DRAFT PALAEONTOLOGICAL IMPACT ASSESSMENT

PROPOSED PHOSPHATE PROSPECTING, LANGEBAANWEG

LANGEBERG 185 PTNS 7 & 12 AND FARM 1043

VREDENBURG MAGISTERIAL DISTRICT, SALDANHA BAY MUNICIPALITY

By

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PREPARED AT REQUEST OF

SITE PLAN CONSULTING (Pty) Ltd

CLIENT

Gecko Fert (Pty) Ltd

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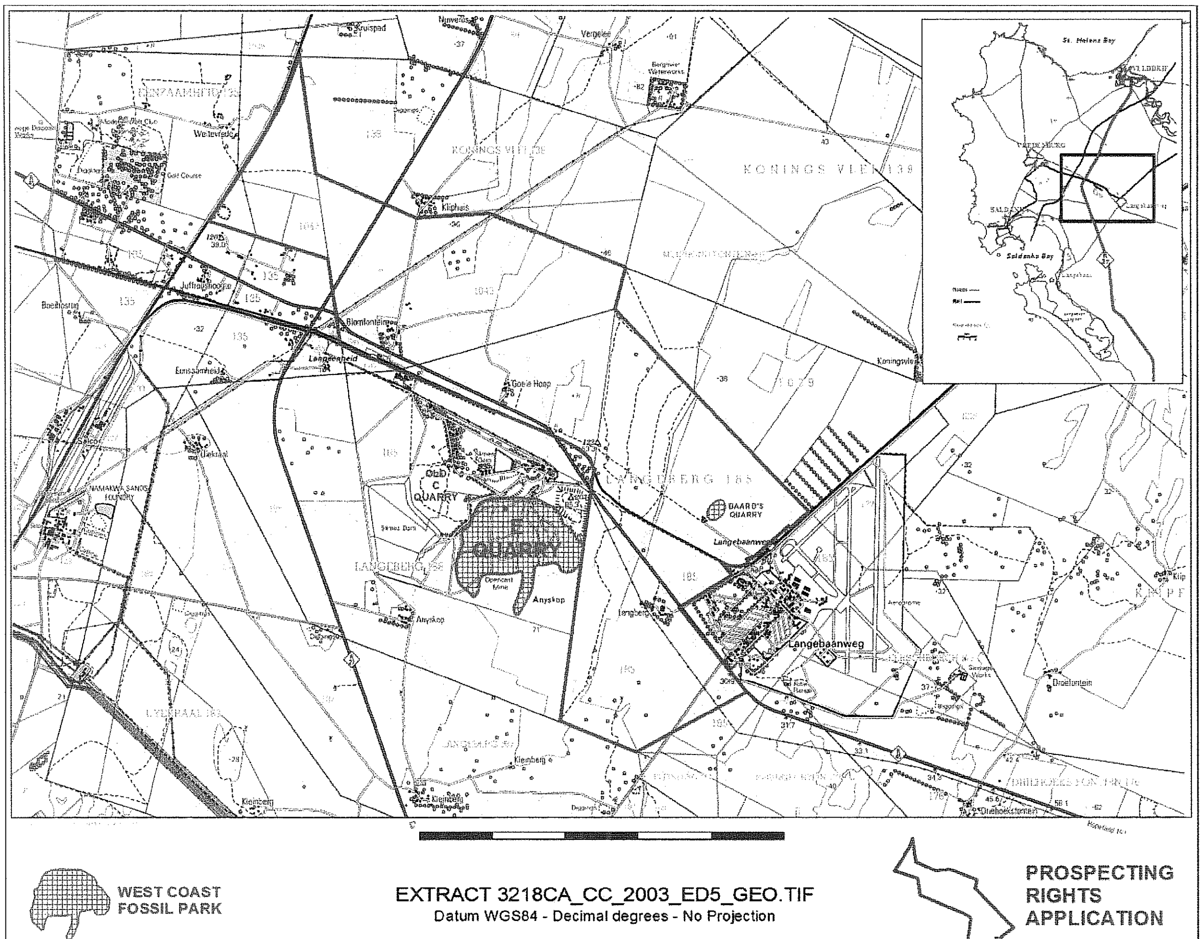
PROJECT DESCRIPTION

The client of Site Plan Consulting proposes to recommence prospecting for phosphate in the vicinity of the existing, inactive phosphate mine near Langebaanweg, on the adjacent properties Langeberg 185 and Farm 1043 (Map 1).



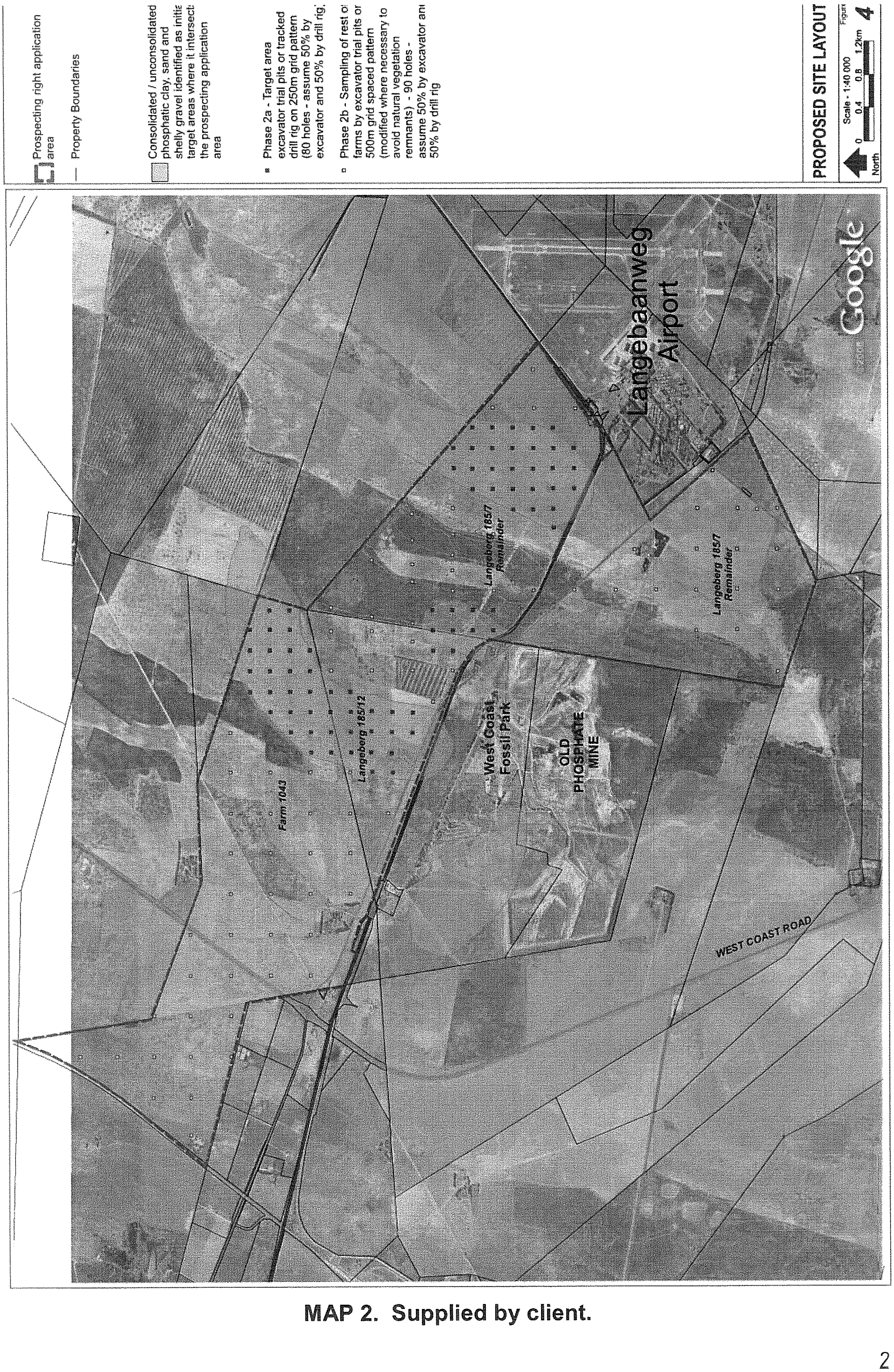
MAP 1

A map supplied by Site Plan (Map 2) shows a proposed sampling programme of two phases. The initial Phase 2a targets the surface outcrop of phosphatic sediments (80 sample sites in green areas). Phase 2b samples more widely over the properties (90 sample sites).

Half of the sites are intended to be sampled by means of trenching with an excavator. The sampling trenches (trial pits) will be approximately 5m long, up to 5m deep and ~1m wide. The other ~50% of the sites will be sampled by percussion drilling down to ~ 12 m deep. The sites of drilling or trenching alternatives are not yet specified, but will be determined by local conditions.

This Palaeontological Impact Assessment (PIA) is prepared in compliance with the National Heritage Resources Act No. 25 (1999). The main purposes of the assessment are to:

- Outline the nature of possible palaeontological heritage resources in the subsurface of the prospecting area.
- Suggest the mitigatory actions to be taken during the prospecting with respect to the occurrence of fossils.



MAP 2. Supplied by client.

Palaeontological Heritage Management

The rescue of fossils or sampling of fossil content (palaeontological mitigation) cannot usually be done prior to the commencement of excavations for infrastructure, prospecting or mining.

Although fossils may be exposed on the surface in the vicinity of some of the sites, this material is usually disturbed and fragmentary. In most cases, such surficial or shallowly-buried material is in an archaeological context, to be dealt with by qualified archaeologists. The intent of palaeontological mitigation is to sample the *in situ* fossil content and describe the pristine stratigraphic sections exposed below any human occupation layers.

These palaeontological interventions thus happen once the EIA process is done, the required approvals have been obtained and excavation of the pits is proceeding.

The action plans and protocols for palaeontological mitigation must therefore be included in the Environmental Management Plan (EMP) for the prospecting.

Palaeontological mitigation is a longer-term process and generally does not *a priori* impede a project. It is possible that during the course of works an exceptional occurrence could be uncovered that may require a more extended mitigation programme or perhaps conservation *in situ*. However, on the scale of prospecting and mining operations, such are limited in extent.

