Palaeontological survey and report for borrow pits in the Amathole district centred on Nqamakwe, Butterworth, Idutywa, Centane and Willowvale

Prepared for: Biotechnology and Environmental Specialist Consultancy cc
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Contents:

Background

The Department of Roads and Public works proposes to utilise borrow pits for upgrade/regravelling projects (20 road sections) located throughout the Amathole District Municipality. BESC have been appointed to compile the Environmental Management plans for these borrow pits. All of the borrow pits are existing and have been used extensively in the past.

Rob Gess consulting was subcontracted to carry out a palaeontological survey and make recommendations regarding palaeontological heritage. Survey work was performed between June and August 2011, weather permitting.

Geology and Palaeontology

These borrow pits are spread over a large area. In the south of the area the underlying strata belong to the Adelaide Subgroup (Beaufort Group, Karoo Supergroup). Over most of this area the Geological Survey have not subdivided the Adelaide Subgroup into formations. Detailed mapping and subdivion of the Adelaide Subgroup has only been conducted west of a north – south line essentially extending from Nqamakwe to East London. Borrow pits within this area include 359 BP01 and 386 BP04 –BP10, which are thereby identified as belonging to the Balfour Formation (Adelaide Subgroup, Beaufort Group, Karoo Supergroup). It may be reasonably extrapolated that the majority of borrow pits within the Adelaide Subgroup, east of this line, also belong to portions of the Balfour Formation. It is possible that some borrowpits nearer to the coast, such as the 355, 356, 359 and 371 series may stratigraphically underlie the Balfour Formation and equate to the Middleton Formation (Adelaide Subgroup, Beaufort Group, Karoo Supergroup) or Koonap Formation (Adelaide Subgroup, Beaufort Group, Karoo Supergroup).

Borrow pits in the north of the study area, including 401 BP07, 182 BP02, 386 BP01, 386 BP03 and 386 BP10 are situated within strata belonging to the Katberg Formation (Tarkastad Subgroup, Beaufort Group, Karoo Supergroup).

Dolerite comprises a number of the borrow pits, including 355 BP02, 344 BP01-03, 355 BP02, 372 BP02-BP03, 386 BP08, 401 BP02-BP04, 486 BP01-BP02, 043 BP02, 043 BP05-BP06.

The strata of the **Karoo Supergroup** were deposited within the Karoo sedimentary Basin, which resulted from shortening and thickening of the southern margin of Africa, with coeval folding and uplift of the Cape Supergroup strata along its southern margin. The Karoo Supergroup strata are between 310 and 182 million years old and span the Upper Carboniferous to Middle Jurassic Periods. During this interval the basin evolved from an inland sea flooded by a melting ice cap, to a giant lake (the Ecca Lake) fed by seasonal meandering (and at times braided) rivers. This lake steadily shrank as it filled with sediment and the basin's rate of subsidence stabilised. The land became increasingly arid and was covered with wind blown sand towards the end of its cycle. Finally the subcontinent was inundated with basaltic lava that issued from widespread linear cracks within the crust, to form the capping basalts of the Drakensberg Group.

As the Ecca Lake silted up a subaerial (exposed) shoreline began to develop, initially in the south

east of the basin. The lake steadily shrank towards the centre of the basin, leaving behind flat silty plains across which long rivers meandered from the Cape Mountains towards the much reduced lake. Sands were deposited along the river channels whereas periodic flooding deposited muds on the broad flood planes. These in time came to form the interbedded sandstones and mudstones of the **Koonap Formation**, **Middleton Formation** and **Balfour Formation** (**Adelaide Subgroup**, **Beaufort Group, Karoo Supergroup)**.

The flood planes of the **Beaufort Group (Karoo Supergroup)** provide an internationally important record of life during the early diversification of land vertebrates. Giant amphibians coexisted with diapsid reptiles (the ancestors of dinosaurs, birds and most modern reptiles), anapsids (which probably include the ancestors of tortoises) and synapsids, the dominant group of the time which included the diverse therapsids (including the ancestors of mammals). Rocks of the Beaufort Group provide the worlds most complete record of the important transition from early reptiles to mammals

Therapsid diversity, along with that of most plant and animals was decimated during the end-Permian extinction event, a serious contender for the most severe extinction event to affect life on Earth. Ongoing research on the effects of this extinction event is facilitated by the detailed record, afforded by Beaufort Group strata, of life immediately before and after the event, as well as the gradual recovery of life afterwards.

The Beaufort Group is subdivided into a series of biostratigraphic units on the basis of its faunal content. The lowermost units, the *Eodicynodon* Assemblage Zone and *Tapinocephalus* Assemblage Zone are not represented in this area.

