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FISCHER, P.-H., DUVAL, M. & RAFFY, A. 1933. Études sur les échanges respiratoires des littorines.—*Archs Zool. exp. gén.* **74**: 627–634.
KOHN, A. J. 1960*a*. Ecological notes on *Conus* (Mollusca: Gastropoda) in the Trincomalee region of Ceylon.—*Ann. Mag. nat. Hist.* (13) **2**: 309–320.
KOHN, A. J. 1960*b*. Spawning behaviour, egg masses and larval development in *Conus* from the Indian Ocean.—*Bull. Bingham oceanogr. Coll.* **17** (4): 1–51.
THIELE, J. 1910. Mollusca: B. Polyplacophora, Gastropoda marina, Bivalvia. *In:* SCHULTZE, L. *Zoologische und anthropologische Ergebnisse einer Forschungsreise im westlichen und zentralen Süd-Afrika* **4**: 269–270. Jena: Fischer.—*Denkschr. med.-naturw. Ges. Jena* **16**: 269–270.

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THE PLIOCENE FOSSIL OCCURRENCES IN 'E' QUARRY, LANGEBAANWEG, SOUTH AFRICA

By

Q. B. HENDEY

Cape Town Kaapstad

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Q. B. HENDEY

South African Museum, Cape Town

(With 6 figures and 4 tables)

[*MS. accepted 27 November 1975*]

ABSTRACT

The Pliocene Varswater Formation in the vicinity of Langebaanweg, Cape Province, is comprised of three main units, now named the Gravel, Quartzose Sand and Pelletal Phosphorite Members. The lowest unit in the succession, the Gravel Member, has yielded a largely marine fauna, including fifteen shark species, incorporated in rocky and sandy beach deposits. The principal source of fossils, the Quartzose Sand Member, was laid down in a variety of depositional environments in and near an estuary. The economically important unit, the Pelletal Phosphorite Member, is fossiliferous in a relatively limited area which was situated in the immediate vicinity of the river mouth. The fossils from the deposits overlying the Gravel Member represent a wide variety of marine, freshwater and terrestrial invertebrates and vertebrates. About seventy-five mammalian species are recorded, including a few belonging to groups not previously recorded from Africa.

CONTENTS

INTRODUCTION

Large-scale production of phosphate from deposits on the farm Langeberg near Langebaanweg, Cape Province, was commenced in 1953 and several years later the presence of fossils in these deposits was reported (Singer 1961). Initially few fossils of good quality were collected, but prospecting revealed the presence of highly fossiliferous deposits south of a small open-cast mine, 'E' Quarry. During 1964 these deposits were exposed in a trench about 240 metres long, 120 metres wide and ranging in depth from 2 to 30 metres (Fig. 1). Soon after the 1964 excavations were commenced it became apparent that the deposits would yield well-preserved fossils in large quantities. Mining of 'E' Quarry (the New Varswater Mine) has been continuous since then and although the number

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of fossils recovered has varied from year to year, the original expectations have been fulfilled. Certainly no other recorded African fossil occurrence of Pliocene age has produced so large an assemblage of specimens representing so wide a variety of species.

During 1968 the South African Museum commenced an investigation of the fossiliferous deposits exposed in 'E' Quarry, this project following on from a similar undertaking directed for a period of ten years by R. Singer of the University of Chicago. The first phase of the Langebaanweg project had also taken into account the mined-out occurrences at 'C' Quarry on the farm Langeberg and Baard's Quarry on the farm Muishondsfontein. The fossils from these sites are limited in both quality and quantity and there are some still unresolved problems relating to their geological associations.

Several publications have resulted from the second phase of the Langebaanweg project, including reviews (Hendey 1970*a*; 1973; 1974*a*), accounts of the geology (Tankard 1974*a*; 1974*b*; 1975), discussions on dating (Hendey 1970*b*; 1972*a*; 1974*b*), as well as descriptions of some of the fossils recovered (e.g. Simpson 1971; Kensley 1972; Gentry 1974).

The geological study of the 'E' Quarry deposits, which has now been largely completed, formed part of a broadly-based investigation of late Cenozoic deposits in the south-western and southern Cape Province, and was undertaken independently of the palaeontological study, although the two have been mutually complementary.

Recently research on the fossils from Langebaanweg has decreased, although there has been an increase in the amount of material collected. The latter development is a direct result of changes in the mining programme. The expected back-filling of 'E' Quarry (Hendey 1973) was commenced during 1974 and collecting was accelerated in those areas to be covered by new mine dumps. In addition, the mining company (Chemfos Limited) removed a large quantity of fossiliferous deposit from one of the threatened areas (East Stream, see Fig. 1) and this is being screened by the first permanent field assistants on site. The nature of the present undertaking is being further influenced by the fact that during 1975 mining of the last of the phosphatic deposits known to be highly fossiliferous was commenced. Until recently these deposits were not scheduled to be mined until about 1990.

Since its inception, the prime object of the present phase of the Langebaanweg project has been the recovery and identification of fossils, with the collecting being as comprehensive as possible. The recent changes in the mining programme have added urgency to this aspect of the undertaking since leisurely collecting and excavation over certain areas of the mine are no longer possible and the areas thus affected will increase with the passage of time. Many of the specimens still in the deposits will be lost if they are not salvaged promptly. In addition, the volume of fossiliferous deposit elsewhere is being steadily reduced by the mining and although some is likely to remain indefinitely, technical difficulties may make it inaccessible to further exploitation. The termination of active field

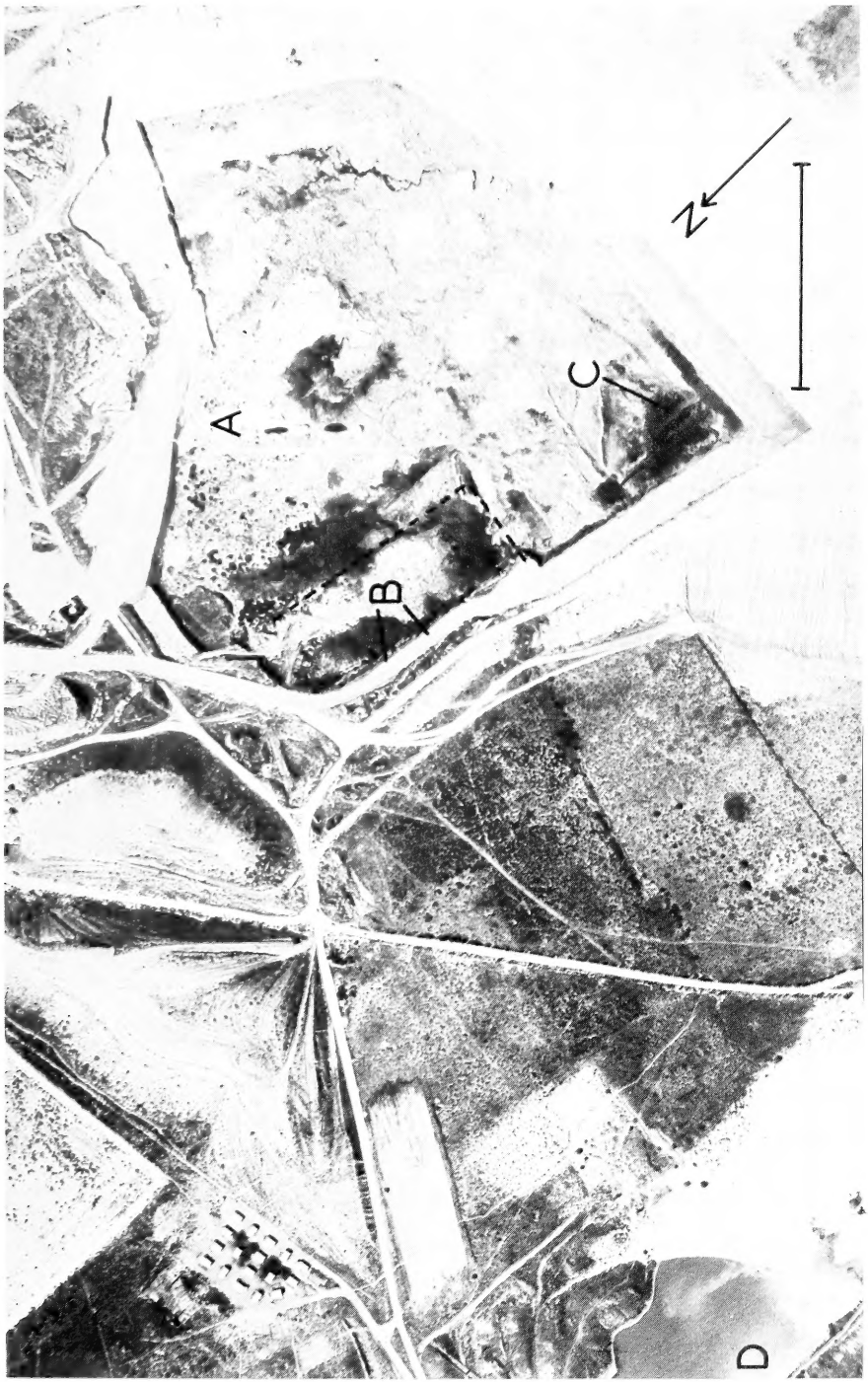

Fig. 1. Aerial view of 'E' Quarry, Langebaanweg (July 1974).
A. East Stream. B. Exposures of bed 3aS. C. Peat bed. Stippled lines around B indicate approximate extent of the 1964 excavation. D. The mined-out 'C' Quarry. Scale line approximately 250 metres.

work at the site in the not too distant future has now become a distinct possibility.

