Palaeontological Heritage Impact assessment for Brakkefontein Farm and quarries, east of Makhanda/Grahamstown.

Prepared for: Makana Brick

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Background

Makana Brick is applying to renew and expand its mining rights on a portion of the farm Brakkefontein 243 as part of a Section 102 Amendment Application. Brakkefontein is situated immediately to the north of Makhanda (Grahamstown) East. A particular shale exposure is earmarked for imminent exploitation, however a PIA for the entire farm was commissioned for the entire farm. Rob Gess Consulting was contracted to conduct the PIA.

Geological Overview

Brakkefontein Farm largely overlies strata of the (Late Devonian to mid Carbniferous) upper Witteberg Group, the upper portion of the Cape Supergroup. These strata range in age from about 370 to approximately 330 million years old. In the extreme west it also overlies the glaciogenic Dwyka Formation, lowermost portion of the unconformably overlying Karoo Supergroup. Both of these are, in part, capped by relict patches of Silcrete - formed as a hard crust at surface during deep leaching of underlying strata during the Cretaceous period. This leaching reciprocally reduced much of the underlying mudstone to kaolinite.

Cape Supergroup rocks represent sediments deposited in the Agulhas Sea, which had opened to the south of the current southern African landmass, in response to early rifting between Africa and South America during the Ordovician period. The Witteberg Group is the uppermost of three subdivisions of the Cape supergroup and was laid down during the Late Devonian and early Carboniferous periods.

Field survey of the area revealed slight inaccuracies in the Geological Survey Map of the area, importantly for example, the small shale quarry intended for most immediate expansion was found to be located within the Kweekvlei Formation as opposed to the more sensitive Witpoort Formation, as shown on the survey map. An adjusted map is attached based on field observation of the contact between the Witpoort and Kweekvlei Formations (Figure 1).

In the north Brakkefontein Farm backs onto the Botha's Hill – Governor's Kop Ridge which represents a giant exhumed north-east to south-west trending anticlinal (upwardly bent) fold of resilient Witpoort Formation quartzite. The eastern extent of Brakkefontein is largely defined by two parallel smaller Witpoort formation folds belonging to the same folding system (Fig. 1, blue). These folds are overturned towards the east. The valleys between these ridges, one containing the Botha's Spruit, and the other the small current shale quarry which is to be expanded, contain mudstones of the overlying Kweekvlei Formation. These are largely mantled by alluvium, including former river terrace deposits.

Further south most of the sedimentary strata have been leached to a white kaolin clay and less altered shale and mudstone is only encountered where excavations have reached some depth, as in the main Brakkefontein quarry. Remains of the silcrete duricrust forms the high ground in the

south of Brakkefontein, though unmapped patches of silcrete also occur on the southern margin of the quarry and, for example at point 13 (Fig.1).