The **Middleton Formation** (**Adelaide Subgroup, Beaufort Group, Karoo Supergroup)** includes the upper *Pristerognathus*, *Tropidostoma* and lower *Cistecephalus* Assemblage zones. These zones are characterised by a changing cast of captorhinind and eosuchian reptiles as well as therapsids of the Dicynodontia, Biarmosuchia, Gorgonopsia and Therocephalia. Small numbers of fish and Amphibia are also known. A diversity of plant fossils of the Glossopteris fauna, as well as a number of trace fossils have also been described.

Though including the upper *Cistephalus* Assemblage Zone and lowermost *Lystrosaurus* Assemblage Zones, the **Balfour Formation** (**Adelaide Subgroup, Beaufort Group, Karoo Supergroup**) largely corresponds to the *Dicynodon* Assemblage Zone. Characterised by the co-occurence of *Dicynodon* and *Theriognathus* this zone demonstrates the Beaufort Groups greatest diversity of vertebrate taxa, including numerous genera and species of dicynodont, biarmosuchian, gorgonopsian and therocephalian and cynodont therapsid Synapsida, together with diverse captorhinid Reptilia and less well represented eosuchian Reptilia, Amphibia and Pisces. *Glossopteris* flora plants and trace fossils are also described.

The beginning of the Triassic Period in South Africa was marked by a change in sedimentation, leading to the distinct sandstone dominated lithology of the **Katberg Formation** (**Tarkastad Subgroup, Beaufort Group, Karoo Supergroup**). Extensive sandy deposits resulted from multi channelled braided river systems that replaced the meandering rivers of the underlying Adelaide Subgroup. This change may have resulted from increased erosion of the landscape due

to widespread extinction of plant groups during the end-Permian mass extinction. A marked faunal change occurs between the *Dicynodon* and *Lystrosaurus* Assemblage Zones approaching the top of the Balfour Formation, corresponding with the major extinction event associated with the Permo-triassic boundary. The Katberg Formation falls entirely within the *Lystrosaurus* Assemblage Zone.

The *Lystrosaurus* Assemblage Zone is dominated by a single genus of dicynodont, *Lystrosaurus*, which together with the captorhinid reptile, *Procolophon*, characterise this zone. Biarmosuchian and gorgonopsian Therapsida do not survive into the *Lystrosaurus* Assemblage Zone, though therocephalian and cynodontian Therapsida exhibit moderate abundance. Captorhinid Reptilia are reduced, however an unprecedented diversity of giant amphibians characterises this interval.

The effects of the end Permian extinction event are also evident in the extensive and important record of fossil plants present in the rocks of the Karoo. Whereas faunas of Permian age are dominated by a wide range of early seed plants, the Glossopteridales (which probably include the ancestors of modern gymnosperms and ultimately angiosperms), this group appears to have gone entirely extinct during the end-Permian extinction. The rocks of the Karoo provide an unrivalled sequential record of these changes and the diversification of other groups of plants in the aftermath of the extinction. The strata of the Karoo basin have also yielded fossil insects and insect leaf damage of a range of ages.

During the formation of the volcanic **Drakensberg Group (Stormsberg Group, Karoo Supergroup)**, during the Jurassic Period, crack like fissures in the earths crust became filled with molten lava that later cooled to form dolerite dykes. Other magma was injected under pressure between horizontal sedimentary strata and cooled to form extensive horizontal sills of dolerite. Dolerite, being an intrusive igneous rock, contains no fossils.

Whereas the Karoo Basin has been well studied in the western Eastern Cape, Western Cape, Northern Cape, Free State and Kwazulu Natal, the former Ciskei and Transkei areas of the eastern Eastern Cape are hardly known palaeontologically. To no small degree this may be attributed to the socio-political history of the area, though the (perhaps valid) perception that this portion of the basin is far more palaeontologically sparse than other parts of the basin has also tended to draw researchers away from it. As a result our understanding of the basin as a whole is now hampered by lack of palaeontological (and geological) information regarding the eastern Eastern Cape, and any material that may be recovered therefrom will be valuable.

Figure 1. (below)

Geological map of the study area, combining Geological Survey data with borrow pit positions.
Q = Quaternary cover,
Jd = Jurassic dolerite,
TRb = Burgersdorp Formation (Tarkastad Subgroup, Beaufort Group, Karoo Supergroup),
TRk = Katberg Formation (Tarkastad Subgroup, Beaufort Group, Karoo Supergroup),
Pba = Balfour Formation (Adelaide Subgroup, Beaufort Group, Karoo Supergroup),
Pa = Adelaide Subgroup (Beaufort Group, Karoo Supergroup),