The collecting of fossils could be expedited by being more selective, but as far as possible this approach is avoided, mainly because it would adversely affect that part of the undertaking concerned with the recording of the nature of the fossil occurrences. This aspect of the investigation already suffers because of its lower priority rating. It is hoped that eventually an analysis of specimens from any given area in terms of species and body part representation, together with their condition and associations, will provide information on environments of deposition, the taphonomy of the fossils and aspects of the ecology of the area at the time of deposition. Some information of this nature is already available.

Although more time has recently been spent on the collecting of fossils and directly related technical matters, some progress has been made in the palaeontological research, and the present report updates some of the information and opinions previously recorded.

GEOLOGY

The phosphatic and fossiliferous deposits exposed in 'E' Quarry make up what is now termed the Varswater Formation (Hendey 1974*a*; Tankard 1975). This formation is Pliocene in age and it is underlain by the Miocene Saldanha Formation (Tankard in press). The overlying deposits, informally termed the 'surface bed', are largely, or entirely Pleistocene and Holocene in age. The Varswater Formation is comprised of three main units which were referred to by a variety of names in earlier publications. The member names used in the present report (Table 1) are those which are now considered most appropriate (A. J. Tankard pers. comm.), while those of the beds are purely informal and likely to be modified at a later date. The Gravel and Pelletal Phosphorite Members are both unequivocally described by their names, but the name of the Quartzose Sand Member refers to the dominant lithological element. This member also includes horizons of carbonaceous sand and clay (the 'peat bed', Fig. 1), clayey sands and silt. The non-geographic names of the members are justified in terms of Section 3.10(*d*) of the South African Code of Stratigraphic Terminology and Nomenclature (1971: 118).

Since Tankard (1975) has described the Varswater Formation in detail, the only other comments on the geology of 'E' Quarry which are included here are those which have a bearing on the palaeontology of the deposits.

The Quartzose Sand Member is the most highly fossiliferous of the three units, while the Pelletal Phosphorite Member is poorly fossiliferous, except for an area still exposed of the west wall of the mine ('bed 3a', Fig. 1). There are only limited exposures of the Gravel Member in a few areas of the mine and relatively little attention has been paid to this unit during the current phase of the Langebaanweg project.

TABLE 1

Stratigraphy of the 'E' Quarry exposures of the Varswater Formation

	Hendey (1974)	Tankard (1975)	Present report	
			MEMBERS	BEDS
VARSWATER FORMATION	Bed 3	Pelletal Phosphorite Member	Pelletal Phosphorite Member	beds 3aS & 3aN (fossiliferous) and other unnamed beds
	Bed 2	Fluvial Sand Member	Quartzose Sand Member	tidal mud flat bed, peat bed and other unnamed beds (fossiliferous)
	Bed 1	Beach Gravel Member	Gravel Member	—

Over most of 'E' Quarry the three members of the Varswater Formation are readily identifiable. The Gravel Member is always unmistakable, although the sandy element of this member may on occasion have been regarded as part of the overlying Quartzose Sand Member. Recognition of the Pelletal Phosphorite Member has, for the most part, not been difficult, although its lower limit has not always been clearly defined. The problems encountered in recognizing the lower limit of this member have been due to a variety of factors. Theoretically the mining is cut off at the base of the Pelletal Phosphorite Member, although in practice this is impossible and irregularities on the floor of the mine do not necessarily reflect the nature of the boundary between the Pelletal Phosphorite and Quartzose Sand Members. In most areas the mining has actually extended into the latter unit where the exposed surface may be contaminated and obscured by spillage from the excavator and slumping of deposit from the vertical mine faces. Furthermore, the Quartzose Sand Member was truncated prior to the deposition of the Pelletal Phosphorite and where it is very thin it has been difficult or impossible to recognize. In certain critical areas the deposits of the two members are superficially similar and although detailed sediment analyses would no doubt resolve the issue in problematical instances, no such analyses have been undertaken.

From the preceding comments it should be clear that difficulties have centred largely on the identification of the upper and lower limits of the Quartzose Sand Member. Added to this is the fact that this member is the most complicated unit in the succession in terms of lithology and the variable character of the deposits has itself led to some confusion in the past. The sometimes striking differences

TABLE 2

The stratigraphy of the East Stream and peat areas of 'E' Quarry

		EAST STREAM	PEAT AREA
VARSWATER FORMATION	PELLETAL PHOSPHORITE MEMBER	Phosphatic sand (? non-fossiliferous)	Phosphatic sand (? non-fossiliferous)
	QUARTZOSE SAND MEMBER	Quartzose sand (vertebrates common)	Silt (invertebrates common)
			Peat (vertebrates common)
	GRAVEL MEMBER	Sand & gravel (marine fossils common)	Sand & gravel (marine fossils common)

in the nature of the Quartzose Sand Member are illustrated by examples of the 'E' Quarry succession given in Table 2.

The difficulty experienced in identifying the units of the Varswater Formation has resulted in some of the fossils collected being of doubtful provenance. In this connection it should also be noted that before the basic three-unit succession was recognized in 1969, little or no data on the source of specimens was recorded and the provenance of many specimens collected before that date may never be known. The same often applies in the case of specimens picked up by mine workers. Although the problem of unprovenanced material is not as serious as it might have been, it is an unfortunate complication in the palaeontological investigation.

In the faunal lists given later, records of unknown or uncertain origin are excluded. The source of most of the more significant specimens from 'E' Quarry is well documented and all the species identified to date are represented by at least one specimen of known provenance.

The characteristics of the units comprising the Varswater Formation are accounted for by the sequence of events which occurred during deposition of the formation. These events have a direct bearing on the interpretation and identification of depositional environments (*vide infra*). They were summarized by Tankard (1974*a*: 219) who stated that, 'In the Pliocene a transgressing sea pushed deltaic marsh sediments ahead of it until it reached a temporary stillstand . . . [with the] temporarily stable conditions [allowing] a barrier bar to build up, behind which estuarine conditions prevailed. The estuary was fed by a river from the north-east. The final transgression reworked the older sediments.' It was at the time of the stillstand that the Quartzose Sand Member was accumulated, while the Pelletal Phosphorite Member was laid down during the final transgression (Fig. 2).

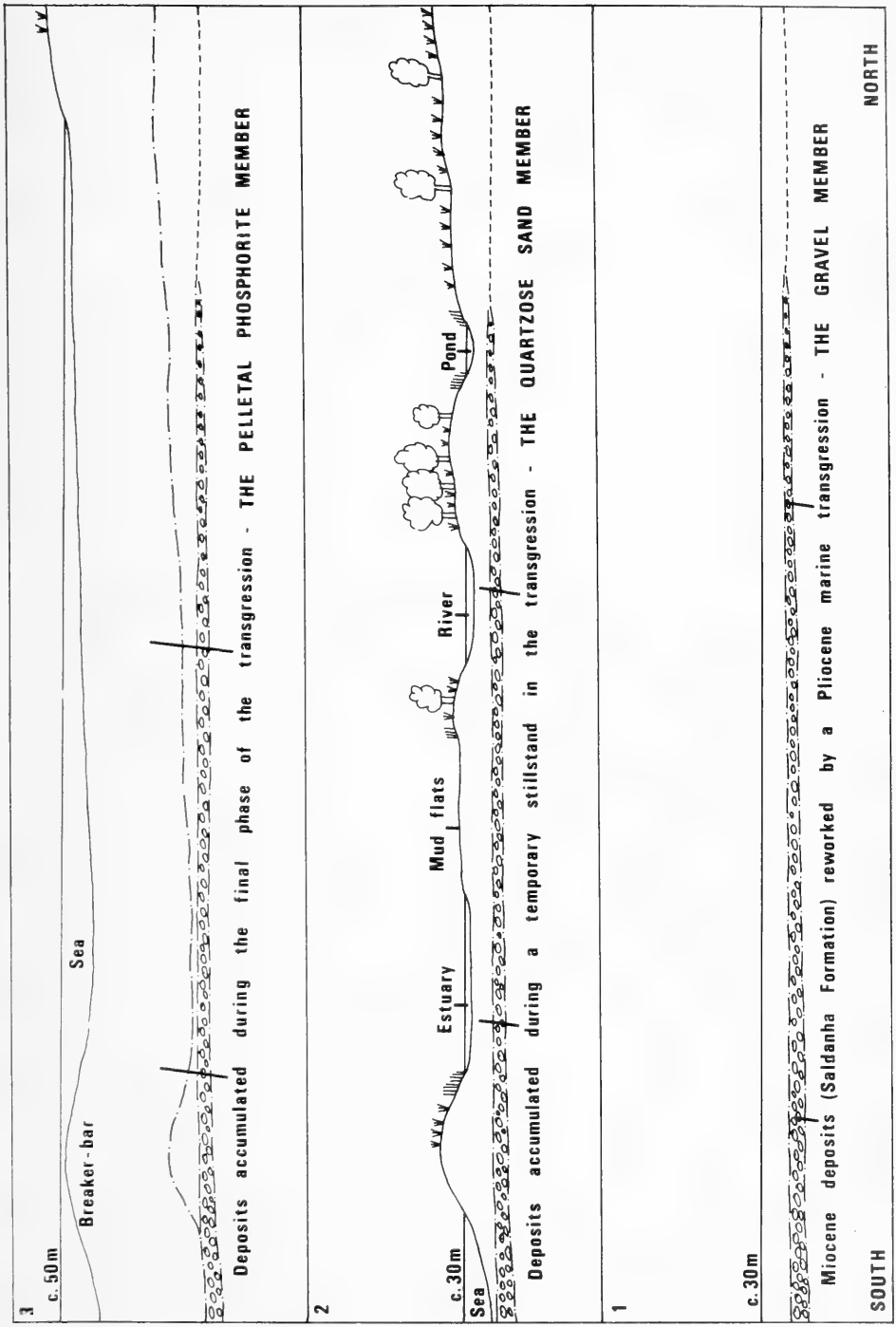

Fig. 2. The depositional history of the Varswater Formation.