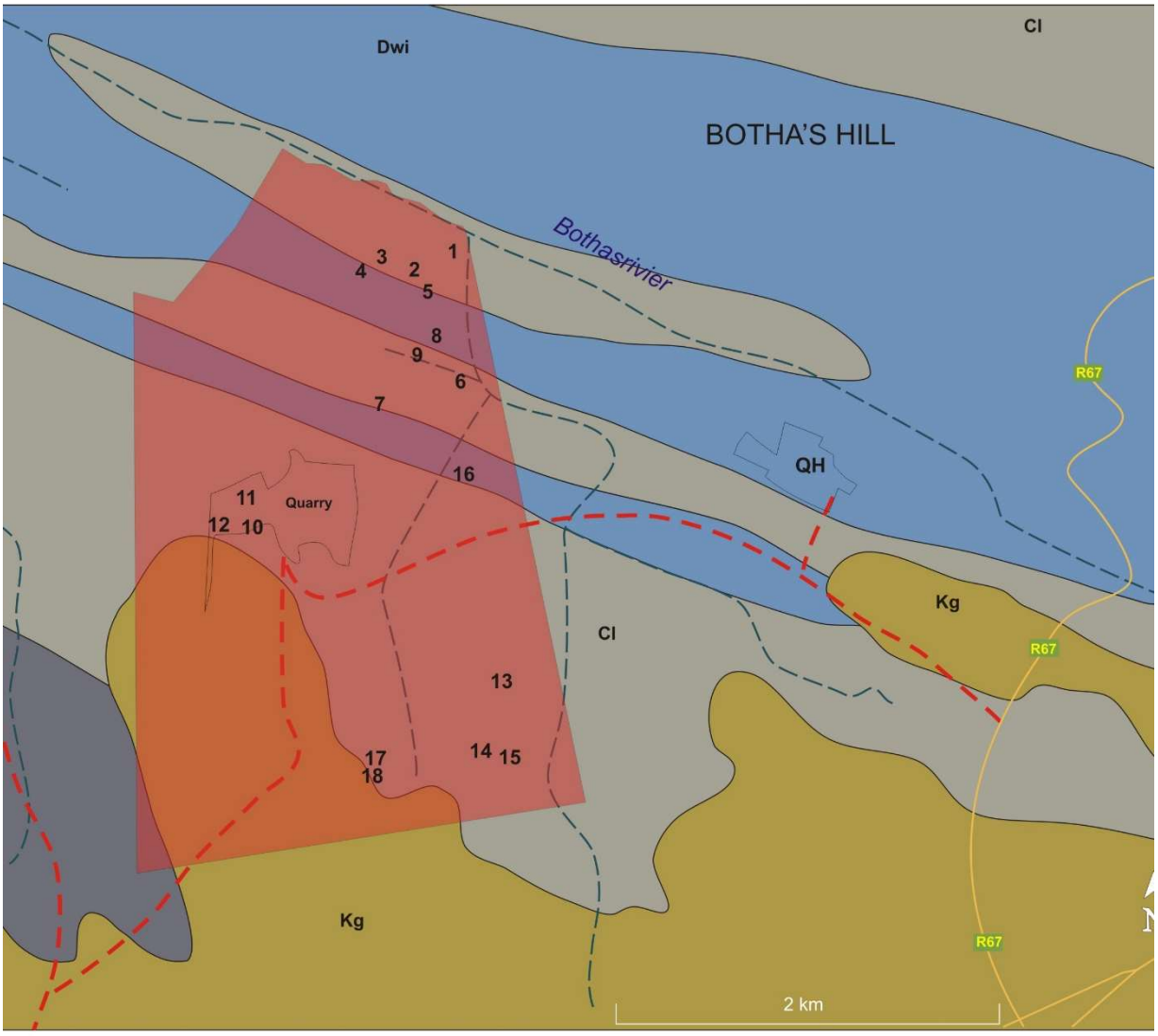

Figure 1: Brakkefontein Farm (pink polygon) superimposed on a geological survey map of the study area modified according to field observations made during this survey. Blue (Dwi) represents the Witpoort Formation (Witteberg Group), light grey (Cl) represents the Lake Metz Subgroup (Witteberg Group), dark grey (C-Pd) represents the Dwyka Formation (Karoo Supergroup) and mustard (Kg) represents the capping of Grahamstown Formation silcrete. Points at which photos in this report are taken are numbered 1- 18.