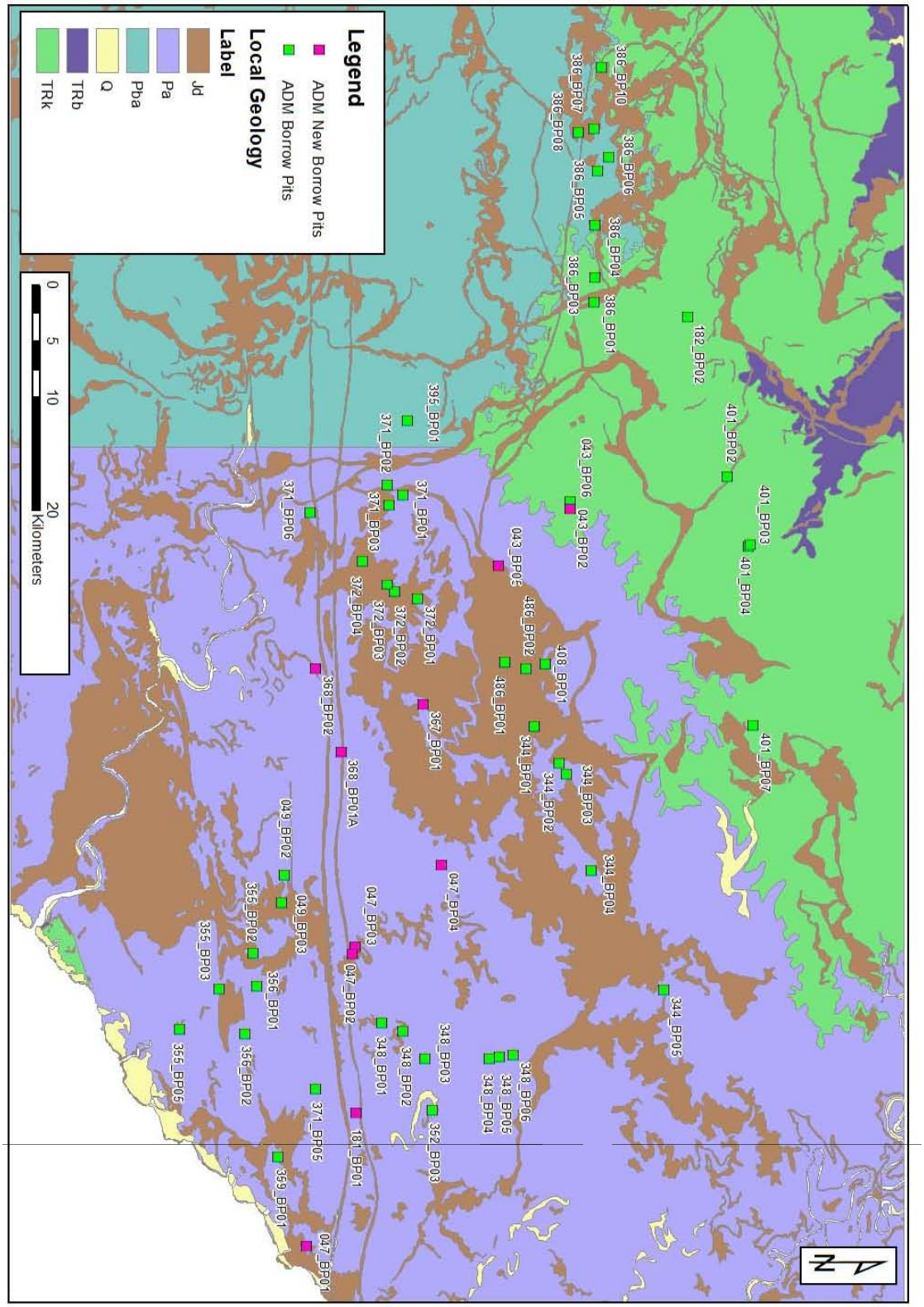
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Figure 1.