Although the geology of the Varswater Formation is now well known, there is still scope for further detailed work. Of particular interest to the palaeontological investigation is geological evidence indicating depositional environments. The relationships between fossils and the deposits in which they occur has hitherto received little attention.

DEPOSITIONAL ENVIRONMENTS

It is now generally accepted that the Varswater Formation accumulated during a marine transgression at a time when a river discharged into the sea in the immediate vicinity of 'E' Quarry. It follows that marine, fluvial and terrestrial environments were then present in the area, together with some of the attendant micro-environments peculiar to each. Theoretically it is therefore possible that deposition of this formation took place in more than one of these environments and also that as the sea transgressed macro- and/or micro-environmental changes might have occurred in any given area now exposed in the mine.

Tankard (1975) has given an account of the depositional environments of the three units comprising the Varswater Formation in 'E' Quarry. They were as follows:

Gravel Member—Rocky and sandy marine beach environments.

Quartzose Sand Member—Essentially estuarine and fluvial environments, although a peat deposit, probably representing a marsh environment, is also mentioned.

Pelletal Phosphorite Member—A shallow-water environment situated between a beach bar and beach.

The means by which the vertebrate fossils in deposits overlying the Gravel Member came to be incorporated in these deposits has been the subject of some dispute in the past (Tankard 1975: 281). There is in fact no single answer to this question and it is clear that just as the depositional environments of the sediments varied, so too did those of the fossils. The characteristics of the deposits change both vertically and horizontally, the most noticeable and frequent changes being in the lower levels of the succession, that is, those levels in which fossils occur most commonly. Although no detailed study of the relationships between sediments and fossils has yet been undertaken, it is obvious that differences in the deposits go together with palaeontological differences.

Some observations on the environments in which the 'E' Quarry fossils were laid down have already been recorded (Hendey 1974*a*), but it is probably worth while at this stage to elaborate on earlier statements.

The Gravel Member

The fauna of the Gravel Member is comprised overwhelmingly of marine species, both invertebrates and vertebrates, and the fossils of this member were undoubtedly accumulated along a marine shoreline. The invertebrates indicate

the presence of both rocky and sandy habitats. Remains of terrestrial vertebrates do occur, but they are invariably fragmented and rolled. This also applies to many of the marine fossils. The condition of the fossils is evidently the result of wave action and it differs from that of fossils from fluvial deposits in the Quartzose Sand and Pelletal Phosphor te Members.

The Quartzose Sand Member

The situation in respect of Quartzose Sand Member depositional environments is complicated. Tankard (1975) has recognized both estuarine and fluvial facies within this member and many of the fossils recovered from the 'E' Quarry exposures must have been deposited in the river and estuary. For example, some of the fossiliferous exposures in the eastern parts of the mine are medium to coarse sands which are a westerly extension of the fluvial deposits referred to by Tankard (1975: 274). On the other hand, the nature of some fossil occurrences suggests that specimens were deposited in areas adjacent to the river and estuary in both subaerial and subaqueous situations (e.g. floodplain and pond).

Evidence suggesting that certain of the Quartzose Sand Member fossils were accumulated on land surfaces has been mentioned elsewhere (Hendey 1974*a*: 349–353). Since this discussion related to carnivore activity rather than environments of deposition, some points concerning the latter were omitted or insufficiently emphasized.

In certain of the Quartzose Sand Member exposures (e.g. the floodplain deposits of East Stream) the condition of the fossils and the nature of their occurrence contrasts with the situation where there is incontrovertible evidence for subaqueous deposition of material (e.g. in the fluvial deposits of the Pelletal Phosphorite Member). The fossils in the latter deposits tend to be abraded and fragmented, while elements of single skeletons are dispersed. Exceptions to these rules were probably specimens which had been protected by soft tissues or which had not been subjected to prolonged transport. The fossils of subaerially accumulated assemblages are generally perfectly preserved and damage to, or dispersal of, specimens can usually be ascribed to carnivore activity or fires.

The fact that there are certain Quartzose Sand Member fossil occurrences where only terrestrial species are recorded, or where they are much more commonly represented than aquatic species, also tends to suggest that there was subaerial accumulation of specimens. The presence of some aquatic species could be explained by periodic inundations of land surfaces. The persistent presence of an aquatic environment would lead to higher proportions of aquatic species being represented and there are occurrences in the Quartzose Sand Member where this is the case. In one such occurrence in the East Stream area a relatively high proportion of fish bones went together with appreciable quantities of abraded bone. These fossils were probably deposited in a channel, a feature for which there was no other obvious evidence.

An example of burnt bone having suggested that a skeleton cannot have been moved after it was partially burnt was given elsewhere (Hendey 1974*a*:

351). The nature of this particular occurrence was the important factor, since burnt bone itself is not necessarily proof that there were fires over areas presently exposed in the mine. Burnt bone might easily have been washed in from elsewhere. There is another recently discovered example of burnt bone which must have been *in situ*. This was a concentration of several hundred bones of small vertebrates, mainly rodents and insectivores, most of which are heavily charred. This occurrence is likely to represent the residue of a burnt owl pellet accumulation, which cannot have been moved after burning without the bones becoming dispersed.

A hitherto unrecorded factor which supports the theory that some subaerial accumulation of fossils occurred concerns the presence of coprolites in the deposits. Coprolites of at least three types have been recovered from the Quartzose Sand Member. The first and largest type were evidently produced by large carnivores, probably hyaenas. The second type are smaller and contain fragmented bones belonging to small vertebrates. They were probably produced by one or more of the smaller carnivores recorded from this member. An account of such coprolites was recently given by Mellett (1974). The last type are small, with no visible bone and tending to be cylindrical when not deformed. Their source is not known but they are extremely abundant in certain areas (e.g. East Stream).

Coprolites have been recovered only in certain parts of the mine and, except for the smallest kind, they are nowhere common. Their condition varies, some being remarkably fresh in appearance, while others are fragmented and distorted. One of the ?hyaena coprolites, which was found together with four others, is flattened, its appearance suggesting that it was trampled when fresh. Some of the smallest coprolites, which are very fine-textured, show clear impressions made by leaves, although they may be otherwise undistorted.

In order for faeces to be preserved intact they must almost certainly have been dropped on a land surface and have been fairly rapidly buried thereafter. Fresh faeces dropped in and then transported by water is unlikely to have survived intact for long. It is also unlikely that groups of specimens would have remained together if they had been transported and there are four instances recorded where groups of 3, 3, 5 and 7 ?hyaena coprolites were found in close association. These groups, together with several isolated specimens, came from a relatively limited area in the eastern part of the mine. Unexcreted faeces could have been carried to its final resting place while still inside a carcass, but none of the coprolites has been found in direct association with other remains of their possible producer. In addition, the shape of the better preserved specimens, and the presence of leaf impressions on some, indicates that they had actually been excreted.

Taken in conjunction the various factors referred to above are here regarded as convincing evidence for subaerial accumulation of at least part of the Quartzose Sand Member fossil assemblage.

The earlier reference to periodic inundations of land surfaces was intended

to indicate seasonal flooding of the river and estuary, but there is also evidence for tidal flooding. A recently exposed deposit in the south-western part of the mine includes an invertebrate fauna which indicates that the depositional environment was a tidal mud flat. The nature of the deposits is in keeping with the fauna which it contains. The limited exposures of this deposit examined prior to their becoming temporarily inaccessible suggested that it overlies the peat bed mentioned earlier (see Table 2).

The faunas of the peat and tidal mud flat beds are strikingly different from one another and both differ from the fauna of more typical exposures of the Quartzose Sand Member elsewhere. The mud flat bed is an exceptional occurrence in this member, being the only one from which large numbers of well-preserved invertebrate fossils have been recovered. Vertebrate remains are rare. By contrast vertebrate fossils occur commonly in the peat bed and in certain other exposures of the Quartzose Sand Member. As fossil-collecting in this member has progressed, it has become apparent that while certain vertebrate species are fairly ubiquitous, others occur only in certain areas, while the overall representation of species and the condition of specimens varies from place to place. While it may not yet be possible to interpret all such evidence meaningfully, a superficial comparison of the peat bed and East Stream faunas should serve to illustrate that different sediments go together with faunal differences.

In this instance the sediment differences are visually striking, the black sands and clays of the peat bed contrasting sharply with the white quartzose sands of the East Stream area. The deposits in the latter area are here regarded as a largely floodplain accumulation, while the peat area is thought to have been a marsh.

The fossils of the peat bed tend to be less complete than those from East Stream, although this may in part, or even largely, be due to the recent disturbance of the peat by mining activities. This disturbance may also account for the fact that whereas at East Stream a number of instances are recorded where partial skeletons of individuals were preserved, nothing on a comparable scale has so far been observed in the peat bed. A notable exception was the discovery of the distal extremities of a sivathere fore- and hindlimb, elements of which were found in articulation standing more or less vertically in the deposit, seemingly all that survived of an animal trapped in the marshy deposits. At East Stream elements of single skeletons were, with few exceptions, found slightly dissociated from one another and they tended to lie more or less horizontally in the deposits. This suggests that they were accumulated on a firm surface.