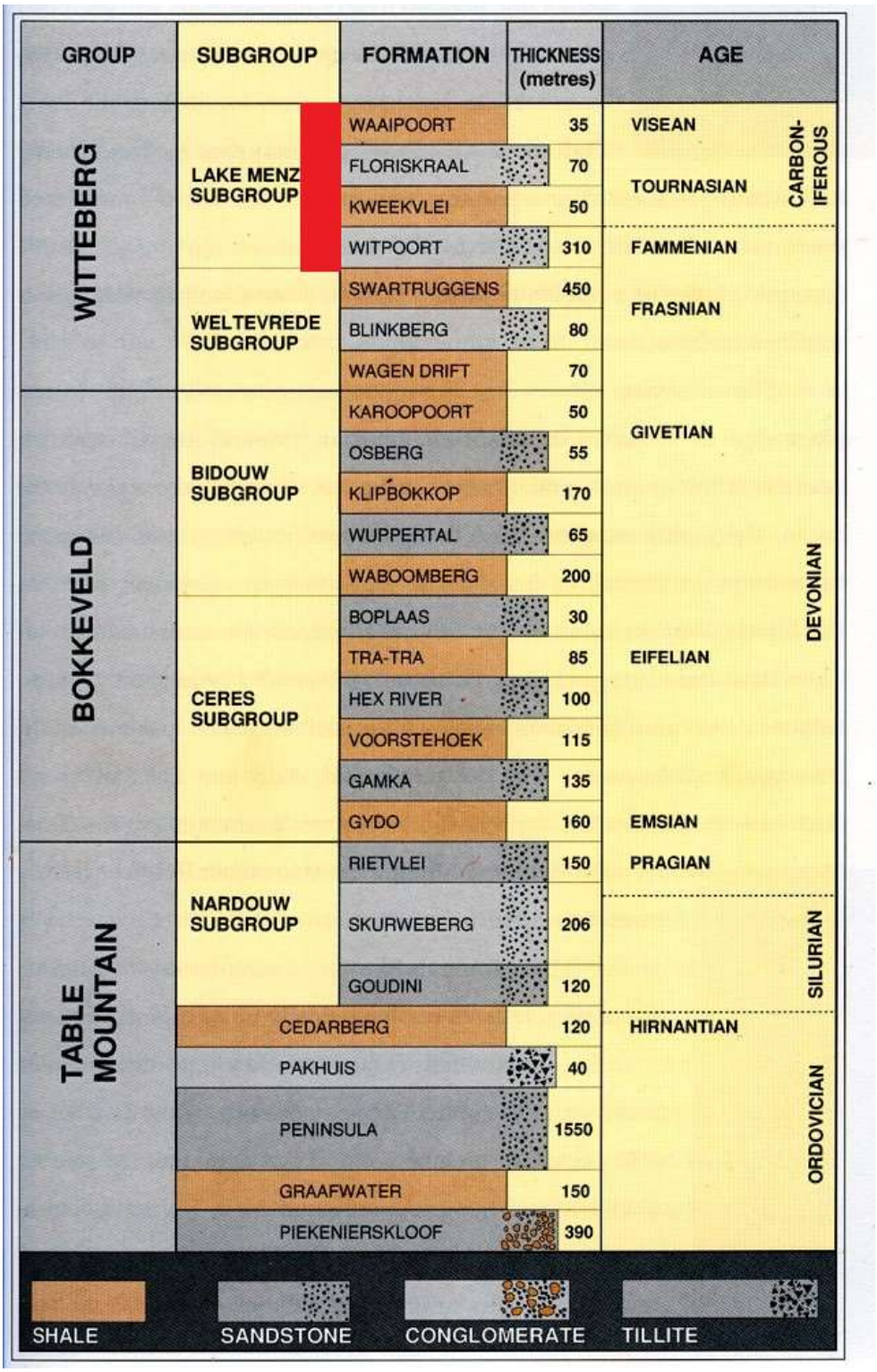

Figure 2: Stratigraphic column of the Cape Supergroup modified after Theron and Thamm (1990) following Cotter (2000). Red highlight indicates strata underlying Brakkefontein.

Palaeontology of affected strata

The Witpoort Formation is Famennian (uppermost Devonian) in age. That is approximately 359 to 372 million years old. It is a largely quatzitic unit representing mature sandy strata deposited along a linear barrier island type coast. The lower portion of the Witpoort Formation tends to have a brownish weathering character, whereas the upper portion (sometimes referred to as the Perdepoort Member) tends to comprise much cleaner whiter weathering quartzites. Particularly around Makhanda/Grahamstown black shale lenses are interbedded within the Witpoort Formation quartzites. These are interpreted as estuarine deposits preserved during brief transgressive events, and have proven remarkably fossiliferous.