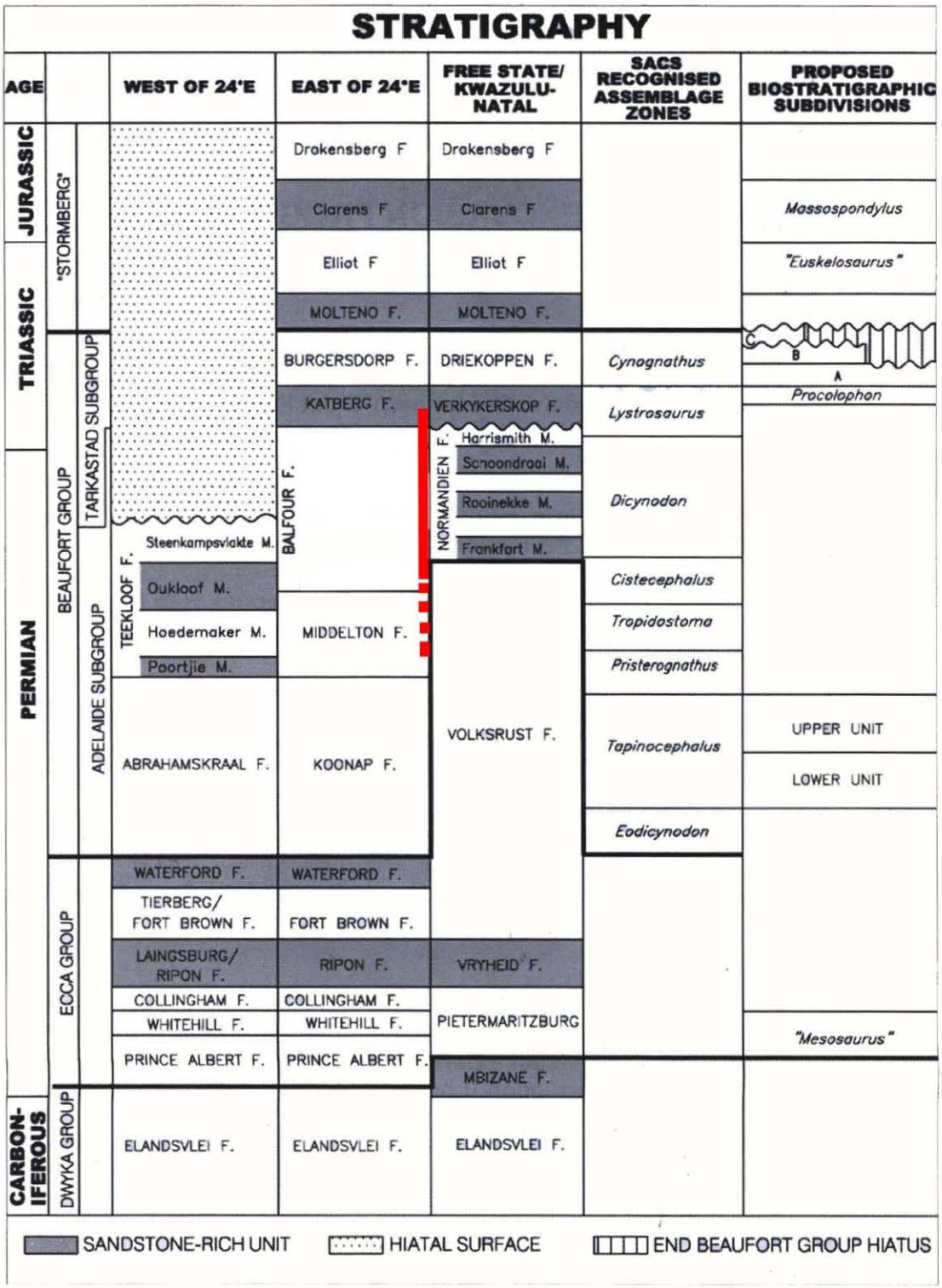

Figure 2. Stratigraphic column and corresponding biostratigraphy of the Karoo Supergroup (modified after Rubidge, B.S. 2005. *South African Journal of Science*. 108: 135-172). Red line indicates probably range of strata affected by the development

Site Visits

Due to an excessively wet winter the survey was conducted piecemeal. Almost all borrow pits were, eventually, exhaustively examined though a few could not be reached due to the dilapidated state of the roads (Fig. 3) or were largely flooded at the time of the survey (fig. 4).

Figure 3. Impassable road east of Komkhulu near Nqamakwe

Figure 4. Borrow pit 344 BP04 largely flooded with rain water.

Borrow pits along the south east of the area, **parallel to the coast**, tended to consist of buff siltstones and sandstones with interbedded greenish shales (Fig. 5). No fossils were observed. Shallow water indicators observed at Mthumeni (in a roadside sloot) included rippled surfaces, invertebrate trace fossils and the pattern left by water flowing gently over an algal mat (Fig. 6).

Figure 5. Sandstones and shales exposed in 356 BP02 in the south of the study area.

Figure 6. Shallow water ripples (left), patterns left by water flowing gently over an algal mat (centre) and invertebrate traces (right), exposed beside the road west of Mthumeni (4 km north of borrow pit 355 BP02).

Inland of the above borrow pits, in the west near **Kentani**, borrow pits tend to exhibit an increasing percentage of finely laminated grey to yellow sandstone (see Fig. 9) Similarly yellowish sandstone occurs as far inland as borrow pit 368 BP01A.

Figure 9. Borrow pit 049 BP03 near Kentani exhibiting finely laminated grey to yellow sandstone.

In the east at a similar distance from the coast a thick band of finely laminated greenish mudstones (weathering to buff) is encountered in borrow pits 348 BP04 and 348 BP05. 348 BP05 contains calcritised casts of small sinuous invertebrate burrows. It is apparent that this mudstone band overlies a cliff forming, regionally very thick and extensive sandstone layer.