Geoheritage and Mining

The proposed prospecting programme seeks to freshly evaluate the known phosphatic sand and rock occurrences around Langebaanweg, mined since 1943. Though the fossil content was seen from the outset, the richness of the fossil content became fully appreciated during the 1960s and 70s, when the "Old/C" and "New/E" Varswater quarries uncovered impressive "Bone Beds", as well as shell beds and peaty layers with plant remains. The sampling and recording of these impressive finds ensued under the auspices of the South African Museum and Dr Brett Hendey, who soon attracted specialist palaeontologists from worldwide to study the wealth of fossils present. The Langebaanweg phosphate quarry became one of the most important palaeontological sites in the southern hemisphere, providing an unprecedented insight into the Pliocene fauna of southern Africa.

The study of the fossils continues and the foresight and efforts of many concerned, not least the previous and current mining companies and industry sponsors, has resulted in the preservation of the Langebaanweg quarry as a geoheritage site, the West Coast Fossil Park (WCFP). Thus more material can be discovered and the previous and new discoveries can be shared in the wider community and farther, as a geotourism and educational attraction.

The "windows" into the subsurface provided by prospecting drilling, trenches and open-cast pits, such as made by phosphate and diamond mining, have been invaluable to the science of fossils and geological history. They provide an opportunity to see the hidden pages of the landscape. In this sense, large holes in the ground can be an asset beyond their economic/material motivation, provided that the information they show is interpreted and appropriately communicated to citizens and visitors.

The awareness of geotourism possibilities in South Africa is growing rapidly. This is part of a world-wide realization. The geological community is thus increasingly engaging in geoheritage and geotourism concerns *e.g.* the Vredefort Dome World Heritage Site. The West Coast Fossil Park is the geotourism precedent on the West Coast. Almost every issue of the quarterly Geobulletin of the SA Geological Society has material about geoheritage. The Council for Geoscience now has a geoheritage wing.

REGIONAL GEOLOGICAL SETTING

Early geological and palaeontological work in the Saldanha Bay area described the calcareous aeolianites, their basal marine beds and occurrences of phosphatic deposits (Du Toit, 1917; Wybergh, 1919, 1920; Haughton, 1932a,b). The overall perspective on the surface geology in this area has been provided by Visser & Schoch (1973) and the accompanying map. They document valuable observations from the earlier phosphate exploration phase. Further details of the "Langebaan" or "Coastal Limestones" are provided by Siesser (1970, 1972).

Mining of the phosphatic deposits led to the discovery of fossil-rich "bone beds" at Langebaanweg (Fig.1) and the exposures provided by mining and exploratory drilling greatly expanded the knowledge of the stratigraphy and fossil record of the area (Tankard 1974a,b, 1975a,b; Dingle *et al.*, 1979; Hendey, 1981a,b and previous publications). Kensley (1972, 1977) described the taxa and palaeoenvironmental significance of the invertebrates present in the Gravel and Quartzose Sand members of the Varswater Formation.

Rogers (1980, 1982, 1983) reviewed and described the wider-scale geology of the Saldanha coastal plain, *viz.* gross bedrock topography, sediment thicknesses and lithostratigraphy, as revealed by a Department of Water Affairs drilling programme. Useful reviews and summaries that include the geology and palaeontology around Saldanha are Dingle *et al.* (1983), Hendey (1983a,b,c), Hendey and Dingle (1990), Pether *et al.* (2000) and Roberts *et al.* (2006).

The coastal deposits around Saldanha are subsumed in the Sandveld Group, which is comprised of the following formations:

TABLE 1

SANDVELD GROUP	Age and lithology
Witzand Formation	Holocene and recently active dune fields and cordons
Springfontyn Formation	Pleistocene to Holocene calcareous sandstone (aeolianite) with interbedded palaeosols
Velddrif Formation	Pleistocene estuarine coquina, calcarenite, sand and conglomerate
Langebaan Formation	Late Pliocene to Late Pleistocene aeolianites
Prospect Hill Formation	Mio-Pliocene aeolianite
Varswater Formation	Mio-Pliocene littoral and shallow marine sandstone, coquina and conglomerate
Elandsfontyn Formation	Miocene fluvial muds, peats, sands and gravels
Adapted from Roberts *et al.*, 2006.	

The Elandsfontyn Formation - fluvial/river deposits

Over much of the coastal plain of the southwestern Cape, the deeply weathered, late Precambrian-early Cambrian bedrock is overlain by the fluvial Elandsfontyn Formation (Rogers, 1980, 1982), which attains its greatest thicknesses in bedrock topographic lows and is never exposed. In the Saldanha area it is distinguished from overlying paralic and marine sediments by the angularity of its sands and the lack of carbonate and phosphate. A number of fining-upward cycles terminating in muddy and peaty layers are usually present. The strong variations in mud content recorded in the graphic borehole logs in Rogers (1980) are consistent with the mud being primarily depositional. The depositional environments are interpreted to be those of meandering rivers under humid climatic conditions (Rogers, 1980, 1982). The Elandsfontyn Formation sediments are considered to be derived from the deeply weathered, coastal-plain bedrock as “newly released, first cycle” material (Rogers, 1980, 1982, 1983).

The Elandsfontyn Formation contains fossil pollen indicative of forest vegetation with palms and is considered to be Miocene in age (Coetzee, 1978; Rogers, 1982; Hendey, 1981a). In the Langebaanweg area (S1 borehole), the pollen from peats of the Elandsfontyn Fm. suggested a middle Miocene age (Coetzee and Rogers, 1982). The characteristics of the Elandsfontyn Fm. in the wider region are detailed in Cole & Roberts (1996) and Cole & Roberts (2000). Notwithstanding, the existing fossil plant data have not provided more tightly-constrained age estimates for the various occurrences.

The Varswater Formation – estuarine/paralic and marine

Phosphatic and bone-bearing estuarine and marine deposits of the Varswater Formation (Tankard, 1974b) overlie the Elandsfontyn Formation. For the most part, the Varswater Fm is concealed beneath Langebaan Fm aeolianites, but its distribution is known from boreholes. Its proximity to the surface is betrayed by phosphatic rocks and nodules.

The extensive vertebrate assemblage recovered from the Langebaanweg quarry indicates an early Pliocene age (Hendey, 1981a, 1981b). Similar vertebrate fossils are found in the 50 m Package along the West Coast, which is a transgression to 50-55 m asl. The Varswater Formation and the 50 m Package have been correlated with the early Pliocene high sea-level 5-4 Ma (Pether *et al.*, 2000).

Phosphatic sands are recorded up to ~90 m asl. in the Elandsfontyn borehole No. S22 south of Langebaanweg (Rogers, 1980). While these are currently included in the Varswater Formation, it is possible that these high-elevation phosphatic deposits may date to the middle Miocene and correlate with the 90 m Package marine deposits of Namaqualand ("Kleinzee Fm. of the Alexander Bay Group"; modified after Roberts *et al.*, 2006). Such 15-6 Ma marine deposits are likely to be eroded remnants overlain by old aeolianites.

Westwards towards the coast, the Varswater Formation has been eroded during a subsequent high sea level and is expected to thin and eventually pinch out, except for pockets preserved locally in topographic lows in the granite bedrock or in the top of the Elandsfontyn Formation. It is overlapped by the following formation.

The Uyekraal Shelly Sand Formation - marine, mainly sublittoral

Between the Langebaanweg Mine and Saldanha Bay, a plain averaging ~12 m asl. is underlain by marine sediments named the Uyekraal Shelly Sand Formation (Rogers, 1983). Although the Uyekraal farm is the "type area" of the Uyekraal Formation, there is no type section available and the Uyekraal Fm. is known only from boreholes. Thus no detailed descriptions of exposures exist and the fossil content and age is not adequately established. It has a capping hardpan calcrete, beneath which is green-hued shelly, gravelly sand with phosphatic casts (steinkerns) of molluscs and shark teeth (Rogers, 1982, 1983).

At the coast, outcrops with extinct and warm-water fossil shells occur at Langebaan, Leentjiesklip, Bomgat, Sea Harvest, Elandspunt and the lower quarry at Diazville. These are regarded as the outer, eroded edge of the Uyekraal Formation.

The Uyekraal Formation is spatially consistent with being equivalent to 30 m Package deposits, seen in Namaqualand diamond mines as a substantial, prograded marine formation built out seawards from a sea-level maximum of 30-35 m asl. This formation, up to a few km wide, underlies the outer part of the coastal plains of the West Coast. It is probably of middle Pliocene age, 3.0-3.4 Ma.

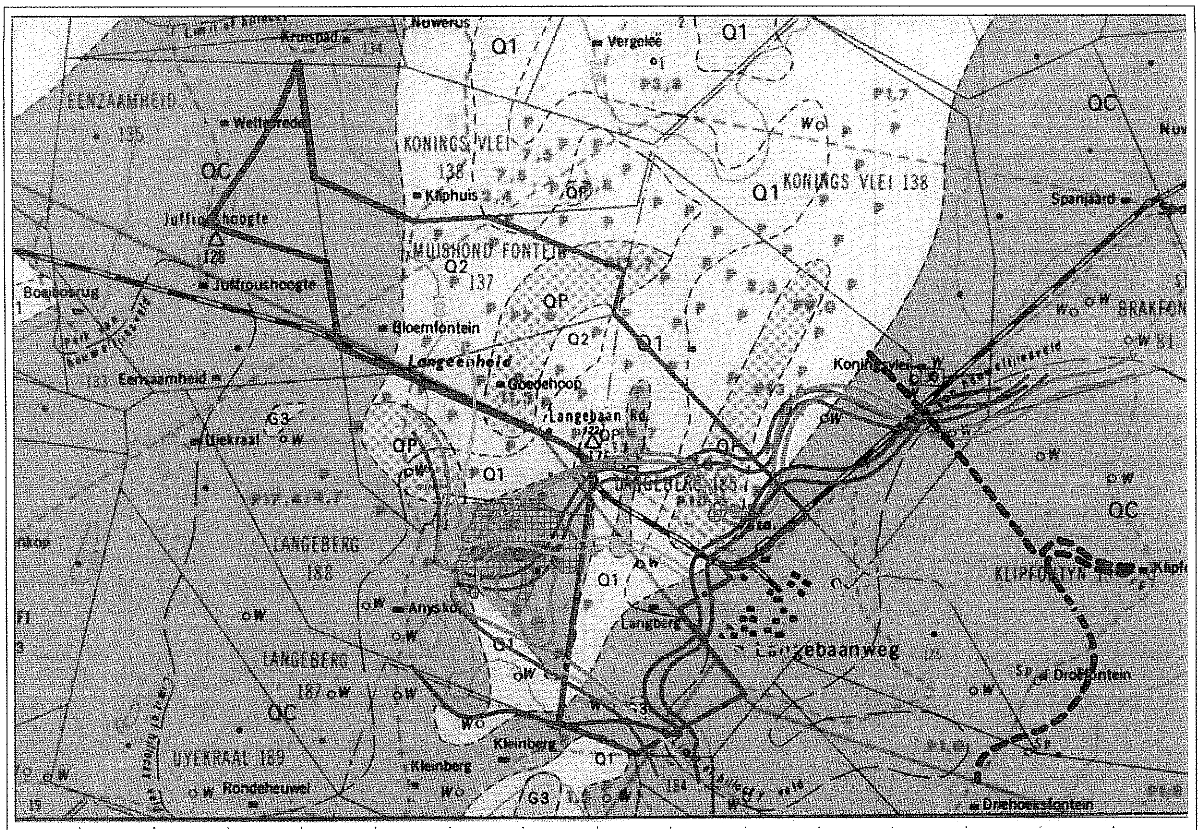
Note that the Uyekraal Shelly Sand Formation is not formally recognized and, for the present, is still included in the Varswater Formation.