Although a single species of land tortoise (*Chersina* sp.) is the most commonly represented vertebrate in both areas, there are otherwise some marked differences in the representation of species. There are many species recorded from East Stream which are not known from the peat bed, although the reverse either does not apply or is at least much less obvious. Another example concerns the pig, *Nyanzachoerus*, which is known from the peat bed on

the basis of only a few isolated teeth and bones, whereas at East Stream the remains of at least fifteen individuals, some represented by incomplete skeletons, have been collected. Birds, which are common in both areas, provide another example. In the East Stream assemblage the most common species is a francolin, which is a terrestrial bird, but in the peat bed it is rare, while waterbirds are relatively more common (G. Avery pers. comm.).

Another rather curious difference between the two faunas concerns the representation of the seal, *Prionodelphis capensis*. This species is not common in either of the faunas, but at East Stream it is represented almost exclusively by the remains of very young individuals, whereas only a few isolated teeth and bones of adult seals are known from the peat bed. There are also differences in the coprolite occurrences in the two areas. East Stream is one of the areas in the mine where the smallest type of coprolite occurs in great numbers, while the larger type with visible bone and those of ?hyaenas are rare. The only coprolites known from the peat bed are a few specimens of the type which contains visible bone.

A complete analysis of the two assemblages will no doubt provide further and more precise examples of their similarities and differences, which are presumably more than just fortuitous.

The potential importance of faunal analysis in determining depositional environments is illustrated by the fact that there are obvious differences in faunal assemblages even where deposits are superficially little different or indistinguishable. Such differences have been observed at the same level in apparently homogeneous deposits over distances of only a few metres. An example mentioned earlier was the occurrence in the East Stream area of a 'channel' containing a relatively high proportion of fish remains and abraded bones. A second example concerns a quartzose sand exposure in the vicinity of the peat bed which was found on screening to contain large numbers of frog bones, but very few terrestrial vertebrate fossils. In similar deposits elsewhere the representation of fossils was reversed, with frogs being rare and terrestrial vertebrates common. The presence of a pond, which left no other obvious traces, could account for the amphibian-rich occurrence.

Although the question of depositional environments within the Quartzose Sand Member has received only passing attention during the current phase of the palaeontological investigation, there is evidence for fossils having accumulated in estuarine, fluvial, marsh, mud flat, pond and floodplain environments.

The Pelletal Phosphorite Member

The Pelletal Phosphorite Member covers a wide area and is much the thickest of the units in the Varswater Formation, but it is known to include vertebrate fossils in large numbers only in a relatively limited area, exposures of which still exist along the more northerly part of the west wall of the mine. These fossiliferous deposits are informally termed 'bed 3a' and reasonably large fossil samples have been recovered from two exposures, designated 'bed 3aS' and 'bed 3aN' (Fig. 3).

Fig. 3. The new westerly extension to 'E' Quarry (August 1975), showing exposures of bed 3aN (arrowed right) and bed 3aS (arrowed left, behind trees).

The bed 3aS deposits are exposed along the lower mining face ('bottom cut') of the west wall, while the bed 3aN deposits are approximately 100 metres north-north-west on the upper mining face ('top cut') at elevations of between 2 and 4 metres higher. The bed 3aN deposits are close to the northerly limit of economically recoverable phosphate and are only between 2 and 3 metres thick, of which only the lowest 0,5 to 1 metre is fossiliferous. Some fossils have been recovered from the uppermost levels of the Pelletal Phosphorite in this area, but they are not regarded as part of the bed 3aN sample. The bed 3aS deposits are also between 2 and 3 metres thick in an area sampled by controlled excavations during 1969 and 1970. In this area fossils were concentrated in three distinct levels spread over the lowest 1,5 metres of deposit. Bed 3aS deepens in a southerly direction, where there may be more than three levels of concentration. The thickness of both beds 3aS and 3aN is considerably less than the 25 metre maximum development of the Pelletal Phosphorite Member.

In the bed 3aN area the base of this member is marked by a 0,75 metre thick phosphatic sandstone. The surface of the rock at its most northerly exposure appears to be fairly smooth and more or less horizontal, while the overlying deposits are apparently not fossiliferous. A little further south the rock surface dips markedly to the south-west and it becomes progressively more irregular. Crevices and potholes filled with coarse sand and gravel are common and the rock eventually becomes discontinuous. Fossils occur in abundance where the rock surface is irregular, being concentrated in the irregularities and becoming progressively less common upwards in the overlying finer-grained sediments. The latter have a clay component in the more northerly exposures, but this is absent in the southerly exposures where the deposits which immediately overly the rock are unconsolidated sands. The ill-defined boundary between these two types of deposit runs from north-east to south-west. Indications are that there was a channel of fast-flowing water directed in a south-westerly direction in that area where the rock surface is irregular and where the overlying deposits are unconsolidated sands. The clayey-sands apparently formed the northern bank of the channel.

The nature of the bed 3aS fossiliferous occurrences is essentially similar, except that in this instance there is no rock horizon at the base of the deposits, there are no clayey deposits indicating a channel bank and fossils are concentrated at more than one level in the deposits. The exact stratigraphic relationship between bed 3aS and bed 3aN is not known, but the lower elevation and more southerly situation of the former suggests that it was laid down earlier during the marine transgression than bed 3aN. There may, however, be a direct link between the highest of the bed 3aS levels of fossil concentration and bed 3aN.

Indications are that bed 3a was laid down in, or in the direct path of the river which discharged into the sea most of the sediment making up the Pelletal Phosphorite Member and that the course of the river shifted northwards as the sea transgressed. A structure contour map of the base of the Pelletal Phosphorite Member (Tankard 1975: fig. 3), a modified version of which is reproduced here

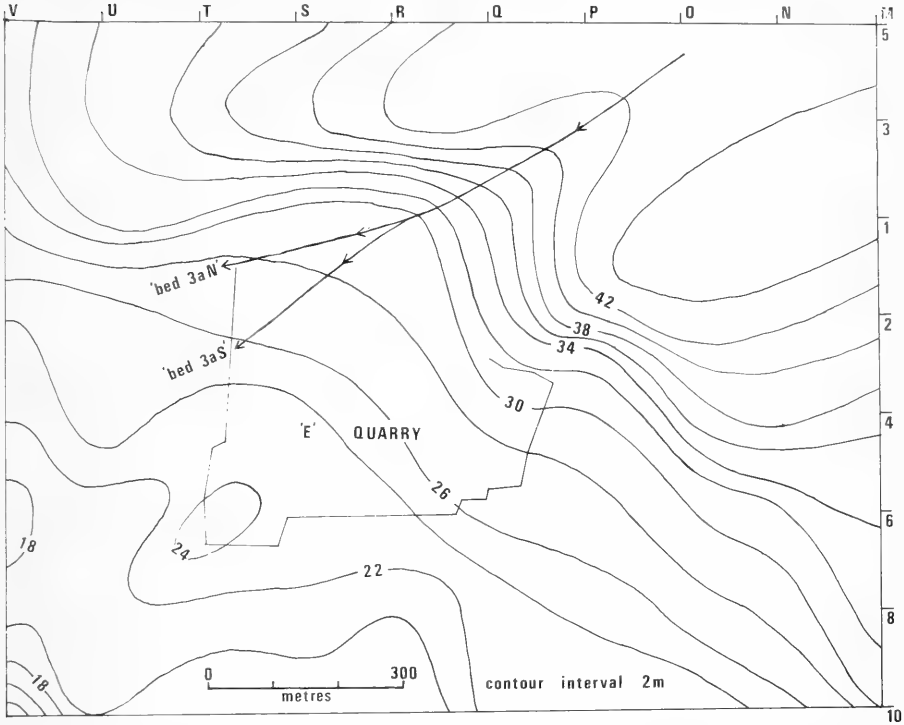

Fig. 4. Structure contour map of the base of the Pelletal Phosphorite Member. Arrowed lines indicate the probable courses of the river at the time that beds 3aS and 3aN were laid down. (Adapted from Tankard 1975: Fig. 3.)

(Fig. 4), supports the suggestion that the lower course of the river was directed towards the area where bed 3a is now exposed.

The nature of the bed 3a fossil occurrences, and particularly those of bed 3aN, provide clear evidence for deposition by fast-flowing water. Specimens trapped by irregularities in the rock surface had protruding parts either completely abraded away or broken up and the fragments scattered in a south-westerly direction. In many instances specimens on the rock surface had their lower parts abraded, apparently by the coarser sediment fraction carried along the rock surface by the flowing water. Individual elements of single skeletons were dispersed and in some instances were traced by following connected series of irregularities in the rock surface.

A feature of the faunas of both beds 3aS and 3aN was the large number of specimens of the seal, *Prionodelphis capensis*, which are represented. Several well-preserved skulls of this species were recovered from bed 3aN, while the several skulls of the similarly-sized hyaena, *Hyaena abronia*, found in the same deposits were not as well preserved or as complete. The more numerously represented and better preserved remains of the aquatic carnivore suggests that deposition

was in a subaqueous environment and that the remains of the terrestrial species had suffered transport over longer distances. As a general rule the terrestrial fossils from bed 3a are more fragmented and less well preserved than similar specimens from some of the Quartzose Sand Member deposits.