A series of lenses at Waterloo Farm, to the south of Grahamstown, have provided southern Africa's most important Late Devonian locality, representing an entire coastal estuarine ecosystem and adjacent terrestrial environment. It has yielded fragmentary remains of Africa's earliest known four legged animals, the aquatic tetrapods, *Tutusius umlambo* and *Umzantsia amazana* and at least 20 taxa of fossil fish (including jawless fish (Agnatha), armoured fish (Placodermi), spiny sharks (Acanthodii), sharks (Chondrichthyes), ray finned fish (Actinopterygii) and lobe finned fishes (Sarcopterygii) including Coelacanths (Actinistia), lungfish (Dipnoi) and Osteolepiformes. Of these nine have as yet been described including the world's oldest lamprey fossil, *Priscomyzon riniensis,* and Africa's earliest coelacanth from the world's oldest known coelacanth nursery, *Serenichthys kowiensis.* Seaweeds, brack water charophytes and fresh to brack water bivalves have been described and a giant Eurypterid identified. The terrestrial realm is represented by the remains of a scorpion, *Gondwanascorpio emzantsiensis*, the oldest known terrestrial animal from the supercontinent Gondwana, Dozens of land plant taxa have been revealed, including zosterophylls, lycopods (eg. *Kowieria alveofolis, Colpodexylon pullumpedes* and *Leptophloem rhombicum*), iridopteralian-like plants (*Flabellopteris lococannensis*), sphenophytes (eg *Rinistachya hilleri*) and early progymnosperms, such as *Archaeopteris notosaria*, southern Africa's earliest known fossil tree. Abundant trace fossils have also been collected. Witpoort Formation quartzites have yielded a range of plant stem taxa and trace fossils. Lag deposits of bone have not, as yet, been discovered, but may be expected.