The Langebaan Formation - aeolianite

The Langebaan "Limestone" Formation most visibly includes the old aeolianites (dune sandstones), beneath a capping calcrete crust, that are evident in the landscape (Map 3, QC). These contain further calcretes and leached *terra rossa* soils at depth, attesting to reduced rates of sand accumulation, with soil formation showing the surface stability. The aeolianites overlie wind-deflation erosion surfaces formed on the underlying marine deposits, *i.e.* the Varswater and Uyekraal formations. At this stage the Langebaan Fm. includes various aeolianites of different ages and is an "amalgam" of the dune plumes that formed on the coastal plain, at differing places and times, mainly during the last ~5 Ma (Pliocene to the late Pleistocene).

Some aeolian accumulations are recognized as distinctly older. For instance, the **Prospect Hill Formation** is the aeolianite ridge stretching north from Saldanha Bay (Fig. 1) that has been found to have fossil eggshell fragments of extinct ostriches (*Diamantornis wardi*) and extinct land snails (Roberts & Brink, 2002). *Diamantornis wardi* is dated as Miocene 10-12 Ma in the Namib Desert (Senut & Pickford, 1995). Alternatively, marine microfossils suggest that the dunes could have formed by deflation of 50 m Package deposits (Dale & McMillan, 1999).

At the Diazville lower quarry, Langebaan Fm aeolianite overlying the mid-Pliocene, marine Uyekraal Shelly Sand Formation enclosed vertebrate material indicative of a late Pliocene or younger age (Roberts & Brink, 2002). The fossil suid (bushpig) from Skurwerug dates the fossil dune-plume there to the early Pleistocene (Hendey & Cooke, 1985). Middle and late Pleistocene ages are indicated by relationships to LIG and earlier shoreline deposits. Recently, dating of aeolianites by luminescence methods shows accumulation during MIS 7 and MIS 5, with calcrete formation in the intervening glacial periods (Roberts *et al.*, in press).



GEOLOGY - VISSER & SCHOCH, 1973
Sheet 255: 3217D & 3218C (St Helenabaai), 3317B & 3318A (Saldanhabaai).

MAP 3

Coastal -plain Deposits

Q1: A recent soil-unit, white to slightly-reddish sandy soil, which blankets much of the surrounding area and locally covers units Q2, QB1 and QC.

Q2: Older surficial cover of light reddish-brown, sandy soil of the "heuweltjiesveld".

QC: Langebaan Formation aeolianite limestones. These are surface outcrops of old, cemented calcareous dunes. Underlain by Pliocene and Quaternary marine deposits 5 - 0.4 Ma.

QP: Varswater Formation: Consolidated and unconsolidated sand, clay and shelly gravel.

Bedrock

G3: Saldanha Granite.

LOCAL GEOLOGY/PALAEONTOLOGY

The properties under prospecting application span an area of elevated phosphate occurrence (Map 3, Ps) arcing around north and east of the WCFP. The phosphate values reflect outcropping and reworked Varswater Fm (QP) which closely underlies the surface in an area where the overlying Langebaan Fm aeolianite accumulation (QC) bifurcates to form two palaeoplumes on either side of the De Kop/Kleinberg granite bedrock high.

Overburden of Langebaan limestone occurs on Farm 1043 west of Blomfontein and on Langeberg 185 south of Langberg and as a low ridge east of the WCFP. Older soil of the "heuweltjiesveld" (Q2) covers most of the area, except where a swath of younger, more recently mobile sands (Q1) crosses the area.

Superimposed on the geological map are five basic palaeogeographries (Hendey, 1981a) that show shorelines and the courses of the palaeo-Berg River as "snapshots". These time slices are inferred from geometrical aspects of the deposits exposed in the quarry and surrounding area. The time slices are generalizations referring to particular strata or "members" of the Varswater Fm (Figure 1).

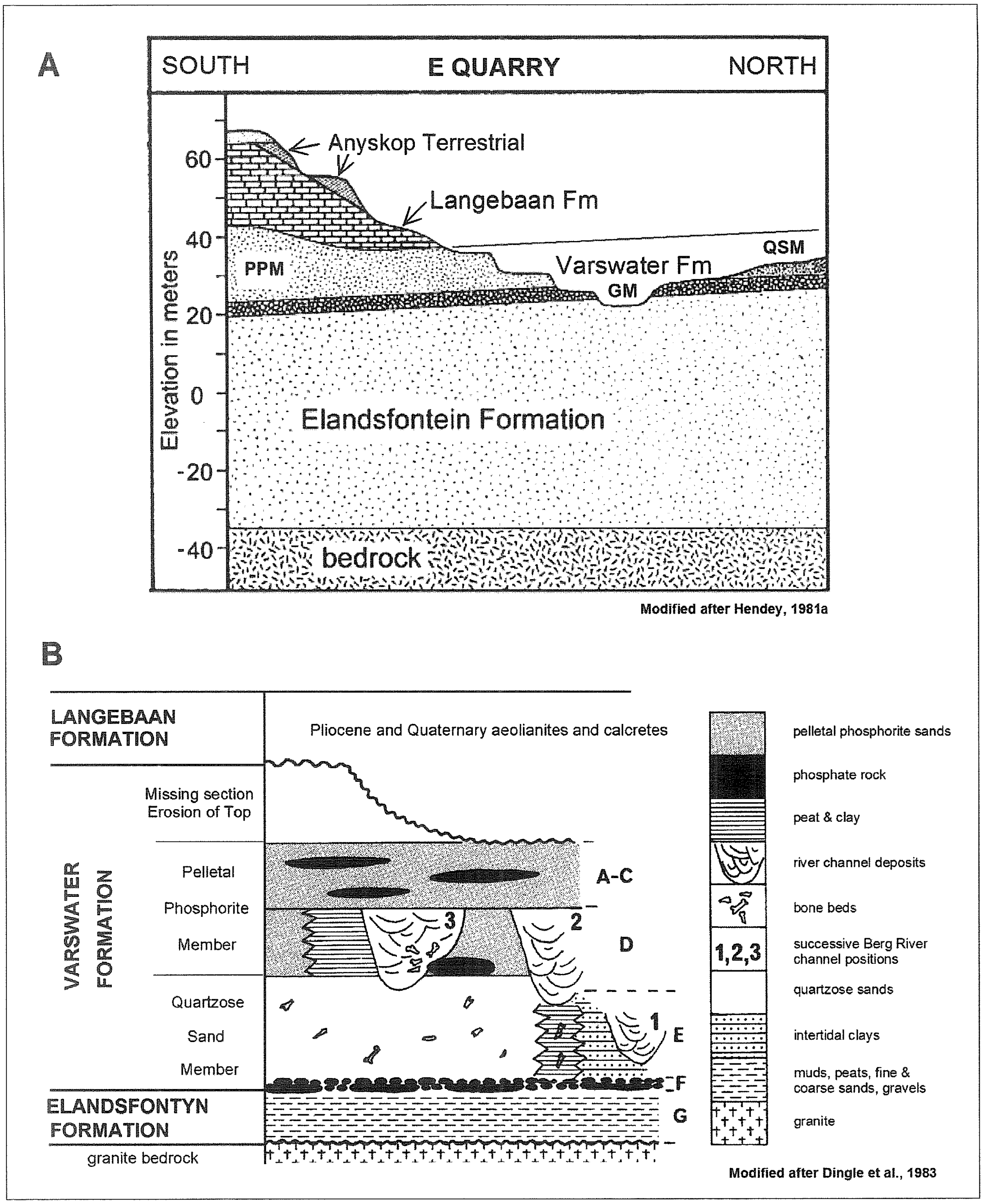


Figure 1. **A:** Simplified section of E Quarry. **B:** Schematic of the Varswater Formation.

Members of the Varswater Formation

Langeenheid Clay Member

The nature of the transition between the Elandsfontyn and Varswater formations is somewhat equivocal in the type area - see discussion in Dingle *et al.* (1983). Weakly-phosphatic quartz sands underlie the GM (Hendey & Dingle, 1990). The sediments underlying the GM have also been described as "kaolinitic clay" (Tankard, 1974b), consisting of pyritic black clays and sands. This is evidently underlain by a thin phosphatic sandstone and Fe-oxide-mottled silty clay. Roberts (in Roberts *et al.*, 2006) described this pre-GM unit as "clayey sand" and named it the "Langeenheid Clay Member" of the Varswater Fm. As identified in boreholes, it is a thick unit, up to ~11 m, and thus a significant part of the stratigraphy.

However, its fossil content is virtually unknown, mainly because it is below quarry footwall. This unit is not shown in the earlier schematics reproduced in Figure 1.