Approaching **Willowvale,** the geology changes as it becomes stratigraphically higher. Borrow pits display repeated fining up sequences and purplish mudstone layers occur. A number of borrow pits were found to contain plant fossils including leaves of various forms of Glossopterid plants and stems of sphenophytes (c.f. *Phyllotheca*) and other plants. These include borrow pit 348 BP06 comprising interbedded greenish coarse to fine grained mudstone and fine purplish mudstone, from which samples of *Glossopteris* and c.f. *Phyllotheca* were collected for the Albany Museum (fig 10).

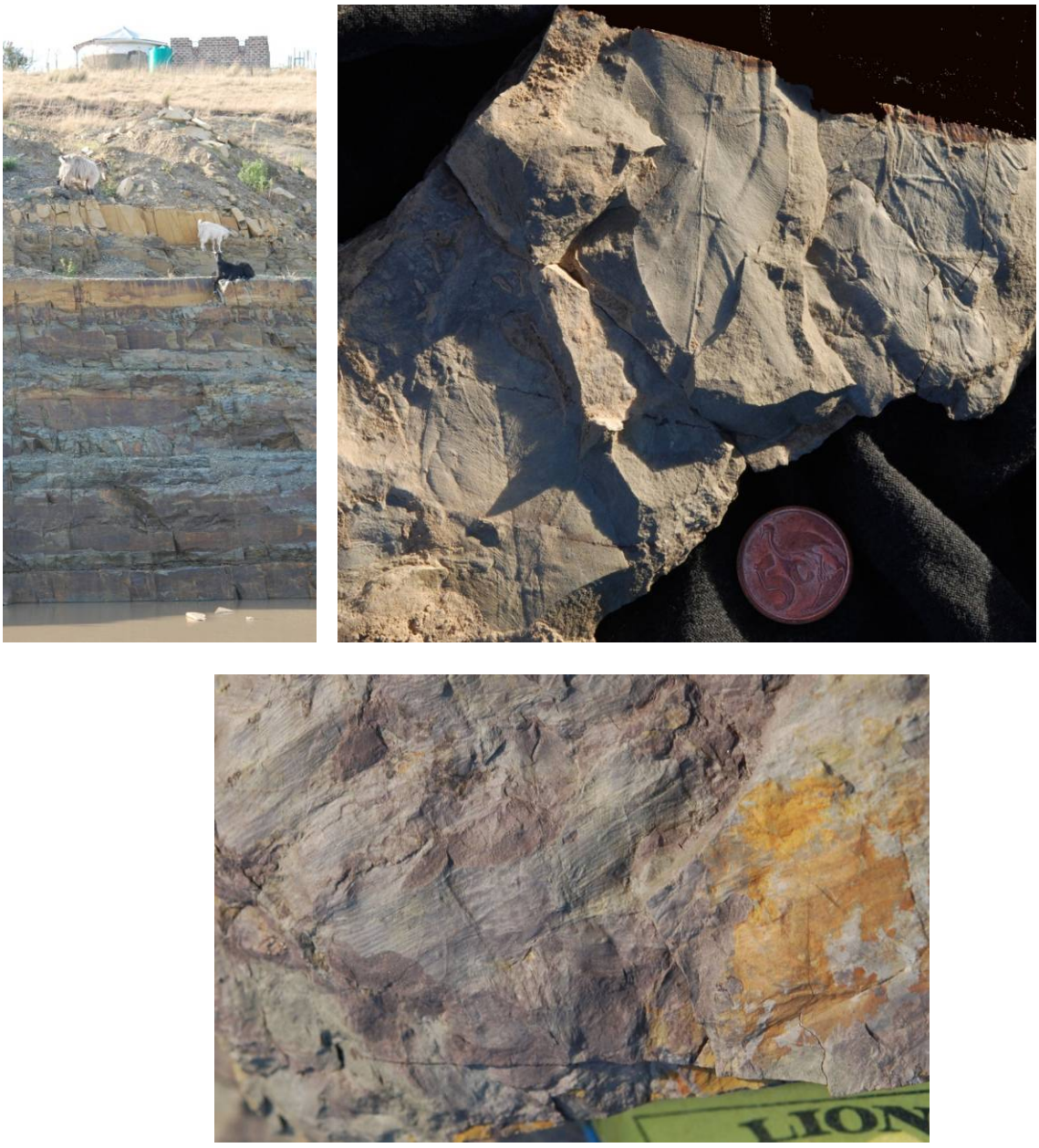

Figure 10. Borrow pit 348 BP06, interbedded coarse and fine grained mudstone (left),

Glossopterid leaves (top right), *Phyllotheca* sphenophyte stems (bottom right).