While most of the bed 3a fossils probably were deposited subaqueously, the possibility cannot be ruled out that some subaerial accumulation of material also took place (e.g. on the river banks and/or sand bars). A ?hyaena coprolite was recovered from the clayey deposits of bed 3aN, that is, those deposits regarded as having formed the northern bank of the channel at the time that the fossils of bed 3aN were being accumulated. The smallest type of coprolite is not uncommon in bed 3aS, but the majority of these specimens are fragmented, their condition being in marked contrast to the generally very well preserved specimens from the Quartzose Sand Member.

The previously stated opinion that some of the fossils from what is now termed bed 3aS were derived from the Quartzose Sand Member (Hendey 1970*b*: 122), may be relevant to the question of the bed 3aS coprolites. These specimens could well be part of the derived element of the bed 3aS assemblage, having hardened sufficiently while incorporated in the Quartzose Sand Member to survive transport to, and redeposition in the Pelletal Phosphorite Member. On the other hand, they were in most cases not hard enough to survive the transportation intact.

While there is a strong likelihood that the bed 3aS deposits include fossils derived from the Quartzose Sand Member, there is no evidence to suggest that this was the case with bed 3aN. Truncation of the Quartzose Sand Member after the 30 metre stillstand must have been confined to the early stages of the final transgression, that is, the time when the lower levels of bed 3aS were being laid down. The great majority of the bed 3aS coprolites come from the lower levels. The relatively high elevation of bed 3aN virtually precludes the possibility of it containing fossils derived from the Quartzose Sand Member.

Occasional fossils have been recovered from exposures of the Pelletal Phosphorite Member other than beds 3aS and 3aN. Some specimens have been collected in the west wall area from deposits overlying bed 3a, including a few from the uppermost level. These specimens were probably also transported into the area by the river. Their rarity may be due to the river mouth having been some distance away when these deposits were laid down, the fossils representing the remnants of occasional carcasses which had floated out to sea from the river mouth. Specimens have also been collected from several different levels in the most north-easterly exposures of the Pelletal Phosphorite Member. These fossils are probably the remains of animals accumulated near the southern side of the river mouth, while those of bed 3a accumulated in, ahead of and on the northern bank of the river mouth (Fig. 4).

FAUNA

During the past six years large numbers of fossils have been collected from 'E' Quarry, most material having come from surface collecting, excavations at random and screening of deposit, but some also having been recovered in controlled excavations. The deposits sampled extend over an area of about 28 hectares (70 acres), with specimens having come from all the known fossiliferous horizons within the Varswater Formation. There is considerable variation in the size of assemblages from individual occurrences within the deposits, while the total assemblages from each of the three members are also of unequal size. The fauna of the Quartzose Sand Member is the largest and best known, since it has been exposures of this member which have been the principal focus of attention during the current phase of the Langebaanweg project (Fig. 5). Mining of highly fossiliferous Pelletal Phosphorite Member deposits (bed 3a) was recommenced during 1975 so that there has recently been a substantial increase in the amount of material collected from this member. Relatively little time has been devoted to the collecting of fossils from the Gravel Member, exposures of which are limited.

In terms of the requirements for taxonomic studies, many species, mainly amongst the smaller vertebrates, are more than adequately represented in existing collections and in such instances the addition of further material may be of little or no significance. There are, however, many more species which are poorly represented and in these instances there is still a real need to build up sample sizes. Since 1969 the annual additions to the collections have always included several new records for the site, while there has also been further identification of material already in the collections. The 'E' Quarry fauna is, in general, comparatively well known, although most of the specimens have still to be studied in detail.

The following summary accounts of groups represented in the fauna include references to recent new records, recent and current studies, significant additions to previously existing species assemblages, as well as other comments on available material.

Invertebrates

Many of the invertebrate fossils recovered from 'E' Quarry have already been described (Kensley 1972), this material having come from the Gravel Member, while Tankard (1975) has mentioned other invertebrates from the Varswater Formation. Additional material is now available, including the first substantial invertebrate assemblage from the Quartzose Sand Member. This material is from the tidal mud flat deposit mentioned earlier and includes marine, freshwater and terrestrial molluscs. Many of the specimens are remarkably well preserved, some even retaining traces of their original colour. This material is being studied by B. Kensley (South African Museum) and P. Nuttall (British Museum (Natural History)).

Fig. 5. A south-easterly view across 'E' Quarry. The Quartzose Sand Member is exposed over the floor of the mine, while the two lower vertical faces in the background are exposures of the Pelletal Phosphorite Member. The lighter deposit above the roof of the mechanical excavator on the right is the surface bed.

Lower vertebrates

No progress has been made in the identification of bony fish, amphibians and reptiles, but P. A. Hulley (South African Museum) has completed a preliminary investigation of the cartilaginous fish from the Gravel Member (Table 3). Of particular interest was the fact that the Selachii proved more diverse than anticipated, with the assemblage being complicated by the presence of derived specimens (see p. 243).

TABLE 3

A provisional list of the cartilaginous fish from the Gravel Member of the Varswater Formation, including derived material. (Identified by P. A. Hulley of the South African Museum.)

SELACHII
- Hexanchidae
  - *Notidanus serratissimus*
- Carcharhinidae
  - *Carcharhinus melanopterus*
  - *Carcharhinus limbatus*
  - *Galaeorhinus* sp.
  - *Prionace glauca*
  - *Negaprion* sp. or *Hypoprion* sp.
- Odontaspidae
  - *Odontaspis accutissima*
  - *Odontaspis* sp. B
  - *Odontaspis* sp. C
- Otodontidae
  - *Megaselachus megalodon*
- Carcharodontidae
  - *Carcharodon* sp.
- Isuridae
  - *Isurus* sp.
- Squalidae
  - *Squalus* sp.
- Squatinidae
  - *Squatina africana*
  - *Squatina* sp.

BATOIDEI
- Rajidae
  - *Raja* sp.
- Trygonidae
  - Gen. & sp. indet.
- Myliobatidae
  - *Myliobatis* sp.

Birds

Although the 'E' Quarry birds probably constitute the largest late Tertiary avian assemblage from anywhere in Africa, they have received only superficial attention, with only one species, a penguin, having been positively identified (Simpson 1971). The original study of the penguin remains suggested the presence of a second species and this has now been confirmed by more recently discovered material, although the second species remains unidentified (Simpson

1975). G. Avery (South African Museum) has identified to the family or genus level about a dozen other birds, but there are many more which are completely unclassified. The Quartzose Sand Member has been the source of the largest number and the best preserved of the specimens. New material includes incomplete skeletons of two large raptors and another belonging to a stork-like species. The tidal mud flat deposits of the Quartzose Sand Member contain fragments of bird egg-shell, some of which retain their colour.

Mammals

The mammalian fossils from the 'E' Quarry exposures of the Quartzose Sand and Pelletal Phosphorite Members have been the principal focus of the current phase of the Langebaanweg project. The number of species recorded from these deposits has grown steadily over the years and approximately seventy-five have now been positively or tentatively identified (Table 4). Only about one-third have been described and even these include a number which are incompletely classified, largely because of inadequacies in available material. In some instances newly discovered material has made positive identifications distinctly possible.

Mammalian microfauna

The updated list of 'E' Quarry mammals differs most markedly from those previously published by including provisional identifications of many of the small mammals from the Quartzose Sand Member. This part of the list was provided by T. N. Pocock (Vanderbijlpark, Transvaal). Of interest is the first record of a bat from the site. The small mammals of the Pelletal Phosphorite Member, which are generally represented by more fragmentary material, remain unstudied. The rodents are to be studied by Craig C. Black (Carnegie Museum, Pittsburgh).

Primates

Although a cercopithecoid is tentatively recorded, there has been increasing doubt about its presence in view of the continued lack of positively identifiable material. Primates feature prominently in the late Cenozoic fossil record of Africa and their great rarity in, or complete absence from the Varswater Formation is a perplexing aspect of its fauna. A feature of this fauna is its great diversity and the situation which exists in respect of so successful a group as the primates is indeed curious. The situation of Langebaanweg in a coastal environment at the southern continental extremity is likely to be related to the rarity or absence of this group. The Quaternary fossil record of the south-western Cape Province is characterized by a similar dearth of primates.

Carnivores

In contrast with the primates, carnivores are an exceptionally well represented and diverse group. Fully one third of the Varswater Formation mammals identified to date are carnivores.

TABLE 4

A provisional list of the mammals from the Quartzose Sand and Pelletal Phosphorite Members of the Varswater Formation.