Gravel Member

The Gravel Member (GM) is the effective "footwall" of the Varswater Fm and is a fossiliferous, polyphase phosphatic gravel, formed by phases of erosion and re-cementation of phosphatic sandstone. It is suggested to be a condensed record of Middle to Upper Miocene transgression and regression (Hendey, 1981a,b).

Quartzose Sand Member

The Quartzose Sand Member (**QSM**) is an estuarine deposit consisting of river floodplain, salt marsh and tidal-flat environments, laid down when the shoreline of the rising sea-level was just west of E Quarry and a beach-barrier or spit had formed across the estuary mouth. It is richly fossiliferous, with a diversity of bones, shells and microfossils reflecting the various environments.

Pelletal Phosphorite Member

The Pelletal Phosphorite Member (**PPM**) contains phosphatic sands of ore grade. Its formation reflects the increasing inundation of the area by rising sea level. Deposition took place in an expanded estuarine system; seals and fishes reflect the aquatic estuarine habitat, while most of the fossil bone is of terrestrial animals carried in by the river. The PPM becomes more open-marine in the upper part, with marine microfossils, fish teeth and shell fragments, but few bones, and evidently reflects deposition in an embayment. The upper PPM is also referred to as the "PPM undifferentiated" (Hendey, 1981a) or the PPM2 (Dingle *et al*, 1983).

The early Pliocene transgression reached 50-60 m asl. (**E PLIO SHORE**). As the upper PPM infills this bay, it is likely a prograded shoreface deposit, laid down as the shoreline built out during and subsequent to the highstand, when sea-level declined. The top of the exposed marine sediments would then have been subjected to erosion by streams and wind, reducing the original thickness substantially.

Anyskop Terrestrial Deposits

The Anyskop Terrestrial Deposits (**AT**) is a fossiliferous hill-slope deposit that is "plastered" on the northern flank of Anyskop. Anyskop itself is formed of aeolianite deposited on the eroded top of the PPM and is thus classified as part of the Langebaan Fm. The age of the fossils on the hill slope is not well-constrained; Hendey (1981a) considered the deposit to be younger than the Varswater assemblage, but probably older than the from Baard's Quarry deposits.

Baard's Quarry Fluviatile Deposits

The Baard's Quarry Fluviatile Deposits (**BQF**) are a complex of bone-bearing, small stream channels that were exposed in this former quarry (Map 1) (now backfilled). The presence of *Equus* (horse/zebra) indicates an age younger than 2.6 Ma., whilst other taxa suggest an age >2 Ma.

PALAEONTOLOGY EXPECTED DURING PROSPECTING

In and around the areas mapped QP (Map 3) are scattered occurrences of outcropping phosphatic rocks (phoscrete) and phoscrete is variably developed in and around the areas as discontinuous layers and nodules of various shape and size. This post-depositional cementing occurred in phosphatic sand with earlier, small phosphatic nodules, calcrete and ferricrete nodules (or clasts?) and bone fragments (Visser & Schoch, 1973). This upper unit is possibly a reworked top of the underlying and adjacent formations.

In a pit at Trig. Beacon 122, beneath ~2 m of Langebaan Fm calcrete and white sand, bones occurred in a layer of phosphatized sand (Visser & Schoch, 1973).

The observations at Baard's Quarry and Muishond Fontein show that the top of the Varswater Fm may be incised by donga-like, small-scale channels with multiple cut & fill structures (Tankard, 1974b; Visser & Schoch, 1973). In the BQF example, the lower channel fills were very fossiliferous (Hendey, 1978).

Prospecting pits NW of the "Old C Quarry" showed variously-cemented, white, yellow and brown phosphatic sandstones and pale-green muds; bone fragments (incl. tortoise) are noticeable. Gravels and coarse sand were also revealed, with abundant fossil shell, shell casts, shark teeth and bone fragments (Visser & Schoch, 1973). The depth of the prospecting pits is not known, but these observations suggest that the fossiliferous gravel bed (Gravel Member) is shallower to the north. This is expected towards the edges of the depository and Tankard (1974b) shows the approximate base of the Varswater Fm ascending to the NE.

The above indicates that fossil bones may be expected in the immediate subsurface of the areas closely underlain by the Varswater Fm, in trenches and shallow boreholes:

- As an "ambient" or background of mainly fragmentary material in the reworked top of the upper PPM
- Concentrations at localities where reworking has been more intense, such as stream-channels of local drainage systems which have concentrated bones from the surrounds, cf. BQF deposits.
- Concentrations at places on or just above strata boundaries that were more persistent palaeosurfaces in the landscape, such as erosion or deflation palaeosurfaces marked by palaeosols and the erosion contact on the *in situ* PPM.

At some depth, the area is expected to be underlain by the upper PPM. Bone and shell fossils are relatively scarcer in the upper PPM *cf.* the underlying units, but are expected as:

- A background of bone and shell material within the PPM.
- Local concentrations in the PPM such as on bedding planes and in swales.

It is likely that the QSM and lower PPM progressively pinch out updip to the NE beneath the NE portion of the area. The fossiliferous basal gravels (GM) of the Varswater Fm may thus be encountered, overlying Elandsfontyn Fm or a transitional unit.

An alternative or additional possibility is that the area to the NW of the Varswater Quarry is actually the mid-Pliocene Uyekraal Fm, the shallow "GM" there being its basal gravel.

The boreholes (down to ~12 m) in the area to the east of the WCFP will encounter the upper PPM2 unit. Should some boreholes be driven deeper, down to ~25 m, they will sample the richly-fossiliferous lower PPM, QSM and GM, ending in a poorly-known transitional unit or the Elandsfontyn Fm. Considerable complexity is expected, concomitant with channel migration and short-range lateral variation in the estuarine setting (Figure 1 B). Although there is a high background of bone, bone bed concentrations should be discernible in cores.

The Langebaan Fm aeolianites do not appear to be very fossiliferous, but fossils from this formation and its correlates have been a prime source of information on Quaternary faunas and archaeology. Most of the fossils in the aeolianites are associated with particular contexts, particularly buried, stable surfaces (palaeosurfaces) where time has permitted bones to accumulate. The common fossils include shells of land snails, fossil tortoises, ostrich incl. egg fragments, sparsely scattered bones etc. Bone and shell concentrations related to buried Early and Middle Stone Age archaeological sites may occur in this context in the aeolianite, particularly in its upper part. "Blowout" erosional palaeosurfaces may carry fossils concentrated by the removal of sand by the wind. Hollows between dunes (interdune areas) are the sites of ponding of water seeping from the dunes, leading to the deposits of springs, marshes and vleis. Being waterholes, such are usually richly fossiliferous.

The lairs of hyaenas, with concentrations of bones of antelopes and small carnivores, have proved a rich source of "stashed" bones of various ages.. The calcretes have facilitated overhangs and crevices for use as lairs, superimposing bone concentrations into an older, partly-cemented aeolianite.

Impact Assessment

Significance

In lieu of belabouring the inestimable worth of the fossil heritage endowed to the area by the ancient berg River, attention is drawn to the attached bibliography of knowledge gleaned. It is incomplete and lists only the core output; many articles on particular fossil groups would discuss the material from Langebaanweg, but do not have explicit reference to the place in the title or keywords.

A major portion of the Cenozoic Palaeontology collection at the Iziko S.A. Museum is from Langebaanweg. Research is ongoing on material collected decades ago. Previously studied material is re-examined and updated and new techniques and insights are applied *e.g.* palaeodietary analyses using stable isotopes and tooth-wear. Although bulk-samples of sieved deposit may appear to the uninitiated to be a pile of nondescript bone and tooth fragments, the appropriate specialist recognizes the identity and significance of particular pieces. Many specimens of the same animals allow for the reconstruction of mortality profiles, enriching the other palaeoecological and taphonomic evidence.

The significance of the fossil heritage resource of the Langebaanweg area extends from its international scientific importance to the local level in the role of the WCFP in tourism and the local economy.

There is a significance to fossils beyond their conventional academic/scientific importance that is more firmly in the realm of cultural aesthetics. Fossils are part of the physical strata of the landscape and deepen the appreciation of the landscape's space-time depth and of the creatures that lived and died in it, were equipped for or adapted to its relentless changes, or did not and faded away to extinction.

Such realizations are inspired by encounters with fossils. Ultimately this heritage resource must be rendered known and accessible to the wider community via educational programmes emanating from *e.g.* museums, sponsorship, NGOs. The first priority, however, is to rescue fossils and attendant information that would otherwise be lost.

Nature of the Impact

Extents

The physical extent of impacts on potential palaeontological resources relates directly to the extents of subsurface disturbance during prospecting (Map 2).

The cultural impact is scientific and international.

Duration

There is the shorter-term duration of the prospecting activity and the "time window" for palaeontological mitigation for this project.

There is a permanent impact: fossils are non-renewable resources and loss of the opportunity to recover them and their contexts when exposed at a particular site is irreversible.

Intensity

The impact of prospecting and mining on fossil resources is high in the absence of mitigation. This is because fossils are rare objects, often preserved due to unusual circumstances. This is particularly applicable to vertebrate fossils (bones), which tend to be sporadically preserved and have high value wrt. palaeoecological and biostratigraphic (dating) information. Note that in spite of the richness of the fossil resource in this case, the really valuable cranial (skull) fossils are rare.

Probability

The likelihood of impact is definite. The area is known to have rich fossil resources.

Confidence

The level of confidence of the nature and degree of impact is medium to high. Existing information has been assessed and the author has made observations in the area.

Status of the impact

Fossils will definitely be lost in the absence of management actions to mitigate such loss.

There remains a medium to high risk of valuable fossils being lost in spite of management actions to mitigate such loss. Machinery involved in excavation may damage or destroy fossils, or they may be hidden in "spoil" of excavated material.

The status of the potential impact for palaeontology is not neutral. From the point of view that the "windows" into the coastal plain depository, that provide access to fossils, would not exist without excavations being made, the impact is positive for palaeontology. However, some fossils will be lost and destroyed, in spite of efforts at mitigation.