Another active borrow pit, approximately 500 metres east of 348 BP06 was found to contain plant fossils. This borrow pit comprised two coarsening up sequences of green sediment, each topped with a layer of purple mudstone. These purple mudstones and the greenish ones immediately underlying them were found to contain *Glossopteris* leaves as well as sphenophyte and other plant fragments. Some bioturbation was observed. Thin underlying sandstones recorded mudcracks and small horizontal and vertical invertebrate burrow traces.

Figure 11. Borrow pit 500m east of 348 BP06, fining up sequence (above), Glossopterid leaves (below), leaf at bottom for scale. Leaf at right 15mm

At Borrow pit 344 BP05 to the north west of Willowvale purplish mudstones are absent. Buff to greenish sandstones and mudstones are host to a number of plant fossils (Fig. 12). These include Glossopterid leaves, occuring both as sparsely distributed clasts in mudstones, and as leaf mats preserved under, on or within thin sandstone. In addition small sphenophyte stems are associated with the mudstones. A number of stem types are preserved in the thick hard greenish sandstone that underlies this section. These include “woody-looking” stems, sphenophyte stems and long striated stems with an apparent midrib but lacking the obvious nodes of sphenophyte stems.

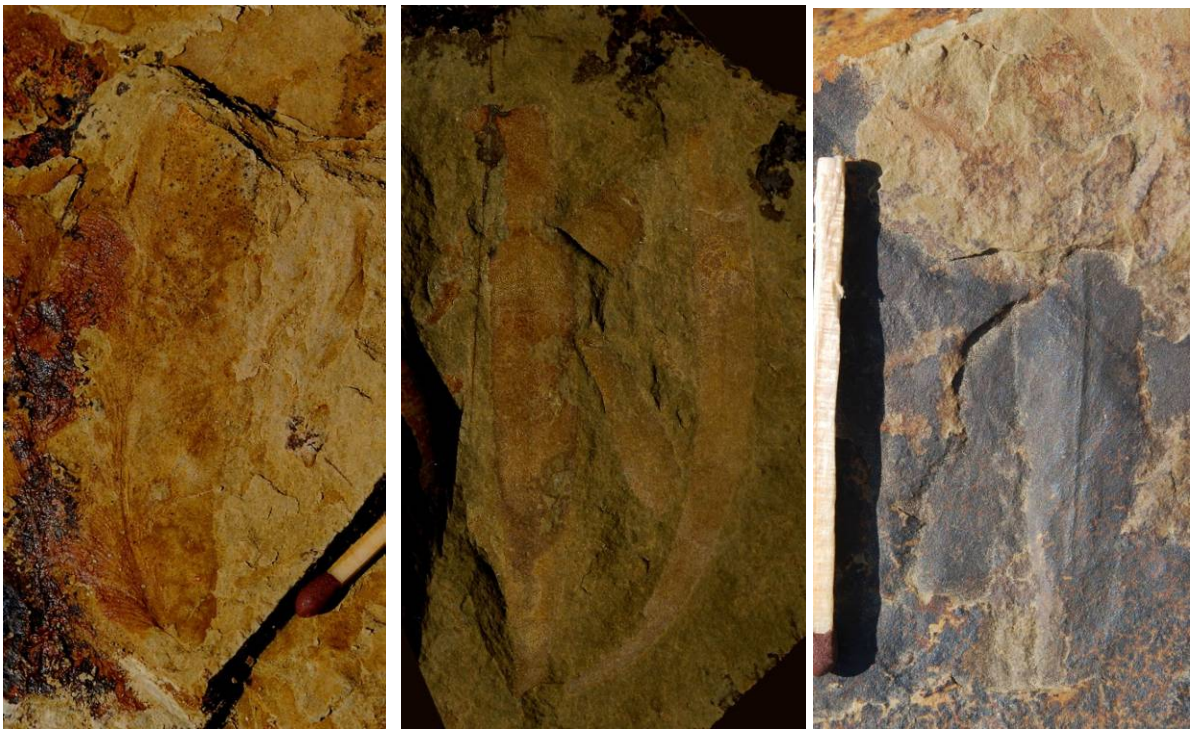

Figure 12. Plant fossils from 344 BP05, top: Glossopterid leaves from thin interbedded sandstones (left), from mudstones (centre) and from sandstone (right); Plant stems from sandstone (below).

South of Butterworth borrow pit 367 BP01 is a largely overgrown borrow pit comprising weathered buff sandstone and mudstone (Fig. 13). The partial remains of a large *Schizoneura*-like sphenophyte whorl were recovered from a prominent sandstone therein (Figure. 13).

Figure 13. Borrow pit 371 BP01, fossil bearing bed (left), c.f. *Schizoneura* partial leaf whorl.

At the west of the study area south of the N2, borrow pit 371 BP01 contains dark green very fine grained mudstones with thin interbedded green to white sandstone interbeds exposed in extensive (currently largely flooded) workings. Sandstone surfaces were observed preserving long c.f. *Phyllotheca* sphenophyte stems (Fig. 14).