	Quartzose Sand Member	Pelletal Phosphorite Member
INSECTIVORA		
Chrysochloridae		
Chrysochloris sp.	×	×
Soricidae		
Myosorex sp.	×	
Suncus sp.	×	
Soricidae gen. & sp(p). indet.		×
Macroscelididae		
Elephantulus sp.	×	×
CHIROPTERA		
Vespertilionidae		
Eptesicus sp.	×	
? PRIMATES		
? Cercopithecidae		
Gen. & sp. indet.	×	
PHOLIDOTA		
Manis sp.	×	
TUBULIDENTATA		
Orycteropus sp.	×	×
CARNIVORA		
Canidae		
Vulpes sp.		×
Ursidae		
Agriotherium africanum		×
? Procyonidae		
Gen. & sp. indet.	×	
Mustelidae		
Mellivora aff. *punjabiensis*		×
Mellivorinae gen. & sp. indet. (aff. *Plesiogulo*)	×	
Enhydriodon africanus		×
Viverridae		
Viverra leakeyi	×	×
Viverrinae gen. & sp. indet.	×	
Genetta sp.	×	
Herpestes sp. A	×	×
Herpestes sp. B	×	×
Herpestinae sp. C	×	
Herpestinae sp. D	×	
Herpestinae sp. E	×	
Hyaenidae		
Percrocuta australis	×	
Hyaenictis preforfex		×
Euryboas sp. nov.	×	
Hyaena abronia	×	×
Hyaenidae sp. B	×	
Hyaenidae sp. E		×

	Quartzose Sand Member	Pelletal Phosphorite Member
CARNIVORA (*cont.*)		
Felidae		
Machairodus sp.	×	
Homotherium sp.	?	×
Felis sp. (small)	×	
Felis aff. *issiodorensis*	×	×
Felis obscura		×
Dinofelis diastemata	×	×
Carnivora (possibly Lutrinae) gen. & sp. indet.	×	
PINNIPEDIA		
Phocidae		
Prionodelphis capensis	×	×
PROBOSCIDEA		
Gomphotheriidae		
Gen. & sp. indet.	×	×
Elephantidae		
Mammuthus subplanifrons	×	?
HYRACOIDEA		
Procavia cf. *antiqua*	×	?
PERISSODACTYLA		
Equidae		
Hipparion sp. A	×	
Hipparion sp. B	×	
Hipparion namaquense		×
Rhinocerotidae		
Ceratotherium praecox	×	?
ARTIODACTYLA		
Tayassuidae		
Gen. & sp. indet.		×
Suidae		
Nyanzachoerus sp(p).	×	×
Hippopotamidae		
Hippopotamus sp.		×
Giraffidae		
Sivatherium sp.	×	×
Giraffa sp.	×	×
Bobidae		
Tragelaphus aff. *angasi*	×	×
Mesembriportax acrae	×	×
Bovini gen. & sp. indet.	×	×
Reduncini sp. A		×
Reduncini sp. B		×
Alcelaphini sp. A		×
Alcelaphini sp. B		×
Raphicerus sp.	×	×
Gazella aff. *vanhoepeni*		×
?Ovibovini gen. & sp. indet.	×	
LAGOMORPHA		
Gen. & sp. indet.	×	×

	Quartzose Sand Member	Pelletal Phosphorite Member
RODENTIA		
Bathyergidae		
Bathyergus sp.	×	×
Cryptomys sp.	×	
Hystricidae		
Gen. & sp. indet.	×	
Muscardinidae		
Graphiurus sp.	×	
Cricetidae/Muridae		
Aethomys sp. A	×	
Aethomys sp. B	×	
Mus sp. A	×	
Mus sp. B	×	
Rhabdomys sp.	×	
Otomyinae gen. & sp. nov.	×	
Mystromys sp. A	×	
Mystromys cf. *darti*	×	
Mystromys cf. *hausleitneri*	×	
Desmodillus sp.	×	
Dendromus sp.	×	
Steatomys sp.	×	
Rodentia gen. & spp. indet.		×
CETACEA		
Gen. & spp. indet.	×	×

By far the best represented species is the seal, *Prionodelphis capensis* (Hendey & Repenning 1972). At the time that it was described, the species assemblage was already unusually large for a fossil phocid and since then many new specimens have been collected. *P. capensis* is evidently the best represented fossil phocid in the world. New material includes several nearly complete skulls (Fig. 6), parts of many more and hundreds of postcranial bones. Most of the material is from the Pelletal Phosphorite Member, the newest and best specimens having come from bed 3aN.

In view of the environments of deposition in the Varswater Formation, other aquatic carnivores are surprisingly rare. Only one specimen belonging to the otter, *Enhydriodon africanus*, is known, although the assemblage does include one unidentified carnivore which might also have been an otter (Hendey 1974*a*).

Until recently Canidae were known only on the basis of a few isolated teeth belonging to a small species and, as with the primate, there had been a growing doubt about identification. This doubt was dispelled by the discovery of a skull and associated postcranial bones belonging to the species. The skull has characters which indicate that the animal concerned was a fox (*Vulpes* sp.). It is known only from the Pelletal Phosphorite Member.

Another of the carnivores from this member, the bear, *Agriotherium africanum* (Hendey 1972*b*), remains one of the rarer elements in the fauna, although some additional postcranial bones were found recently.

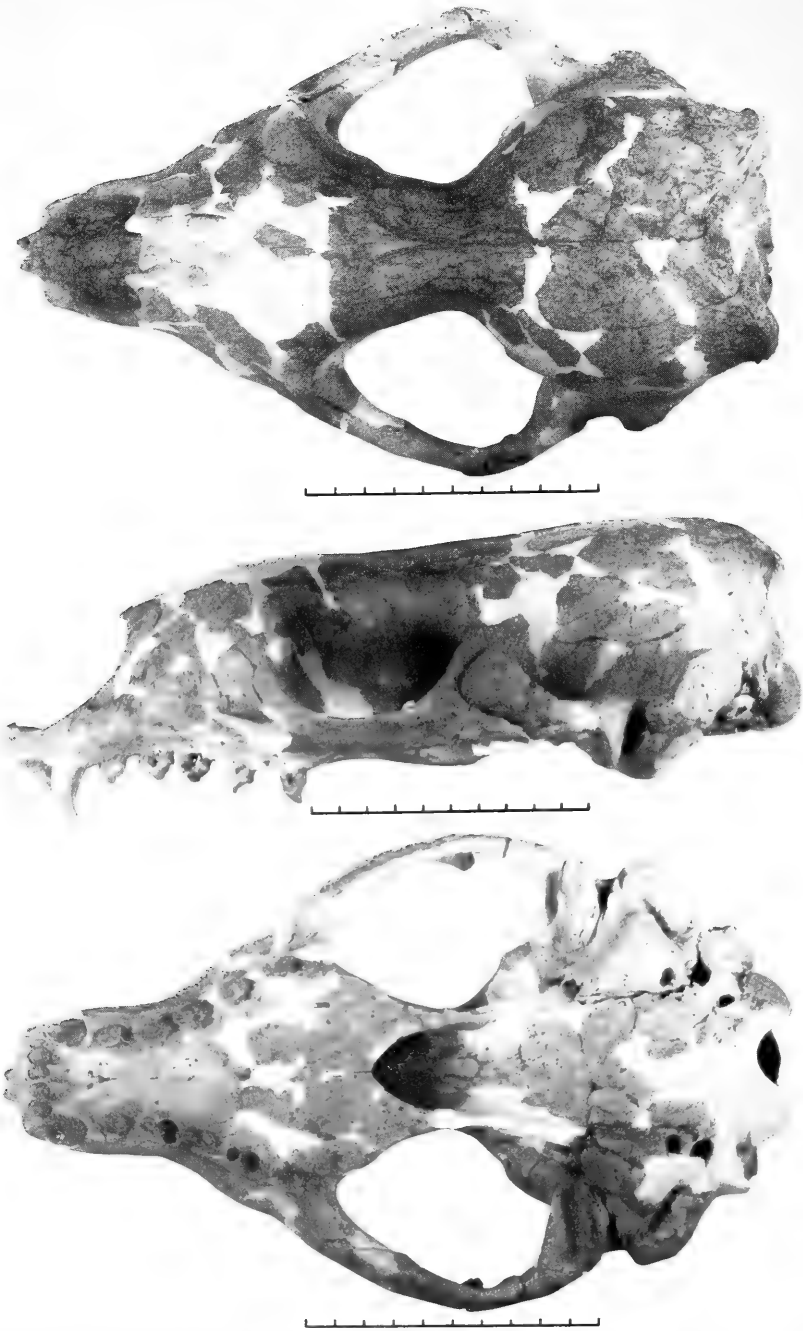

Fig. 6. Dorsal, lateral and ventral views of a skull of the seal, *Prionodelphis capensis* (SAM–PQ–L 31976) from bed 3aN, Pelletal Phosphorite Member, 'E' Quarry. Scale in centimetres.

Agriotherium was an unexpected addition to the 'E' Quarry fauna, being the first African record of the subfamily to which it belongs. Another similarly 'exotic' species was recently tentatively identified, this time a procyonid. The Procyonidae were widely distributed in Eurasia and North America during the late Tertiary, but have not previously been recorded from Africa. The Langebaanweg procyonid, if that is indeed what it is, may prove to be an enduring problem since it is poorly represented, with the only specimens having come from an area now covered by a mine dump. The specimens in question are fragments of the skull of an immature individual and parts of the hindfoot of an adult.

The Mustelidae include another of the new records for the site and this species is as exotic as the *Agriotherium* and ?procyonid in terms of the known distribution of its closest relatives. The new species is a giant form whose size approaches that of *Megalictis*, from the North American Miocene, which is the largest of all known mustelids. It belongs to a group of wolverine-like carnivores which includes *Megalictis* and which has previously been recorded only in Eurasia and North America. The presence in Africa of a member of this group is in a sense even more unexpected than the presence of the bear and ?procyonid since, unlike them, the giant wolverines are not recorded from southern Asia, which is the Eurasian region with the greatest faunal resemblances to Africa.

The giant wolverine and ?procyonid, which are both from the Quartzose Sand Member, join the list of Langebaanian species that belong to groups with an essentially Eurasiatic (and North American) record (Hendey 1974*a*: 61).