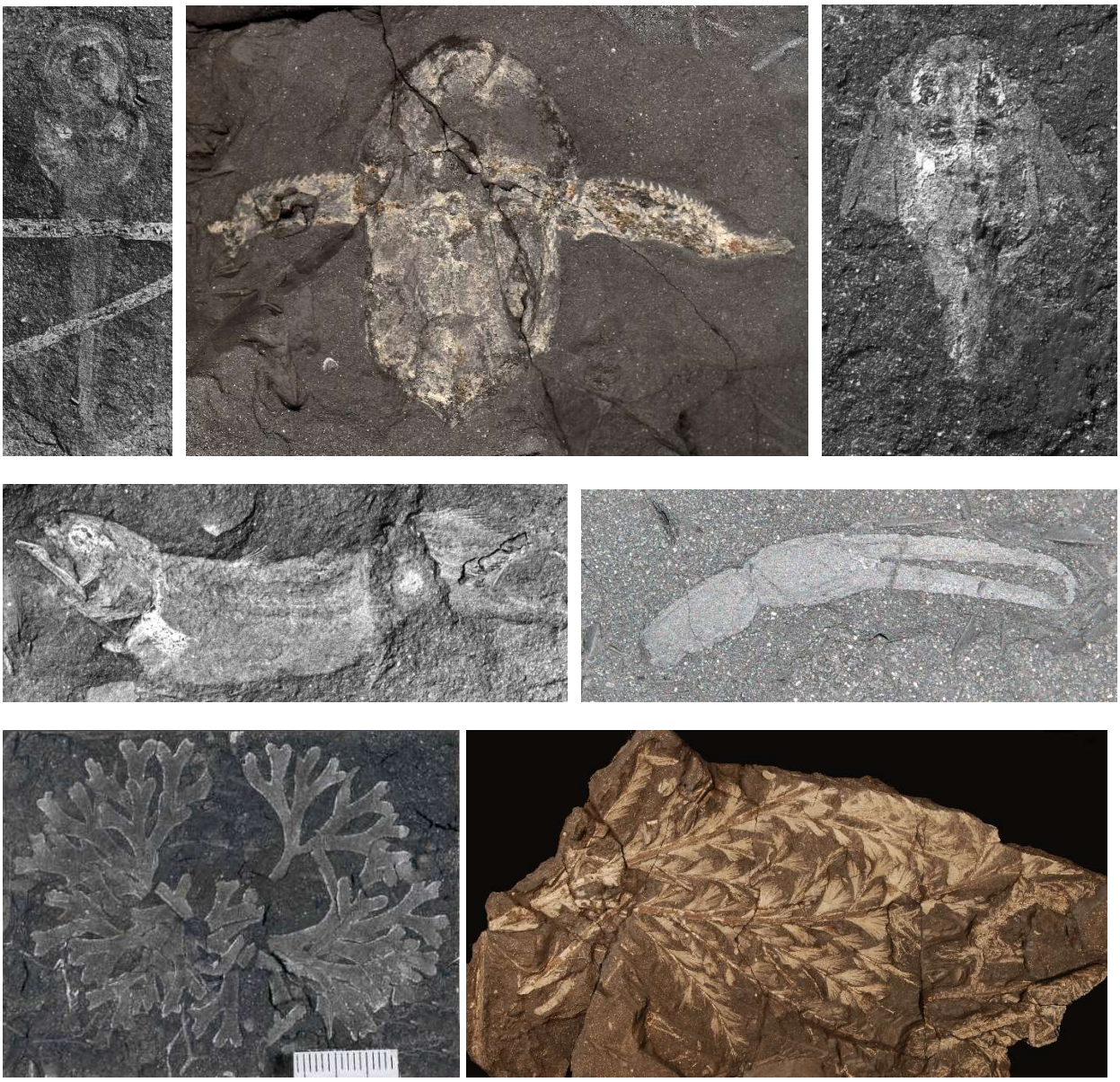

Figure 3: Selection of fossils recovered from a black shale lens at Waterloo Farm: *top left*, 4.2 cm long *Priscomyzon riniensis* (the world's oldest fossil lamprey); *top middle*, 6.5 cm long head and trunk armour of a young *Bothriolepis africana,* an antiarch placoderm fish; *top right*, 2.5 cm long neonatal *Groenlandaspis riniensis*, an arthrodire placoderm fish; *middle left*, 5.5 cm long type specimen of the coelacanth *Serenichthys kowiensis*; middle left, 3,4 cm long pincer of the scorpion, *Gondwanascorpio emzantsiensis* (the oldest known terrestrial animal from Gondwana); *bottom left*, 7 cm across tuft of the seaweed *Hungerfordia fionae*; *bottom right*, 30 cm long fronds of the progymnosperm tree *Archaeopteris notosaria* (the oldest known species of woody tree from southern Africa).

Figure 4: Fossils in quartzites at Waterloo Farm: left lycopod *Leptophloem rhombicum* stems; right, progymnosperm *Archaeopteris* trunk.

In 2015 roadworks to the south east of Brakkefontein, on the Governor's Kop section of the adjacent ridge at Coombs Hill and Rabbit Ridge, uncovered a number of palaeontologically important black shale lenses. Those along Rabbit Ridge (Green Hills) represented exposure of an extensive vertically tilted black shale horizon that yielded evidence for a monotaxic assemblage of lingulid brachiopods (*Dignomia* sp.) in a back-barrier tidal flats environment. This represented the first record of predominantly marine invertebrate shells within the Witpoort Formation. These sites also produced fragmentary plant remains, an arthrodire placoderm skull roof and extensive trace fossils.

Figure 5: *left*, Lingulid brachiopods and a lycopod stem on a slab from Rabbit ridge; *right*, Chris Harris, chief excavator of Rabbit Ridge and Coombs Hill at a shale outcrop on Rabbit Ridge in 2015.

The roadworks at Coombs Hill, slightly further to the east revealed a number of black shale horizons, which contained more than one species of bivalve, in addition to a wealth of plant

fossils, some of which are remarkable well preserved. Plant fossils included lycopod taxa new to science and the best preserved fronds of the progymnosperm tree, *Archaeopteris notosaria* known. Study of these is ongoing with, as yet one species of lycopod, *Colpodexylon mergae*, having been formerly described.