Potential Benefits

The prospecting trenching has the potential to expose fossils from deposits post-dating the early Pliocene Varswater Fm., *i.e.* middle to later Pliocene and earliest Quaternary deposits in possible BQF-equivalent contexts or on a palaeosurface equivalent to the Anyskop Terrestrial deposits. This is particularly significant as good assemblages from these times are lacking for the southwestern Cape.

Trenching may also expose the poorly-documented upper PPM2 and possibly the updip continuation of the GM, holding the possibility of improving the fossil collections and observations of these units.

The new boreholes, situated surrounding the Varswater Quarry and towards the edges of the depository, have the potential to further elucidate several aspects of the geology, *inter alia*, more detail on the sedimentary architecture and, if deep enough, the nature of the poorly-understood lower or "transitional" units.

In the west of Farm 1043, boreholes and trenches are predicted to intersect the transgressive maximum of the Uyekraal Fm (= 30 m Package). Should this be the case, it will be a critical finding for the correlation of southwestern Cape coast stratigraphy with that exposed in the Namaqualand diamond mines! Speculatively, the Anyskop Terrestrial palaeosurface may relate to this shoreline.

RECOMMENDED MANAGEMENT - MITIGATION

It is not possible to predict the buried fossil content of an area other than in general terms. Fossil bones with diagnostic features are usually sparsely scattered in coastal deposits and much depends on spotting them as they are uncovered during digging *i.e.* by monitoring excavations. In contrast, shelly layers are usually fairly extensive and normally are exposed in the sides of the finished excavation, when they can be documented and sampled easily during primary fieldwork.

It is proposed that an acceptable degree of mitigation be carried out. This entails:

1. Initially, a field check for any exposed fossil occurrences potentially threatened by the prospecting.
2. Monitoring of trenches while they are being made.
3. Detailed inspection, sampling and description of the finished prospecting trenches (primary fieldwork).

The initial field check

This would involve a "patrol" of the prospecting lines and the access routes to them, along which the movement of machinery may destroy or conceal fossil material on the surface. Specimens of probable diagnostic value are to be collected and the basic "surface bone density" can be mapped, to serve as a preliminary alert.

A contracted archaeologist is to undertake a similar surface survey for archaeological occurrences. This report will doubtless provide initial information on locations of bone occurrences and speed up the exercise.

Monitoring

The monitoring of excavations takes place while they are being dug, with the object of spotting the more rare fossils, such as bones, as they are turned up. This depends on a persistent presence.

In the case of very sporadic, smaller fossils, it is an exercise in optimism. However, a monitoring presence is critical for immediately spotting a major "strike" and stopping further damaging excavation.

Additionally, at that point it is also paramount to establish the precise stratum in which the fossils occurred.

Since it is impractical to have all excavations constantly monitored by a specialist during the prospecting, it is very desirable to have the co-operation of the people on the ground. By these are meant personnel in supervisory/inspection roles, such as the geologist, surveyor, site foremen, *etc.*, whom are willing and interested to look out for occurrences of potential heritage/scientific significance.

To aid this process, some background information is useful. This PIA should be circulated to site management persons. There should be guidelines for finds and a reporting/action protocol in place when finds are uncovered during monitoring.

Primary mitigation

The primary fieldwork phase entails the specialist documentation and sampling of the pits, to establish their stratigraphic and palaeoenvironmental contexts. When a set of excavations are completed:

- The excavation faces must be inspected for fossil content and representative samples of fossils must be collected.
- The fossiliferous sections and other key vertical sections representative of the exposures must be systematically measured, described in detail sedimentologically (logged), duly photographed at various appropriate scales and the sediments sampled, including apparently "barren" units. The latter may contain microfossils and lithological components of relevance.

For best cost-effectiveness, this activity should coincide with times of maximum exposure, when a large number of open pits are available.

This is not a duplication of the prospecting geologist's work. The latter will have other priorities *viz.* channel-sampling (vertical slots) for grade determinations, geotechnical sampling *etc.* Palaeontological mitigation involving specialists will provide complementary input to the geological understanding of the deposits.

Percussion drilling

Details of the sampling method employed by the percussion drilling are not available at present. Notwithstanding, the draft EMP cites verbal discussion to the effect that "Core samples should be made available for palaeontological (and geological) research purposes" and "All core that is not required in terms of the prospecting and mineral law can be made available for palaeontological research".

Here a collaborative interpretation of core material would maximize value. Possibly a few boreholes in different areas could be drilled to greater depth, *e.g.* through to the GM. This would aid in "locating" the surrounding boreholes and pits in the stratigraphy.

Mitigation: role of the West Coast Fossil Park

It has been suggested that the adjacent WCFP play a major role in palaeontological mitigation for the proposed prospecting programme, for the obvious reasons of expertise, reduced response times and reduced costs of travel.

Not pre-empting the specifics of an agreement that might be reached between the WCFP and the prospecting license applicant, such arrangements should involve, *inter alia*:

- Liaison protocols with a suitably-placed client representatives with respect to scheduled excavation planning and the progress being made.
- Permission for access to the diggings to monitor and log pits.
- Agreement as to the provision of personnel to carry out the monitoring, whether WCFP employees or the clients employees.
- Provision of some degree of training for monitors.
- Reporting protocol when finds are uncovered during excavation monitoring.
- Action protocol when finds are uncovered during excavation monitoring.
- Agreement regarding the specialists to be involved.

Mitigation Approaches

In principle, the strategy during mitigation is to "rescue" the fossil material as quickly as possible. Below are a range of possible actions.

If major bone finds are encountered, the contracted specialist should be immediately informed and come and evaluate the occurrence. A temporary pause in activity at the limited locale (pit) will be required, while prospecting may continue nearby at following sites,

The method of collection would depend on the preservation or fragility of the fossils and whether in loose or in lithified sediment.

- On-site selection and sieving in the case of robust material in sand.
- In the case of considerable occurrence of fossils, the methods could include the removal of a large, disturbed sample by excavator and conveying this by truck from the immediate site to a suitable place for "stockpiling". This material could then be processed later.
- Fragile material in loose/crumbly sediment would be encased in blocks using Plaster-of Paris or reinforced mortar.
- During monitoring, isolated finds that are turned could be kept in the custody of the monitor or other designated person for safekeeping. The monitor/collector must note immediately the stratum where the fossil came from, ideally marking this in some way *e.g.* by spraypaint.
- Excavated material with a clump of fossils included can be stockpiled temporarily beside the pit, ideally as a separate, marked pile (and also marking the level in the pit).

In the initial stage of prospecting, and from area to area of different geology/fossil density, it would be desirable to train the monitor as to what constitutes isolated/minor, medium and major occurrences.

THE REPORT

At the end of the task a detailed report must be submitted. This report is in the public domain and copies of the report must be deposited at the IZIKO S.A. Museum and Heritage Resources Western Cape. It must fulfil the reporting standards and data requirements of these bodies.

The report will be in standard scientific format, basically:

A summary/abstract.
Introduction.
Previous work/context.
Observations (incl. graphic sections, images).
Palaeontology.
Interpretation.
Concluding summary.
References.
Appendices

A prescribed data requirement is adequate 3D spatial referencing. This I would require the assistance of the surveyor wrt. coordinates and base maps, to plot the locations of finds during monitoring, the measured sections, samples and other observations. Preferably, this would be in geo-referenced digital format *e.g.* a CAD dxf file or ESRI GIS shape files.

The draft report may be reviewed by the client, or externally, before submission of the Final Report.

ADDITIONAL NOTES

Interested and Affected Parties

The following parties will have concerns and probably additional inputs to the recommendations for palaeontological mitigation for the proposed prospecting programme. This draft PIA should be circulated to them.

Identified in the EMP

- West Coast Fossil Park. Ms Pippa Haarhoff (manager) and the WCFP Board.
- Cape West Coast Biosphere Reserve. Ms Nicole Loebenberg.
- Terra Nominees (Pty) Ltd (Part of BHP Billiton). Ms Elsa Wloschowsky.
- Heritage Western Cape - Archaeology, Palaeontology & Meteorites Committee. Chair: Dr Janette Deacon.

Additional I & APs

- IZIKO SA Museum. , Dr Deano Stynder, Dr Graham Avery.
- UCT Dept of Geological Sciences. Dr John Rogers and Assoc. Prof. John Compton.
- Council for Geoscience. Dr Dave Roberts.
- Articulation with local interests, yet to be identified.

Enhancement

The client might desire a display/exhibition of findings and features: out of a combination of interest, public-mindedness and to demonstrate diligence wrt. heritage/science resources. This would have to be at a location and under conditions approved under the auspices of the IZIKO S.A. Museum and the Heritage Resources Authority Western Cape (*e.g.* at the Fossil Park).

Application for a Palaeontological Permit from Heritage Western Cape

The supervisor of the palaeontological mitigation project is required to obtain a palaeontological permit from the relevant Provincial Heritage Resources Authority in order to carry out the work. The application for this needs details of the registered owners of the sites, their permission and a site-plan map.

All samples of fossils and sediments must be deposited at a SAHRA-approved institution.

REFERENCES

Coetzee, J.A. 1978. Climatic and biological changes in south-western Africa during the late Cainozoic. *Palaeoecology of Africa* **10**: 13-29.

Coetzee, J.A. and Rogers, J. 1982. Palynological and lithological evidence for the Miocene palaeoenvironment in the Saldanha region (South Africa). *Palaeogeography, Palaeoclimatology, Palaeoecology* **39**: 71-85.

Cole, D.I. and Roberts, D.L. (1996). Lignite from the western coastal plain of South Africa. *Journal of African Earth Science* **23**: 95–117.

Cole, D.I. and Roberts, D.L. (2000). Lignite potential of the western coast, Western Cape Province, South Africa. *Memoir of the Council for Geoscience* **89**: 107 pp.

Dale, D.C. and McMillan, I.K. 1999. *On the beach. A field guide to the Late Cainozoic micropalaeontological history , Saldanha region, South Africa*. Cape Town: De Beers Marine. 127 pp.

Dingle, R.V., Lord, A.R. and Hendey, Q.B. 1979. New sections in the Varswater Formation (Neogene) of Langebaan Road, south-western Cape, South Africa. *Annals of the South African Museum* **78**: 81-92.

Dingle, R.V., Siesser, W.G. and Newton, A.R. 1983. *Mesozoic and Tertiary Geology of Southern Africa*. Rotterdam: A.A. Balkema. 375 pp.