Apart from the otter, or otters, and the giant wolverine, the only other mustelid known from 'E' Quarry is a small, poorly represented species of *Mellivora* (Hendey 1974*a*), one additional specimen of which was recently collected from the Pelletal Phosphorite Member.

The Viverridae is the most diverse of the carnivore families known from the Varswater Formation. Previously only one civet (*Viverra leakeyi*) had been recorded, but new material indicates that there is at least one other species as well. The available civet material is problematical largely because it is so fragmentary. A large number of new specimens belonging to smaller viverrids have been discovered. Most of the material belongs to herpestines, but a small genet is also represented. When the herpestines were first studied (Hendey 1974*a*) only two species were recognized (*Herpestes* spp. A and B) and they are now the most commonly represented viverrids in the 'E' Quarry assemblage. The new material includes a few specimens which apparently belong to three additional species (Hendey 1974*b*: 157).

The most common of the larger terrestrial carnivores from the site are hyaenas, which now include one additional record, an apparently new species of *Euryboas*. The more advanced species of this genus were the long-legged and sharp-toothed 'hunting hyaenas' which occurred in Africa and southern Europe early in the Pleistocene (Hendey 1975). Four hyaena species had previously been recorded, namely, *Percrocuta australis*, *Hyaena abronia*, hyaenid species B and

Hyaenictis preforfex, while a fifth, hyaenid species E, was tentatively identified (Hendey 1974*a*). The status of the latter remains unresolved. Additional specimens, readily identifiable with *P. australis*, *H. abronia* and Species B, have been discovered, but *H. preforfex* is still only known from the remains of a single, aged individual. A detailed study of the hyaenid material now available is warranted. *H. abronia*, the best represented of the species, may prove particularly useful in resolving the problem of whether or not the Quartzose Sand and Pelletal Phosphorite Members are substantially different in age (*vide infra*).

The Felidae also include a recent new record, a small wildcat-sized species from the Quartzose Sand Member. Although specimens in addition to those already described have been discovered, only the false sabretooth, *Dinofelis diastemata*, is reasonably well represented.

Proboscideans

The Varswater Formation has yielded relatively few proboscidean specimens and those that have been found are generally fragmentary. The only exception is the incomplete skeleton of an elephant from the East Stream exposures of the Quartzose Sand Member (Maglio & Hendey 1970; Hendey 1974*a*: 349). Remains of an unidentified gomphothere occur more commonly than those of the elephant, *Mammuthus subplanifrons*.

Perissodactyls

Only one rhinoceros, *Ceratotherium praecox*, is known from the Varswater Formation (Hooijer 1972). It is perhaps the most commonly represented of the larger mammals from the Quartzose Sand Member, but only a few fragmentary specimens from the Pelletal Phosphorite Member may belong to this species.

The situation in respect of the Equidae is more complex. The material from the Quartzose Sand Member is here regarded as belonging to two species of *Hipparion*, an opinion rejected by Hooijer (in preparation). A few specimens thought to be from the Pelletal Phosphorite Member were excluded from Table 4 because of uncertainties about their provenance. Otherwise the only significant specimen from this member is an incomplete lower dentition from the uppermost level of the deposits in the bed 3aN area. Hooijer (in preparation) has referred it to *Hipparion namaquense* Haughton, 1932. It is notable in being the only record of this species in the Langebaanweg area. Also no other specimens from the same horizon have yet been positively identified.

The Equidae, perhaps more than any other group represented in the various fossil occurrences near Langebaanweg, are potentially important in resolving the problems of relative age and stratigraphic relationships of the deposits in which they occur. For example, although the Gravel Member in 'E' Quarry has produced few useful terrestrial vertebrate fossils, one interesting exception is an incomplete equid tooth, which, together with two teeth from the same horizon in 'C' Quarry, is tentatively identified with the Miocene species, *Hipparion primigenium*. Hooijer (in preparation) also rejects this identification, but if the

material does indeed represent a Miocene species, it must have been reworked from the underlying Saldanha Formation. This formation would therefore be younger than 12,5 m.y. B.P., since before this date *Hipparion* was not present in Africa, or elsewhere in the Old World (Hooijer 1975).

The Baard's Quarry assemblage includes both *Hipparion* and *Equus*, the latter indicating that at least part of the fauna is younger than that from the Varswater Formation. The *Hipparion* material from Baard's has recently proved to be as controversial as that from 'E' Quarry, but the assemblage is here regarded as being comprised of two species, the more commonly represented being distinct from the 'E' Quarry hipparions. Earlier it had been indicated that only one *Hipparion* was represented in the Langebaanweg occurrences (Hendey 1972*a*; 1974*a*), but this is now discounted. The various issues relating to the Langebaanweg equids should eventually be resolved satisfactorily.

Artiodactyls

Perhaps the most unexpected of the recent new records from 'E' Quarry is that of a peccary. Previously the species concerned had been regarded as a miniature pig (Hendey 1974*a*: 47), but additional material from bed 3aN led to the revised identification being suggested by both A. W. Gentry (British Museum (Natural History)) and H. B. S. Cooke (Dalhousie University) (pers. comm.). This is the first African record of the family Tayassuidae and it is also the most recent Old World occurrence. The nearest peccary record in both a geographic and temporal sense is the Miocene *Pecarichoerus orientalis* from the Siwalik Hills of India (Colbert 1933). The Langebaanweg peccary, which is one of the smallest ever recorded, was the subject of a recent preliminary study (Hendey in press).

Nyanzachoerus is the only pig which occurs in the Varswater Formation and it is known from most of the fossiliferous exposures of the Quartzose Sand Member, having been particularly common in the East Stream area. The species from this member is remarkably well represented, the available assemblage being larger than those of previously described members of this genus. Recently *Nyanzachoerus* was recorded from the Pelletal Phosphorite Member for the first time. The specimen concerned, a fragmented and incomplete skull, differs in some respects from the Quartzose Sand Member specimens and probably represents a second species. Although not yet studied in detail, the Quartzose Sand Member *Nyanzachoerus* has already proved useful in the relative dating of the deposits (Hendey 1973), and the Pelletal Phosphorite Member species promises to be equally useful in this respect (see p. 244).

The apparent absence of hippopotamus from the 'E' Quarry fauna has previously given rise to comment, since the depositional environments of the Varswater Formation were such that this animal might have been expected to occur quite commonly (Hendey 1974*a*: 48). A few fragmentary hippo remains were found for the first time during 1975 in the bed 3aN exposures of the Pelletal Phosphorite Member. The fact that hippos are rare in this member and

that they are still not recorded from the extensively sampled Quartzose Sand Member has yet to be satisfactorily explained.

The 'E' Quarry Giraffidae are fairly well represented by elements of the postcranial skeleton, but cranial material is rare and invariably fragmented and incomplete. Some of the best giraffid specimens, belonging to both *Sivatherium* and *Giraffa*, have come from bed 3aN. The material is being studied by J. M. Harris (Kenya National Museum).

One additional bovid species, a reduncine, was recently recorded from 'E' Quarry. Curiously, Bovidae are not as well represented at this site in terms of numbers of individuals as they are at some of the Pleistocene fossil occurrences in the region. In addition, there are relatively few species recorded from the Quartzose Sand Member, which is otherwise remarkable for the diversity of species represented. On the other hand, certain deposits tend to include individuals of particular species in numbers which are disproportionately high in terms of their bovid assemblages as a whole. For example, the boselaphine, *Mesembriportax acrae* (Gentry 1974), is by far the most commonly occurring bovid in the Quartzose Sand Member, while in bed 3aS it is alcelaphines which are abundant. At least some of the Quartzose Sand Member boselaphine remains are believed to have accumulated sub-aerially, indicating that this species was an inhabitant of the area now exposed in the mine. Gentry (1974) suggested that the boselaphine was an open woodland species and this sort of habitat may well have existed in the immediate vicinity of the old estuary. The situation in respect of the Pelletal Phosphorite alcelaphines was probably quite different. Many, and perhaps all of the specimens were apparently washed to their final resting-places by the river and their carcasses may have originated upstream where the river crossed open plains, the probable preferred habitat of the alcelaphines.

Other mammals

Other terrestrial mammals recorded from the Varswater Formation include a pangolin, an aardvark, a dassie (hyrax) and a porcupine. All are rare. Cetacea are more common, but are represented mainly by undiagnostic postcranial bones. Both whales and dolphins occur, remains of the latter having been found for the first time during 1975.

The porcupine is known only from a fragmented skull of a large and unidentified species which is currently being studied by Judy M. Maguire (Bernard Price Institute for Palaeontological Research). This specimen was found in the Quartzose Sand Member shortly after publication of a comment on the supposed absence of porcupines from the Varswater Formation (Hendey 1974*a*: 42).

The dassie, *Procavia* cf. *antiqua*, was originally identified on the basis of very fragmentary specimens, but more and better material is now available. The most complete specimens are from easterly exposures of the Quartzose Sand Member.

The aardvark is amongst the most poorly represented of the 'E' Quarry mammals and until recently the same applied to the pangolin. The situation in respect of the latter has been slightly improved by the discovery of an incomplete skeleton, including parts of the skull, much of the tail and parts of all four limbs.

FLORA

Prior to the exposure of the peat bed the only botanical remains recovered from the 'E' Quarry exposures of the Varswater Formation were some fossil root fragments from the Quartzose Sand Member. A series of samples from the peat bed submitted to the Institute for Environmental Sciences at the University of the Orange Free State included one which was pollen-rich. Approximately 92 per cent of the sporomorphae belonged to one unidentified taxon (E. M. van Zinderen Bakker pers. comm. to A. J. Tankard). This may represent a locally abundant marsh plant. Interestingly, both tree and grass pollens were identified and this lends support to the earlier suggestion that these vegetation types must have been present in the area at the time that the deposits were laid down (Hendey 1973).