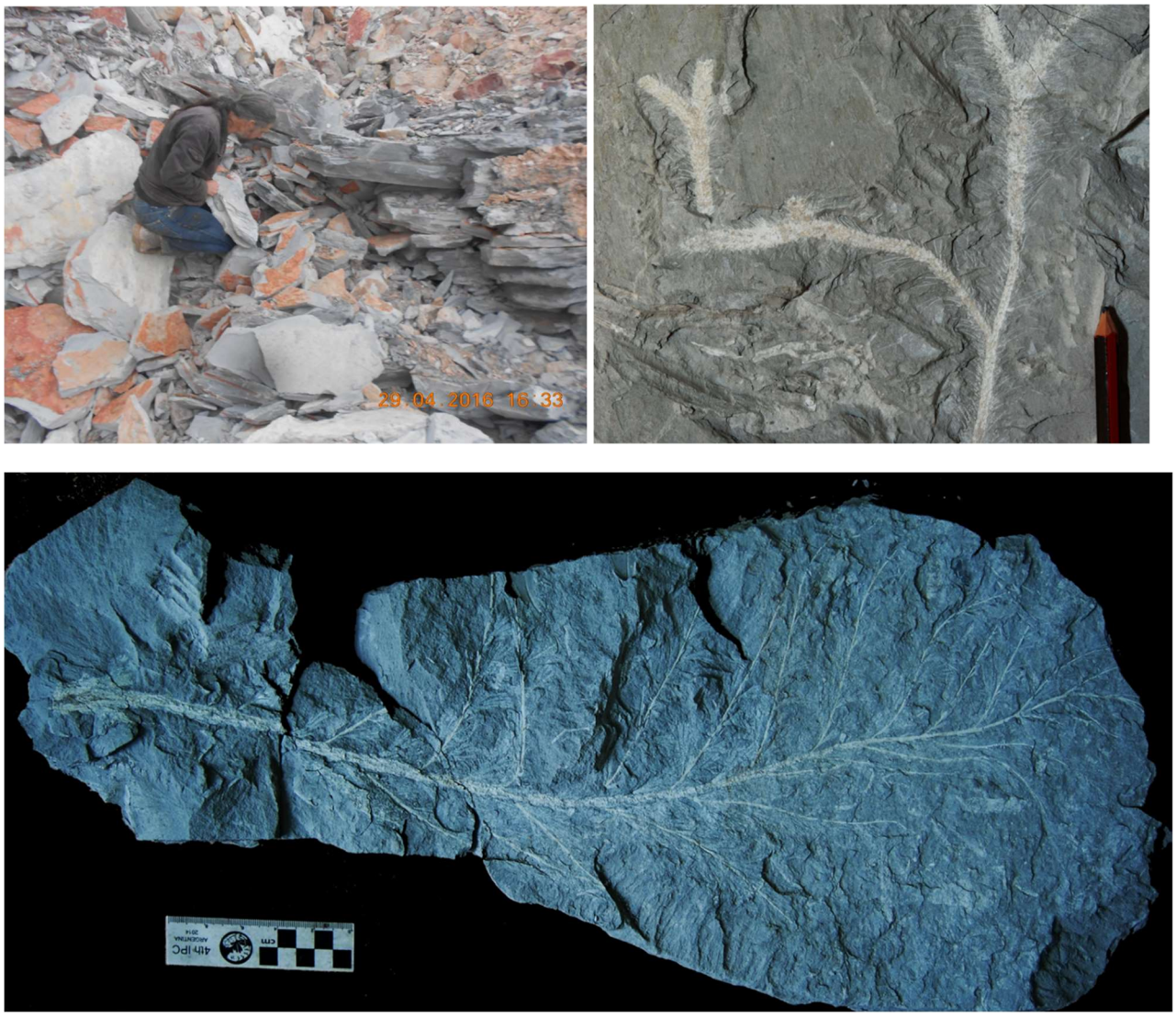

Figure 6: Black shale and fossils from Coombs Hill: *top left*, black shale disturbed during roadworks at Coombs Hill, *top right*, new species of lycopod plant; *bottom*, frond of *Archaeopteris notosaria*.

Fossil black shales (commonly fossiliferous) are interbedded with quartzites all along the ridge though these are generally reduced to soil or clay near surface. They are normally revealed where quarrying or roadworks cut into the land surface, for example in the hardrock quarry 1.7 kilometres east of Brakkefontein (Fig. 1, QH). Black shales here were protected from leaching by overlying quartzitic strata which have been penetrated by quarrying. Preliminary investigation revealed these to contain silvery white plant fossil fragments.

Figure 7: Stacked Witpoort Formation quartzite strata in a quarry at Point QH (Fig 1), overlying black shale visible at bottom right.

Figure 8: Black carbonaceous shale exposed in quartzite quarry (Fig 1., Point Qh) showing reddish possibly sideritic layers (left) and silvery white fossil plant fragments (right).