Du Toit, A.L. 1917. Report on the phosphates of Saldanha Bay. *Memoir of the Geological Survey of the Union of South Africa* **10**: 38 pp.

Haughton, S.H. 1932a. The Late Tertiary and Recent deposits of the west coast of South Africa. *Transactions of the Geological Society of South Africa* **34**: 19-58.

Haughton, S.H. 1932b. On the phosphate deposits near Langebaan Road. *Transactions of the Geological Society of South Africa* **35**: 119-124.

Hendey, Q.B. 1978. The age of the fossils from Baard's Quarry, Langebaanweg, South Africa. *Annals of the South African Museum* **75** : 1-24.

Hendey, Q.B. 1981a. Palaeoecology of the Late Tertiary fossil occurrences in "E" Quarry, Langebaanweg, South Africa, and a re-interpretation of their context. *Annals of the South African Museum* **84**: 1-104.

Hendey, Q.B. 1981b. Geological succession at Langebaanweg, Cape Province, and global events of the Late Tertiary. *South African Journal of Science* **77**: 33-38.

Hendey, Q.B. 1983a. Cenozoic geology and palaeogeography of the Fynbos region. In: Deacon, H.J., Hendey, Q.B. and Lambrechts, J.J.N. (eds), *Fynbos palaeoecology: a preliminary synthesis.* South African National Scientific Programmes Report No. **75**: 35-60.

Hendey, Q.B. 1983b. Palaeontology and palaeoecology of the Fynbos region: an introduction. In: Deacon, H.J., Hendey, Q.B. and Lambrechts, J.J.N. (eds.), *Fynbos palaeoecology: a preliminary synthesis.* South African National Scientific Programmes Report No. **75**: 87-99.

Hendey, Q.B. 1983c. Palaeoenvironmental implications of the Late Tertiary vertebrate fauna of the Fynbos region. In: Deacon, H.J., Hendey, Q.B. and Lambrechts, J.J.N. (eds.), *Fynbos palaeoecology: a preliminary synthesis.* South African National Scientific Programmes Report No. **75**: 100-115.

Hendey, Q.B. and Cooke, H.B.S. 1985. *Kolpochoerus paiceae* (Mammmalia, Suidae) from Skurwerug, near Saldanha, South Africa, and its palaeoenvironmental implications. *Annals of the South African Museum* **97**: 9-56.

Hendey, Q.B. and Dingle, R.V. 1990. Onshore sedimentary phosphate deposits in south-western Africa. In: Burnett, W. C. and Riggs, S.R. (eds.), *Phosphate Deposits of the World*, Vol. **2**: 200-206. Cambridge: Cambridge University Press.

Kensley, B.F. 1972. Pliocene marine invertebrates from Langebaanweg, Cape Province. *Annals of the South African Museum* **60**: 173-190.

Kensley, B.F. 1977. A second assemblage of Pliocene invertebrates from Langebaanweg, Cape. *Annals of the South African Museum* **72**: 189-210.

Pether, J, Roberts, D.L. and Ward, J.D. 2000. Deposits of the West Coast (Chapter 3). In: Partridge, T.C. and Maud, R.R. (eds.), The Cenozoic of Southern Africa. *Oxford Monographs on Geology and Geophysics, Oxford University Press, New York*. No. **40**: 33-55.

Roberts, D.L. and Brink, J. (2002). Dating and correlation of Neogene coastal deposits in the Western Cape (South Africa): implications for neotectonism. *S. Afr. J. Geol.*, **105**, 337–352.

Roberts, D.L., Botha, G.A., Maud, R.R. and Pether, J. 2006. Coastal Cenozoic Deposits. In: Johnson, M. R., Anhaeusser, C. R. and Thomas, R. J. (eds.), The Geology of South Africa. Geological Society of South Africa, Johannesburg/Council for Geoscience, Pretoria. 605-628.

Rogers, J. 1980. First report on the Cenozoic sediments between Cape Town and Elands, Bay. *Geological Survey of South Africa Open File Report.* 136 pp.

Rogers, J. 1982. Lithostratigraphy of Cenozoic sediments between Cape Town and Eland's Bay. *Palaeoecology of Africa* **15**: 121-137.

Rogers, J. 1983. Lithostratigraphy of Cenozoic sediments on the coastal plain between Cape Town and Saldanha Bay. *Technical Report of the Joint Geological Survey/University of Cape Town Marine Geoscience Unit* **14**: 87-103.

Siesser, W.G. 1970. Carbonate components and mineralogy of the South African coastal limestones and limestones of the Agulhas Bank. *Transactions of the Geological Society of South Africa* **73**: 49-63.

Siesser, W.G. 1972. Petrology of the Cainozoic coastal limestones of the Cape Province, South Africa. *Transactions of the Geological Society of South Africa* **75**: 177-185.

Senut, B. and Pickford, M. 1995. Fossil eggs and Cenozoic continental biostratigraphy of Namibia. *Palaeontologia Africana* **32**: 33-37.

Tankard, A.J. 1974a. Petrology and origin of the phosphorite and aluminium phosphate rock of the Langebaanweg-Saldanha area, south-western Cape Province. *Annals of the South African Museum* **65**: 217-249.

Tankard, A.J. 1974b. Varswater Formation of the Langebaanweg-Saldanha area, Cape Province. Transactions of the Geological Society of South Africa **77**: 263-283.

Tankard, A.J. 1975a. The late Cenozoic History and Palaeoenvironments of the coastal margin of the south-western Cape Province. Unpublished Ph.D. thesis. Rhodes University, Grahamstown.

Tankard, A.J. 1975b. The marine Neogene Saldanha Formation. Transactions of the Geological Society of South Africa **7**: 257-264.

Visser, H.N. and Schoch, A.E. 1973. The geology and mineral resources of the Saldanha Bay area. *Memoir Geological Society of South Africa* **63**.

Wybergh, W. 1919. The coastal limestones of the Cape Province. *Transactions of the Geological Society of South Africa* **22**: 46-67.

Wybergh, W. 1920. The Limestone Resources of the Union. *Memoir of the Geological Survey of South Africa* **11**: Vol. 2.

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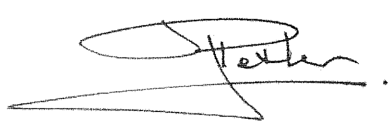

John Pether

18 February 2009

APPENDIX 1 – APPLICANTS CONTACT DETAILS

Company applying for prospecting permit or right

Gecko Fert (Pty) Ltd.

Co Reg #: 2008/01296/07.

P O Box 218, Paarl, 7620.

Physical/ residential address

Van der Spuy en Venote

36 Thom Street, Paarl, 7621.

Applicant's Contact

Mr Ritz de la Bat 021 860 1240

Alternative contact's name

Mr Kobus Swart 083 302 5584

Properties on which mining/ prospecting operations will be conducted

Farm 1043	Blomfontein Trust.
Portion 7 of Langeberg 185	Joachim Paulus Bester.
Portion 12 of Langeberg 185	Blomfontein Trust.

Company compiling the EMP for the application

Site Plan Consulting (Pty) Ltd.

Contact

Craig Donald

0845111520

021 854 4260

Fax: 021 854 4321

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APPENDIX 2: BIBLIOGRAPHY

1932 Haughton, S.H On the phosphate deposits near Langebaan Road. Transactions of the Geological Society of South Africa 35: 119-124.

1943 Frankel, J.J. The constitution of the Langebaan phosphate rock. SAJS 34: 102-108.

1958 Singer, R. & Hooijer, D.A. A Stegolophodon from South Africa. Nature 182: 101-102.

1960 Singer, R & Boné, E.L. Modern giraffes and the fossil giraffids of Africa. Ann. S. Afr. Mus. 45(4): 375-548.

1963 Cooke H.B.S. Pleistocene mammal faunas of Africa, with particular reference to Southern Africa. In: African Ecology and Human Evolution, eds F.C. Howell & F. Bourlière, pp. 65-116. Methuen, London.

1965 Boné, E. & Singer, R. Hipparion from Langebaanweg, Cape Province, and a revision of the genus in Africa. Ann. S. Afr. Mus. 48 : 273-397.

1969 Hendey, Q.B. Quaternary vertebrate fossil sites in the southwestern Cape Province. S. Afr. Archaeol. Bull. 24: 96-105.

1970 Gentry, A.W. The Langebaanweg Bovidae. Ann. S. Afr. Mus. 56 : 114-117.

1970 Hendey, Q.B. A review of the geology and palaeontology of the Plio-Pleistocene deposits of Langebaanweg, Cape Province. Ann. S. Afr. Mus. 56 : 75-117.

1970 Hendey, Q.B. The age of the fossiliferous deposits at Langebaanweg, Cape Province, South Africa. Ann. S. Afr. Mus. 56 : 119-131.

1970 Hendey, Q.B. The age of the fossiliferous deposits at Langebaanweg, Cape Province. Ann. S. Afr. Mus. 56 : 119-131.

1970 Maglio, V.J. & Hendey, Q.B. New evidence relating to the supposed Stegolophodont ancestry of the Elephantidae. S. Afr. Archaeol. Bull. 25: 85-87.

1971 Simpson, G.G. Fossil Penguin from the Late Cenozoic of South Africa. Science 171 (3976): 1144-1145.

1972 Hendey, Q. B. The evolution and dispersal of the Monachinae (Mammalia: Pinnipedia). Ann. S. African Mus. 59:99-113.

1972 Hendey, Q. B. & Repenning, C.A. A Pliocene phocid from South Africa. Ann. S.African Mus. 59: 71-98.

1972 Hendey, Q.B. A Pliocene ursid from South Africa. Ann. S. Afr. Mus. 59: 115-132.

1972 Hendey, Q.B. Further observations on the age of the mammalian fauna from Langebaanweg, Cape Province. Palaeoecology of Africa 6: 172-175.

1972 Hendey, Q.B. Palaeontological investigations in the southwestern Cape Province. Palaeoecology of Africa 6: 171-172.

1972 Hooijer, D.A. A late Pliocene rhinoceros from Langebaanweg, Cape Province. Ann. S. Afr. Mus. 59 : 151-191.

1972 Kensley, B.F. Pliocene marine invertebrates from Langebaanweg, Cape Province. Annals of ther South African Museum 60: 173-190.