Figure 14. c.f. *Phyllotheca* sphenophyte stems in sandstone at borrow pit 371 BP01

North of the N2 borrow pit 395 BP01 exhibits yellowish green siltsone. Further to the north borrow pits 386 BP01 and 386 BP03 (Fig. 15), though expected from the geological map to be situated in the lower part of the Katberg Formation, are comprised of similar greenish siltstones and sandstones, suggesting that they may more correctly be situated within the uppermost Balfour Formation. Mudstones and siltstones form a minor part of 386 BP01 (mainly composed of weathered dolerite) which has baked the sandstone and siltstone. Nonetheless small horizontal invertebrate burrow casts were discovered on the surface of a sandstone bed at 386 BP01 (Fig.16).

Figure 15. Greenish grey mudstones and sandstones at borrow pit 386 BP03

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Figure 16. Invertebrate trace fossils at 386 BP01.

Borrow pit BP05 contains strata baked by proximity to a dolerite dyke. These include greenish buff shale, dark olive green fine grained mudstone and a thin sandstone layer which contains plant drag marks. The olive green mudstone contains plant fragments including those of sphenophyte stems (Fig 17).

Figure 17. Plant fragments at borrow pit BP05

Borrow pit BP06 is a large borrow pit with generally coarse greeny grey mudstone, occasionally with a slightly maroonish tinge. These mudstones also contain plant fragments. A coarse sandy layer towards the bottom of the exposed sequence additionally contains the fossilised remains of horizontal plant roots.

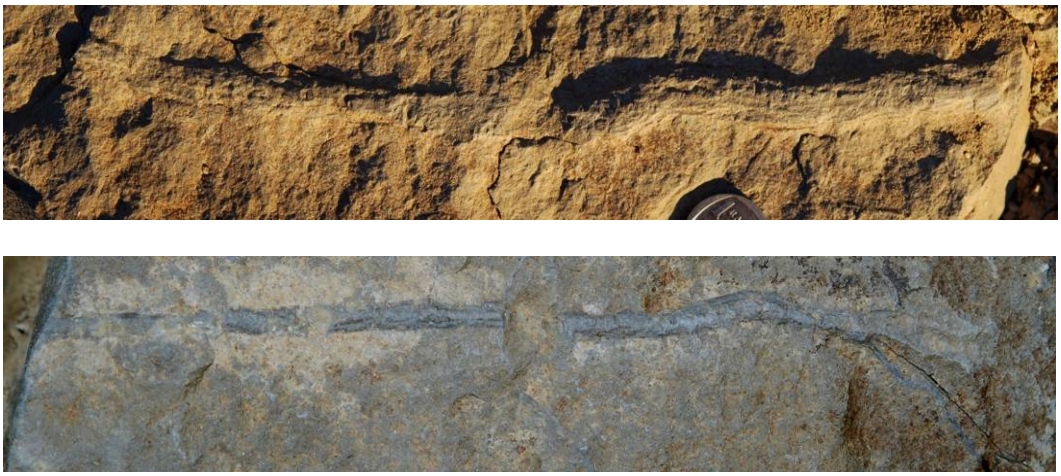

Figure 16. Fossil root containing sandstone bed at 386 BP06, fossil roots below.

Only two borrow pits within this study area expose maroon mudstones and shales attributable to the **Katberg Formation** (Tarkastad Subgroup, Karoo Supergroup).

One of these, borrow pit 401 BP07, consists of an extensive series of workings that have followed the edge of a sandstone layer capping a low hill, in order to extract the maroon shale that stratigraphically underlies it. Apart from a few small vertical invertebrate burrows, these workings were not found to be fossiliferous.

By contrast the shale horizon being utilised at **borrow pit 182 BP02 at Masinanyane Mission** was found to be exceptionally rich in vertebrate burrows. The horizon underlying that which is being exploited exhibits large scale mudcacks, bioturbation and small vertical invertebrate burrows. This is overlain by the thick layer of mudstone which is the source of the road aggregate and which contains the majority of observed vertebrate burrows. Capping this is a layer of coarse sandstone, overlain by more impure sandstones and siltstones. Although the current locus of excavations does not reveal vertebrate burrows, one is situated in older workings immediately adjacent to them (Fig. 17), and an extremely important site is situated not far along the shale horizon, in an area that might appear to be a logical extension of the borrow pit workings.

Figure 17. Natural cast of small vertebrate burrow in pit face at borrow pit 182 BP02 (left), detail of burrow cast (right). Note the light diagonal stripes representing casts of scratch marks.