The top of the Witpoort Formation coincides with the end of the Devonian and is similar in age to the end-Devonian extinction event. It is overlain by rocks of the early Carboniferous aged Lake Mentz Subgroup. The End Devonian Mass Extinction Event completely changed diversity patterns of life on Earth, wiping out all placoderm (armoured fish) as well as most acanthodians (spiny finned fish) and lobe finned fish groups. Thereafter, ray-finned fish and sharks dominated the waters, and tetrapods (animals with four legs) went on to populate the land. Although there are as yet no tetrapods known from South Africa's early Carboniferous rocks, there are a number of fish fossil sites that well illustrate this change in fish diversity. Most famous of these is the 'Lake Mentz' site from near the Darlington Dam in the Addo National Park. Here several layers

of rock covered in fossil fish of many species have been discovered. These appear to have died suddenly from cold or lack of oxygen. In strong contrast to the fish of the Waterloo Farm site, the fish from near Darlington Dam are all ray-finned fish, the group of fish that dominates our seas, lakes and rivers today. Some shark and acanthodian remains have also been recovered from the Lake Mentz Subgroup.

Figure 7: Layers of ray finned fish fossils from rocks of the Lake Mentz subgroup near Darlington Dam, now in the Greater Addo National Part.

In the later part of the Carboniferous and early part of the Permian period, during the breakup of Gondwana, the Agulhas Sea floor was folded up into a chain of high mountains that separated the Karoo Basin from the Sea. The area thereafter became an erosional environment and largely ceased to accumulate sediments. Around 200 million years later, during the Cretaceous and early Tertiary Periods much of Africa was weathered down to a number of level horizons collectively known as the African Surface. The area in the vicinity of Grahamstown was reduced to a flat plain close to sea level, remnants of which are referred to as the Grahamstown Peneplane. During the Tertiary, mudstones, shales and diamictites were leached to considerable depth, transforming them into soft white kaolin clay. Silica, iron and magnesium from these rocks was carried in solution by groundwater and deposited near the ground surface due to steady evaporation of mineral rich waters. This lead to the formation of a hard mineralised capping

layer, often consisting of silicified soil. Resultant silcretes are referred to as the **Grahamstown Formation**. Though occasional occurrences of root and stem impressions have been recorded from the Grahamstown Formation it is generally considered unfossiliferous.

Site visits

The proposed development area was surveyed by vehicle and on foot in December 2021 and March 2022.

Within the northernmost valley, adjacent to the Botha's Spruit (Fig. 8) most of the low lying strata is covered in sandy alluvium which has been exploited for sand, extracted from numerous, now defunct excavations. Some of these also reveal partially cemented sandy alluvium, seemingly displaying an early phase of silicification (Fig. 9).

Underlying shaly strata were only located at one point, on the southern slopes of the valley where exposed in the road bed. These comprised somewhat degraded, extremely fine grained Mudstones lithologically consistent with the Kweekvlei Formation (Fig. 10).

More extensive outcrops of Kweekvlei Formation mudstone were examined in a borrow pit in the next valley at point 6 (Fig. 1) (see figs 8-15). These in places exhibited varving (Fig. 13) and interbedded sandstone bodies (Fig. 14). Although the borrow pit was meticulously examined virtually no palaeontological material was observed, and this limited to rare small burrow traces in the mudstone (Fig. 15). Along the northern flank of this second valley the underlying strata are mantled by geologically recent river terrace deposits (Fig. 16).

Figure 8: View westwards of northernmost valley on Brakkefontein, from point 1 (Fig 1).

Figure 9: Semi silicified soily alluvium exposed in a former sand mine at point 3 (Fig. 1).

Figure 10: Weathered Kweekvlei Formation mudstone at point 2 (Figure 1).

Figure 11: Extensive exposures of Kweekvlei Formation mudstone in borrow pit at point 6 (Fig. 1).

Figure 12: Finely laminated Kweekvlei Formation mudstone at point 6 (Fig. 1).

Figure 13: Varved layers within Kweekvlei Formation mudstone at point 6 (Fig. 1).

Figure 14: Interbedded sandstone body in Kweekvlei Formation mudstone at point 6 (Fig. 1).