1973 Butzer, K. Provisional comments on the sedimentary sequence from "E" Quarry, Langebaanweg, Cape Province. Quaternaria 17: 237-243

1973 Hendey, Q.B. Fossil occurrences at Langebaanweg, Cape Province. Nature, 244 : 13-14.

1973 Visser, H.N. and Schoch, A.E. The geology and mineral resources of the Saldanha Bay area. Memoir Geological Society of South Africa 63.

1973 Wolff, R.G., Singer, R. & Bishop, W.W. Fossil bear (Agriotherium Wagner, 1837) from Langebaanweg, Cape Province, South Africa. Quaternaria, 17 : 209-236.

1974 Gentry, A.W. A new genus and species of Pliocene boselaphine (Bovidae, Mammalia) from South Africa. Ann. S. Afr. Mus. 65: 145-188.

1974 Hendey, Q. B. Faunal dating of the late Cenozoic ofSouthern Africa, with special reference to the Carnivora. Quaternary Research 4:149-161

1974 Hendey, Q.B. The late Cenozoic Carnivora of the southwestern Cape Province. Ann. S. Afr. Mus. 63 : 1-369.

1974 Tankard, A.J. Chemical composition of the phosphorites from the Langebaanweg-Saldanha area, Cape Province. Trans. Geol. Soc. S. Afr. 77 (2): 185-190.

1974 Tankard, A.J. Petrology and origin of the phosphorite and aluminium phosphate rock of the Langebaanweg-Saldanha area, south-western Cape Province. Ann. S. Afr. Mus. 65: 217-249.

1974 Tankard, A.J. Varswater Formation of the Langebaanweg-Saldanha area, Cape Province. Transactions of the Geological Society of South Africa 77: 263-283.

1975 Hendey, Q. B. Relationships of North American hyaenas. South African Journal of Science, 73: 187..

1975 Simpson, G.G. Notes on variation in penguins and on fossil penguins from the Pliocene of Langebaanweg, Cape Province, South Africa. Ann. S. Afr. Mus. 69 : 59-72.

1975 Tankard, A.J. The marine Neogene Saldanha Formation. Transactions of the Geological Society of South Africa 7: 257-264.

1976 Harris, J.M. Pliocene Giraffoidea (Mammalia, Artiodactyla) from the Cape Province. Ann. S. Afr. Mus. 69 : 325-353.

1976 Hendey, Q.B. The Pliocene fossil occurrences in 'E' Quarry, Langebaanweg, South Africa. Ann. S. Afr. Mus. 69 : 215-247.

1976 Hendey, Q.B. Fossil Peccary from the Pliocene of South Africa. Science 192 (4241): 787-789.

1976 Hooijer, D.A. The late Pliocene Equidae of Langebaanweg, Cape Province, South Africa. Zool. Verh. Leiden, 148 : 1-39.

1976 Pocock, T.N. Pliocene mammalian microfauna from Langebaanweg (Cape Province) : a new fossil genus linking the Otomyinae with the Murinae. S. Afr. J. Sci. 72 (2) : 58-60.

1977 Hendey Q.B. & Deacon H.J. Studies in Palaeontology and Archaeology in the Saldanha region. Trans. roy. S. Afr. 42: 371-381.

1977 Hendey, Q. B. Fossil bear from South Africa. SAJS 73: 112-116.

1977 Kensley, B. A second assemblage of Pliocene invertebrate fossils from Langebaanweg, Cape. Ann. S. Afr. Mus. 72 : 189-210.

1978 Coetzee, J.A. Climatic and biological changes in south-western Africa during the late Cainozoic. Palaeoecology of Africa 10: 13-29.

1978 Hendey, Q.B. Late Tertiary Hyaenidae from Langebaanweg, South Africa, and their relevance to the phylogeny of the family. Ann. S. Afr. Mus. 76 : 265-297.

1978 Hendey, Q.B. Late Tertiary Mustelidae (Mammalia, Carnivora) from Langebaanweg, South Africa. Ann. S. Afr. Mus. 76 : 329-357.

1978 Hendey, Q.B. The age of the fossils from Baard's Quarry, Langebaanweg, South Africa. Ann. S. Afr. Mus. 75 : 1-24.

1978 Maglio, V.J. & Cooke, H.B.S. (Eds.). Evolution of African Mammals. Harvard University Press, Cambridge.

1978 Tankard, A.J. & Rogers, J. Late Cenozoic palaeoenvironments on the west coast of southern Africa. J. Biogeogr. 5: 319-337.

1979 Dingle, R.V., Lord, A.R. & Hendey, Q.B.New sections in the Varswater Formation (Neogene) of Langebaan Road, south-western Cape, South Africa. Annals of the South African Museum 78: 81-92.

1979 Simpson, G.G. A new genus of Late Tertiary penguin from Langebaanweg, South Africa. Ann. S. Afr. Mus. 78 : 1-9.

1979 Vrba, E. S. Phylogenetic analysis and classi- fication of fossil and Recent Alcelaphini (family Bovidae, Mammalia). Zool. J. Linn. Soc. 11: 207-228.

1980 Coetzee, J.A. Tertiary environmental changes along the south-western African Coast. Palaeontologica Africana 23: 197-203.

1980 De Muizon, C. & Hendey, Q.B. Late Tertiary seals of the South Atlantic Ocean. Ann. S. Afr. Mus. 82: 91-128.

1980 Gentry, A.W. Fossil Bovidae (Mammalia) from Langebaanweg, South Africa. Ann. S. Afr. Mus. 79 : 213-337.

1980 Hendey, Q.B. Agriotherium (Mammalia, Ursidae) from Langebaanweg, South Africa, and relationships of the genus. Ann. S. Afr. Mus. 81 : 1-109.

1980 Howell, F. C. & Petter, G. The Pachycrocuta and Hyaena lineages (Plio-Pleistocene and extant species of the Hyaenidae). Their relationships with Miocene ictitheres: Palhyaena and Hyaenictitherium. Geobios 13 ; 579-623.

1980 Rich, P.V. Preliminary report on the fossil avian remains from late Tertiary sediments at Langebaanweg (Cape Province), South Africa. S. Afr. J. Sci. 76 : 166-170.

1980 Rogers, J. First report on the Cenozoic sediments between Cape Town and Elands, Bay. Geological Survey of South Africa Open File 136.

1981 Coetzee, J.A. A palynological record of very primitive angiosperms in Tertiary deposits of the south-western Cape Province, South Africa. South African Journal of Science 77: 341-343.

1981 Grine, F. E. & Hendey, Q.B. Earliest primate remains from South Africa. South African Journal of Science 77:374-376.

1981 Hendey, Q. B. Origin of the giant panda. South African Journal of Science, 76:179-180.

1981 Hendey, Q.B. Geological succession at Langebaanweg, Cape Province, and global events of the late Tertiary. S. Afr. J. Sci. 77 : 33-38.

1981 Hendey, Q.B. Palaeoecology of the late Tertiary fossil occurrences in "E" Quarry, Langebaanweg, South Africa, and a reinterpretation of their geological context. Ann. S. Afr. Mus. 84 : 1-104.

1981 Klein, R.G. Ungulate mortality and sedimentary facies in the late Tertiary Varswater Formation, Langebaanweg, south-western Cape Province, South Africa. Ann. S. Afr. Mus. 84 : 233-254.

1981 Oelofsen, B.W. The fossil record of the Class Chondrichthyes in southern Africa. Palaeont. Afr. 24: 11-13.

1981 Siesser, W.G. & Dingle, R.V. Tertiary sea-level movements around southern Africa. Journal of Geology 89: 83-96.

1982 Coetzee, J.A. & Rogers, J. Palynological and lithological evidence for the Miocene palaeoenvironment in the Saldanha region (South Africa). Palaeogeography, Palaeoclimatology, Palaeoecology 39: 71-85.

1982 de Muizon, C Phocid phylogeny and dispersal. Ann. S. Afr. Mus. 89:175-213.

1982 Hendey, Q.B. Langebaanweg : A Record of Past Life. Cape Town, South African Museum.

1982 Klein, R.G. Patterns of ungulate mortality profiles from Langebaanweg (early Pliocene) and Elandsfontein (middle Pleistocene), southwestern Cape Province, South Africa. Ann. S. Afr. Mus. 90 : 49-94.

1982 Rogers, J. Lithostratigraphy of Cenozoic sediments between Cape Town and Eland's Bay. Palaeocology of Africa 15: 121-137.

1982 Van Bruggen, A.C. Phortion occidentalis n. sp. an extinct endodontoid land snail from Late Tertiary deposits at Langebaanweg, Cape Province. S. Afr. J. Sci. 78 : 108-111.

1983 Coetzee, J.A., Scholtz, A. & Deacon, H.J. Palynological studies and vegetation history of the Fynbos. In: Deacon, H.J., Hendey, Q.B. and Lambrechts, J.J.N. (eds.), Fynbos palaeoecology: a preliminary synthesis. South African National Scientific Programmes Report No.75: 156-173.

1983 Dingle, R.V., Siesser, W.G. & Newton, A.R. Mesozoic and Tertiary Geology of Southern Africa. Rotterdam: A.A. Balkema.

1983 Hendey, Q.B. Cenozoic geology and palaeogeography of the Fynbos region. In: Deacon, H.J., Hendey, Q.B. and Lambrechts, J.J.N. (eds), Fynbos palaeoecology: a preliminary synthesis. South African National Scientific Programmes Report No. 75: 35-60.

1983 Hendey, Q.B. Palaeoenvironmental implications of the Late Tertiary vertebrate fauna of the Fynbos region. In: Deacon, H.J., Hendey, Q.B. and Lambrechts, J.J.N. (eds.), Fynbos palaeoecology: a preliminary synthesis. South African National Scientific Programmes Report No. 75: 100-115.

1983 Hendey, Q.B. Palaeontology and palaeoecology of the Fynbos region: an introduction. In: Deacon, H.J., Hendey, Q.B. and Lambrechts, J.J.N. (eds.), Fynbos palaeoecology: a preliminary synthesis. South African National Scientific Programmes Report No. 75: 87-99.