Burrows are preserved as sandstone infills that were excavated largely into muddy strata. All have a repeated pattern of fine ridges on the outside of the burrow casts, bearing witness to the pattern of scratches left on the inner surface of the burrows by the claws of the (presumed therapsid) excavator. They vary greatly in size, suggesting the presence of organisms of at least 3 taxa. These three organisms produced burrows roughly equivalent in size to those of mongooses (Fig. 18), rabbits (Fig. 19-20) and aardvarks (Fig. 21).

The smallest burrows are approximately 4 to 8 cm wide, slightly curved with a shovel shaped termination. In cross section they are kidney shaped with an arched roof and a slight hump up the centre of the floor (Fig. 18). These are similar to cynodont burrows found near Golden Gate in the slightly younger Burgersdorp Formation, which were found to contain the remains of their likely makers, including adults with young. Similarly sized burrows have been reported by Krummeck and Bordy from the Katberg and Burgersdorp Formations south of Encobo (Proceedings of the 16th Conference of the Palaeontological Society of Southern Africa).

Figure 18. Probable cynodont burrows at 182BP02, in situ (top), dorsal view of reconstructed weathered out specimen (middle), ventral view of same specimen (bottom).

Larger burrows, approximately 10 to 15 cm in diameter occur at the same locality. Most examples consist of a straight obliquely descending gallery (Fig. 19). This may however simply be the entrance tunnel to a more complex burrow system as is suggested by one finely preserved specimen in which a similar gallery descends through siltstones, and a prominent sandstone before bifurcating (Fig. 20). Although one branch of the system has been lost due to weathering the other is still preserved within the underlying mudstone (Fig 20 top).

Figure 19. Medium sized therapsid burrows. Not casts of scratch marks in bottom specimen.

Figure 20. Bifurcating medium sized therapsid burrow (above), note scratch marks at bottom right ; field assistant indicating extent of semi buried entrance gallery to bifurcating burrow.

The largest burrow type is represented by a single specimen, 60 cm wide. It is so unexpectedly large that it was initially mistaken for a sandstone channel fill. Clear scratch marks at its less weathered end, however, confirm that this is a therapsid-type burrow.

Figure 21. Large (60 cm diameter) therapsid burrow: **top lef**t, large burrow from side in foreground (note also burrow also shown in fig 20 cutting sandstone in background right of picture), **top right**, large burrow from above, **bottom**, detail of large burrow from the side showing unweathered surface of cast at right with claw marks of the digger.

Conclusions and Recommendations

This survey was conducted in an area with a palaeontological heritage which has not been well studied for historical reasons. It is clear from this brief survey that much of palaeontological interest is to be found in the Karoo Supergroup sedimentary strata affected by this development, and interesting fossils of varying degrees of importance have been found in a number of proposed borrow pits. The fact that many of the borrow pits were either flooded or overgrown at the time of this survey makes it likely that much fossil heritage went undetected and will potentially come to light when fresh excavation of these borrow pits occurs. With sensitive management this can only be a benefit to the science of palaeontology.

The discovery of presumed therapsid burrows belonging to a number of different taxa at borrow pit 182 BP02 (Masinanyane Mission) is probably the most significant discovery made during this survey. In other parts of the Karoo Basin therapsid burrow casts have sometimes been found to contain skeletons of the species that excavated them. These, almost uniquely, may provide clues as to the lifestyles of their inhabitants. A burrow has for example been found containing an adult and young. Recent acquisition of an advanced scanning device by BPI (Wits University) will now make it possible to non-destructively explore the contents of excavated burrow casts. It is therefore important that burrows are rescued from Masinanyane before further excavations for aggregate occur.

Important new plant fossil localities, particularly in the vicinity of Willowvale were also located. These may also contribute to a more complete understanding of the Karoo basin.

Monitoring of aggregate removal from these borrow pits would clearly be impractical considering their wide dispersal and the probable time frames involved.

It is however **recommended** that:

1. Currently exposed therapsid burrow casts at borrow pit 182 BP02 at Masinanyane Mission are excavated and removed by a palaeontologist before further removal of aggregate occurs.

2. A palaeontologist is required to visit borrow pit 182 BP02, borrow pits 344 BP05, 348 BP06 and 348 BP04 near Willowvale, as well as 371 BP01 in the south west shortly after removal of aggregate is resumed. This will allow sampling of fresh material and will allow the palaeontologist to communicate with the site foreman who may be asked to put any suitable material he may notice on one side. In the case of 182 BP02 this would be burrow casts and possible fossil bone. In the case of the remainder of sites here mentioned this would consist of slabs containing plant fossils.

3. All borrow pits in the study area containing sedimentary rocks should be resurveyed by a palaeontologist at the end of excavations and prior to any form of rehabilitation. This will allow survey and sampling of freshly exposed palaeontological material and possible recommendations regarding strata to be left unrehabilitated for future access by professionals.