During 1975 two boreholes were sunk from the floor of the mine into deposits underlying the Varswater Formation. They intersected two peat horizons which are evidently part of the Miocene Saldanha Formation. These peats contain both visible and microscopic plant remains.

DATING

A Pliocene age for the Varswater Formation, with an inferred chronometric date of 4–5 m.y. B.P., is still accepted, but there have been new developments concerning the dating of fossils from the Gravel Member and the age difference between the Quartzose Sand and Pelletal Phosphorite Members.

The Gravel Member is composed largely of an abraded and fragmented phosphatic rock which is known to contain bone fragments and which is undoubtedly pre-Pliocene in age. The rock, and other deposits with which it may have been associated, was eroded during the early stages of the Pliocene marine transgression (Fig. 2). The possibility that some fossils might have been reworked from the deposits truncated by the transgression has been recognized, but was not substantiated until a study of the Gravel Member Selachii by P. A. Hulley revealed that some specimens are evidently of pre-Pliocene age. The derived fossils may also include the few isolated *Hipparion* teeth referred to earlier (see p. 240). The derived pre-Pliocene element in the Gravel Member fossil assemblage is likely to make up but a small part of the assemblage as a whole.

Still unresolved is the question of the time taken for the Varswater Formation to accumulate. There were clearly intervals of time between the deposition

of fossils at different levels in the succession, but so far as is known the only one which may have been of sufficient duration to be palaeontologically significant was that between the deposition of the Quartzose Sand and Pelletal Phosphorite Members. The original opinion that the faunas of the two members were broadly contemporaneous (Hendey 1970*b*) was based on the fact that they do have species in common and on the belief that differences between them were due simply to a general dissimilarity in the modes and environments of deposition of the fossils.

On the other hand, the Pelletal Phosphorite Member does postdate the Quartzose Sand Member and it has been recognized that the time factor may have been significant enough to be reflected in the characteristics of individual species represented in the succession and to have influenced the overall composition of the two faunas. Previous studies on species common to the two faunas have provided no conclusive evidence of significant evolutionary changes. For example, the suggestion that the Pelletal Phosphorite *Viverra leakeyi* might be a more advanced variety of the same species from the Quartzose Sand Member (Hendey 1974*a*: 81) has still not been substantiated. In this and other instances comparisons have been complicated mainly by inadequacies in the available material.

The most important indication to date that the two faunas may be separated by a substantial period in time came with the discovery of the first *Nyanzachoerus* specimen from the Pelletal Phosphorite Member. The new specimen is in certain respects more advanced than the Quartzose Sand Member *Nyanzachoerus* and if there was an ancestor/descendant relationship between the two forms, their difference in age may be of the order of several hundred thousand years. Although comparisons with *Nyanzachoerus* species recorded elsewhere are 'complicated by the uniqueness of the 'E' Quarry forms', indications are that the one from the Pelletal Phosphorite is unlikely to be less than 4 m.y. old, while that from the Quartzose Sand dates back probably no more than 5 m.y.

Now that more material from the Pelletal Phosphorite Member is becoming available, the potential for meaningful comparisons between the two main faunas from 'E' Quarry is greatly increased.

Relative dating of the 'E' Quarry fossils and deposits has been based on comparisons of some mammals with their counterparts at various localities in East Africa. The fact that this dating is neither very secure nor very precise is due to the small number of species which have been appropriate for such comparisons. It is increasingly apparent that the Langebaanweg fauna is a good deal more unique than had hitherto been supposed and although individual species do have much in common with their contemporaries further north, they are not always identical. If the fauna does indeed include local endemics, and also perhaps late survivors of lineages which were already extinct elsewhere, the faunal dating of the occurrences will become complicated and less satisfactory.

CONCLUSIONS

The 'E' Quarry fossil occurrences, which are the most important in the Langebaanweg area, are significant for a variety of reasons. There are very few recorded sites in southern Africa which have yielded vertebrate fossils of comparable age and the assemblages from such sites are minuscule by comparison. Consequently the only substantial information on the nature of the subcontinental vertebrate fauna of 4–5 million years ago is derived from the 'E' Quarry record. The nearest important fossil occurrences which are broadly contemporaneous are in East Africa, about 4 500 kilometres away (e.g. Vogel River Series, Lower Kaiso Formation, Mursi Formation of the Omo Group, Kanapoi/Lothagam and Kubi Algi at East Rudolf). However, not even these occurrences have produced assemblages so large and so diverse as that from 'E' Quarry. Elsewhere in Africa the Pliocene fossil record is either poor or non-existent, so Langebaanweg is an especially important source of information on the animal life of this epoch not only in a local sense, but for Africa as a whole. It has the additional merit of being the only important Pliocene occurrence on the continent where both marine and terrestrial faunas are represented.

Certain of the 'E' Quarry species assemblages are already impressively large and, since collecting is continuing, they are still growing. The preservation of specimens is generally very good, all skeletal elements are represented (and collected) and unequivocal associations of cranial and postcranial material are not uncommon. It should therefore ultimately prove possible to provide comprehensive definitions of many species and this may well assist in resolving identification problems in the smaller assemblages from other African sites.

The species diversity is remarkable by any standards and as a result the fauna as a whole will be better known than those of many other sites where important elements may be lacking (e.g. vertebrate microfauna, birds, aquatic species).

The 'E' Quarry fauna, like many others in southern Africa, has so far been dated only in a relative sense and in this respect it is more problematical than many from East Africa. However, the Langebaanweg occurrences are amongst the very few of any importance in southern Africa where generally acceptable geological dating is also possible.

Perhaps the biggest drawback of the site lies with its situation at the southern continental extremity, far from the main focus of African late Cenozoic palaeontological investigation (i.e. East Africa). On the other hand, this may ultimately invest it with a particular interest since, as the contemporary East African fauna becomes better known, similarities and differences of zoogeographic significance may emerge.

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6. SYSTEMATIC papers must conform with the *International code of zoological nomenclature* (particularly Articles 22 and 51).

Names of new taxa, combinations, synonyms, etc., when used for the first time, must be followed by the appropriate Latin (not English) abbreviation, e.g. gen. n., sp. n., comb. n., syn. n., etc.

An author's name when cited must follow the name of the taxon without intervening punctuation and not be abbreviated; if the year is added, a comma must separate author's name and year. The author's name (and date, if cited) must be placed in parentheses if a species or subspecies is transferred from its original genus. The name of a subsequent user of a scientific name must be separated from the scientific name by a colon.

Synonymy arrangement should be according to chronology of names, i.e. all published scientific names by which the species previously has been designated are listed in chronological order, with all references to that name following in chronological order, e.g.:

Family **Nuculanidae**

Nuculana (*Lembulus*) *bicuspidata* (Gould, 1845)

Figs 14–15A

Nucula (*Leda*) *bicuspidata* Gould, 1845: 37.
Leda plicifera A. Adams, 1856: 50.
Laeda bicuspidata Hanley, 1859: 118, pl. 228 (fig. 73). Sowerby, 1871: pl. 2 (figs 8a–b).
Nucula largillierti Philippi, 1861: 87
Leda bicuspidata: Nicklès, 1950: 163, fig. 301; 1955: 110. Barnard, 1964: 234, figs 8–9.

Note punctuation in the above example:
comma separates author's name and year
semicolon separates more than one reference by the same author
full stop separates references by different authors
figures of plates are enclosed in parentheses to distinguish them from text-figures
dash, not comma, separates consecutive numbers

Synonymy arrangement according to chronology of bibliographic references, whereby the year is placed in front of each entry, and the synonym repeated in full for each entry, is not acceptable.

In describing new species, one specimen must be designated as the holotype; other specimens mentioned in the original description are to be designated paratypes; additional material not regarded as paratypes should be listed separately. The complete data (registration number, depository, description of specimen, locality, collector, date) of the holotype and paratypes must be recorded, e.g.:

Holotype
SAM–A13535 in the South African Museum, Cape Town. Adult female from mid-tide region, King's Beach, Port Elizabeth (33.51S, 25.39E), collected by A. Smith, 15 January 1973.

Note standard form of writing South African Museum registration numbers and of date.

7. SPECIAL HOUSE RULES

Capital initial letters

(a) The Figures, Maps and Tables of the paper when referred to in the text
e.g. '. . . the Figure depicting *C. namacolus* . . .'
'. . . in *C. namacolus* (Fig. 10) . . .'

(b) The prefixes of prefixed surnames in all languages, when used in the text, if not preceded by initials or full names
e.g. Du Toit but A. L. du Toit
Von Huene but F. von Huene

(c) Scientific names, but not their vernacular derivatives
e.g. Therocephalia, but therocephalian

Punctuation should be loose, omitting all not strictly necessary
Reference to the author should be expressed in the third person
Roman numerals should be converted to arabic, except when forming part of the title of a book or article, such as
'Revision of the Crustacea. Part VIII. The Amphipoda.'
Specific name must not stand alone, but be preceded by the generic name or its abbreviation to initial capital letter, provided the same generic name is used consecutively.

Q. B. HENDEY

THE PLIOCENE FOSSIL OCCURRENCES IN 'E' QUARRY, LANGEBAANWEG, SOUTH AFRICA