1983 Rogers, J. Lithostratigraphy of Cenozoic sediments on the coastal plain between Cape Town and Saldanha Bay. Technical Report of the Joint Geological Survey/University of Cape Town Marine Geoscience Unit 14: 87-103.

1984 Coetzee, J.A & Muller, J. The phytogeographic significance of some extinct Gondwana pollen types from the Tertiary of the South Western Cape (South Africa). Annals of the Missouri Botanical Garden 71: 1088-1099.

1984 Cooke, H.B.S. Horses, elephants and pigs as clues in the African later Cainozoic. In: Vogel, J.C. (ed.), Late Cainozoic Palaeoclimates of the Southern Hemisphere. Rotterdam, A.A. Balkema: 473-482.

1984 Hendey, Q.B. Southern African late Tertiary vertebrates. In: Klein, R.G. (ed.), Southern African Prehistory and Paleoenvironments: 81-106. Rotterdam, A.A. Balkema.

1984 Olson, S.L. A hamerkop from the early Pliocene of South Africa (Aves: Scopidae). Proc. Biol. Soc. Wash. 97(4): 736-740

1985 Howell, F.C. & Petter, G. Comparative observations on some middle and upper Miocene hyaenids. Geobios 18: 419-476.

1985 Jacobs, L. L. The beginning of the age of murids in Africa. Acta Zoologica Fennica, 170:149-151.

1985 Olson, S.L. Early Pliocene ibises (Aves : Plataleidae) from south-western Cape Province, South Africa. Ann. S. Afr. Mus. 97 : 57-69.

1985 Olson, S.L. Early Pliocene Procelariiformes (Aves) from Langebaanweg, south-western Cape Province, South Africa. Ann. S. Afr. Mus. 95 : 123-145.

1985 Rich, P. & Haarhoff, P. Early Pliocene Coliidae (Aves, Coliiformes) from Langebaanweg, South Africa. Ostrich, 56 (1-3) : 20-41.

1986 Coetzee, J.A. Palynological evidence for major vegetation and climatic change in the Miocene and Pliocene of the south-western Cape. South African Journal of Science 82: 71-72.

1986 Meylan, P. A. & Auffenberg, W. New land tortoises (Testudines: Testudinidae) from the Miocene of Africa. Zool. J. Linn. Soc. 86:279-307.

1987 Denys, C., J. Michaux, & Hendey, Q.B. Les rongeurs Euryotomys et Otomys: Un exemple d'evolution parallele en Afrique tropicale? Comptes Rendus de l'Académie des Sciences, Paris, ser. 3, 305:1389-1395.

1987 McArthur, J.M., Hamilton, P.J., Greensmith, J.T., Boyce, A.J., Fallick, A.E., Birch, G.F., Walsh, J.N., Benmore, R.A. & Coleman, M.L. Phosphorite geochemistry: isotopic evidence for meteoric alteration, of francolite on a local scale. Chemical Geology (Isotope Geoscience Section) 65: 415-425.

1988 Haarhoff, P.J. A new fossil stork (Aves, Ciconiidae) from the Late Tertiary of Langebaanweg, South Africa. Ann. S. Afr. Mus. 97 : 297-313.

1988 Pickford, M. Un étrange Suidé nain du Néogène supérieur de Langebaanweg (Afrique du Sud). Ann. Paléont. 74 : 229-249.

1989 Olson, S.L. & Eller, K.G. A new species of painted snipe (Charadriformes : Rostratulidae) from the early Pliocene at Langebaanweg, Southwestern Cape Province. Ostrich, 60 : 118-121.

1990 Denys, C. Deux nouvelles espèces d'Aethomys (Rodentia, Muridae) à Langebaanweg (Pliocène, Afrique du Sud) : Implications phylogénétiques at paléoécologiques. Ann. Paléont. Paris, 76 : 41-69.

1990 Hendey, Q.B. & Dingle, R.V. Onshore sedimentary phosphate deposits in south-western Africa. In: Burnett, W. C. and Riggs, S.R. (eds.), Phosphate Deposits of the World, Vol. 2: 200-206. Cambridge: Cambridge University Press.

1991 Denys, C. Un nouveau rongeur Mystromys pocockei sp. nov. (Cricetinae) du Pliocène inférieur de Langebaanweg (Région du Cap, Afrique du Sud). C. R. Acad. Sci. Paris, 313 : 1335-1341.

1992 Cooke, H.B.S. & Hendey, Q.B. Nyanzachoerus (Mammalia : Suidae : Tetraconodontinae) from Langebaanweg, South Africa. Durban Mus. Novit. 17 : 1-20.

1994 Denys, C. Affinités systématiques de Stenodontomys (Mammalia, Rodentia) rongeur Muroidea du Pliocène de Langebaanweg (Afrique du Sud). C. R. Acad. Sci. Paris, 318 : 411-416.

1994 Denys, C. Diet and dental morphology of two coexisting Aethomys species (Rodentia) in Mozambique. Implications for diet reconstruction in related extinct species from South Africa Acta Theriologica 39 (4): 357-364.

1994 Denys, C. Nouvelles espèces de Dendromus (Rongeurs, Muroidea) à Langebaanweg (Pliocène, Afrique du Sud). Conséquences stratigraphiques et paléoécologiques. Palaeovertebrata, 23 : 153-176.

1994 Olson, S.L. Early Pliocene grebes, button-quails and kingfishers from South-Western Cape Province, South Africa. (Aves, Podicepididae, Turnicidae, Halcyonidae). Ann. S. Afr. Mus. 104 : 49-61.

1994 Werdelin, L., Turner, A. & Solounias, N. Studies of fossil hyaenids : the genera Hyaenictis Gaudry and Chasmaporthetes Hay, with a reconsideration of the Hyaenidae of Langebaanweg, South Africa. Zool. J. Linn. Soc. 111 : 197-217.

1996 Hunt, R.M. Basicranial anatomy of the giant viverrid from 'E' Quarry, Langebaanweg, South Africa. In : Stewart, K.M. & Seymour, K.L. (eds) Palaeoecology and Palaeoenvironments of Late Cenozoic Mammals, pp. 588-597. Toronto, Toronto University Press.

2000 Pether, J, Roberts, D.L. & Ward, J.D. Deposits of the West Coast (Chapter 3). In: Partridge, T.C. and Maud, R.R. (eds.), The Cenozoic of Southern Africa. Oxford Monographs on Geology and Geophysics, Oxford University Press, New York. No. 40: 33-55.

2001 Franz-Odendaal T.A. Environmental stress five million years ago on the West Coast of South Africa? Science in Africa web-based publication (www.scienceinafrica.co.za/2001/june/fossils.htm).

2002 Franz-Odendaal TA, Lee-Thorp JA, & Chinsamy A. New evidence for the lack of C4 grassland expansions during the Early Pliocene at Langebaanweg, South Africa. Paleobiology 28:3: 378-388.

2003 Behrensmeyer, A.K., Stayton, C.T & Chapman, R.E. Taphonomy and ecology of modern avifaunal remains from Amboseli Park, Kenya." Paleobiology, 29(1):52-70.

2003 Franz-Odendaal TA, Kaiser TM, & Bernor R. Systematics and dietary evaluation of a fossil equid from South Africa. South African Journal of Science 99: 453-459.

2003 Franz-Odendaal TA, Lee-Thorp JA, & Chinsamy A. Insights from stable isotopes on enamel defects and weaning in Pliocene herbivores. Journal of Biosciences 28:6:101-109.

2003 van Dijk, D.E. Pliocene frogs from Langebaanweg, Western Cape Province, South Africa. SAJS Volume 99 (3/4): 123-124.

2004 Franz-Odendaal T. A. & Solounias N. Comparative dietary evaluations of an extinct giraffid (Sivatherium hendeyi) (Mammalia, Giraffidae, Sivatheriinae) from Langebaanweg, South Africa (early Pliocene). Geodiversitas 26 (4) : 675-685.

2005 Morales, J. & Pickford, M. Giant bunodont Lutrinae from the Mio-Pliocene of Kenya and Uganda. Estudios Geol., 61: 233-246.

2005 Pickford, M. Orycteropus (Tubulidentata, Mammalia) from Langebaanweg and Baard's Quarry, Early Pliocene of South Africa. Comptes rendus. Palévol 4 (8): 715-726.

2006 Lehmann, T. Langebaanweg aardvarks: phylogenetic and palaeobiogeographical implications. Afr. Nat. Hist. Vol. 2: 187-188.

2006 Matthews T., Denys C. & Parkington, J.E. An analysis of the mole rats (Mammalia: Rodentia) from Langebaanweg (Mio-Pliocene, South Africa). Geobios 39: 853-864.

2006 Roberts, D.L., Botha, G.A., Maud, R.R. & Pether, J Coastal Cenozoic Deposits. In: Johnson, M. R., Anhaeusser, C. R. and Thomas, R. J. (eds.), The Geology of South Africa. Geological Society of South Africa, Johannesburg/Council for Geoscience, Pretoria. 605-628.

2006 Sanders, W. Comparative description and taxonomy of proboscidean fossils from Langebaanweg, South Africa. African Natural History 2 (November): 196-197

2007 Botha, J. & Gaudin, T. An early Pliocene pangolin (Mammalia; Pholidota) from Langebaanweg, South Africa. Journal of Vertebrate Paleontology 27(2): 484-491.

2007 Lehmann, T. Comments on the taxonomic history of the order Tubulidentata (Mammalia, Eutheria). Ann. Trans. Mus. (42) In press.

2007 Matthews, T., Denys, C. & Parkington, J.E. Community evolution of neogene micromammals from Langebaanweg 'E' Quarry and other west coast fossil sites, south-western Cape, South Africa. Paleogeography, Paleoclimatology, Paleoecology. 245 332-352.

2007 Sanders, W. Taxonomic review of fossil Proboscidea (Mammalia) from Langebaanweg, South Africa. Transactions of the Royal Society of South Africa 62 (1): 1-16

2007 Ungar, P.S., Merceron, G. & Scott, R.S. Dental Microwear Texture Analysis of Varswater Bovids and Early Pliocene Paleoenvironments of Langebaanweg, Western Cape Province, South Africa. Journal of Mammalian Evolution 14 (3): 163-181.

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