersuchungen in der pliozänen Varswater Serie von Langebaanweg 'E' Quarry, Kapprovinz, geben eine dreifache Aufteilung: *Bed 1.* Drei seichte Komplexe (insgesamt 1,5 m) transgressiver Strandablagerungen, die jeweils phosphatisiert wurden, und eine marine Fauna enthalten; *Bed 2.* Etwa 2 m küstennaher Sand, später z.T. mit Kieselsäure zementiert, mit estuariner Fauna; *Bed 3.* Über 7,5 m Sande, zu unterst feinkörnig und mit Toneinschaltungen, in Künstennähe abgelagert mit estuäriner Fauna; danach grobkörnigere Sande einer Flussmündung, steril, und abschliessend phosphatisiert.

RESÚMEN

El análisis geológico de la formación pliocénica Varswater (Cyclothem), de la Cantera 'E' en Langebaanweg, Provincia del Cabo, permite subdividirla de la siguiente manera: *Lecho 1*, comprende tres depósitos de costa de transgresión, con un espesor total de 1,5 mts.; cada uno conteneindo fauna marina y posteriormente enriquecidos con fosfatos. *Lecho 2*, comprende 2 mts. de depósitos silificados de litoral con fauna estuaria. *Lecho 3*, formado por más de 7,5 mts., de arenas de grado medio con fragmentos de arcilla y seguidas por arenas gruesas, depositadas en medios de tipo costa-mar inicialmente y en tipo estuario posteriormente; la parte inferior con su fauna correspondiente y la parte superior enriquecida con fosfatos.