Figure 15: Fine burrow trace fossils within Kweekvlei Formation mudstone, represented by cut through black infils, at point 6 (Fig. 1).

Figure 16: Geologically recent river terrace gravels and pebbles at point 9 (Fig. 1).

The higher ground towards the north of Brakkefontein, which flanks the two valleys, is all defined by overturned anticlinal (upwardly bent) folds of resilient quartzite of the Witpoort Formation. This varies from orangish weathering impure quartzite, possibly equivalent to the 'Rooirand Member' (figs 17-19) to superficially more massive clean white quartzite reminiscent of the 'Perdepoort Member' (figs 20-23). Within overturned quartzitic strata at point 7 (Fig. 1) a number of narrow fossil lycopod plant stems were discovered cross-cutting bedding, possibly indicative of *in situ* preservation (Figs 22-23). These were less than a metre stratigraphically below a mud chip conglomerate layer, indicative of a high energy depostional event.

Figure 17: Witpoort Formation strata at point 4 (Fig. 1), looking eastwards.

Figure 18: Cross bedded reddish weathering Witpoort Formation strata at point 5 (Fig. 1).

Figure 19: Overturned cross bedding within reddish weathering Witpoort Formation quartzites at point 5 (Fig. 1).

Figure 20: Cleaner weathering Witpoort Formation quartzite at point 16 (Fig. 1), looking westwards.

Figure 21: Overturned Witpoort Formation strata at point 7 (Fig.1), looking eastwards.

Figure 22: Subvertical and inclined lycopod plant stems preserved in overturned Witpoort Formation quartzites at point 7 (Fig. 1).

Fig. 23: Inclined lycopod (plant) stem fossil cross-cutting bedding in overturned Witpoort Formation quartzites at point 7 (Fig. 1).

The southern portion of Brakkefontein is underlain by sediments of the Lake Mentz Subgroup, which have been leached to a great depth, degrading their original sedimentological character. Throughout most of the area they have been reduced to kaolin clay, which would originally have been capped by a layer of silcrete. This silcrete capping currently remains largely in the very south of the area, though small relict patches are also encountered.

Non kaolinized Lake Mentz Subgroup strata were almost exclusively encountered in Brakkefonteins main clay quarry where mining has removed the overlying kaolin. Although these were carefully examined no sign of body fossils were encountered and palaeontological material was restricted to vertical burrow casts observed in sandstone interbeds.

Figure 24: Moderately altered strata of the Waaipoort Formation exposed by deep excavations in the main brick clay quarry at point 10 (Fig.1).

Figure 25: Detail of moderately altered strata of the Waaipoort Formation exposed by deep excavations in the main brick clay quarry at point 10 (Fig.1).

Figure 26: Traces left by vertical invertebrate burrows in interbedded sandstone at point 11.

Figure 27: Kaolin derived from leaching of Waaipoort Formation mudstones, and capped by silcrete crust in the south of the main brick clay quarry at point 12 (Fig. 1).

Figure 28: Kaolin capped by silcrete in disused quarry at point 17 (Fig. 1).

Figure 29: Brown silcrete adjacent to the disused kaolin quarry at point 18 (Fig. 1).

Figure 30: View of Brakkefontein, looking north from point 17. Note small ridge in the middle distance at right (point 13) and main brick clay quarry (white) at centre.

Figure 31: Outclier of white silcrete capping a small hill at point 17 (Figure 1).

Figure 32: Kaolin clay exposed in a test pit at point 14 (Fig. 1).

Figure 33: Semi degraded Lake Mentz subgroup siltstone exposed in a test pit at point 15 (Fig. 1).

Conclusions and Recommendations.

The southern 60 percent of Brakkefontein is deeply underlain by highly kaolinized sediments of the Lake Mentz Subgroup, exposed by partial geomorphological removal of the overlying Grahamstown Formation silcrete. In the south the edge of the main remaining body of silcrete capping is encountered, where it defines the northern edge of the Grahamstown Peneplane surface. A small outlier of silcrete also occurs further to the north, maintaining an erosion resistant ridge.

Throughout this area the underlying strata are generally so degraded by leaching during and following the Cretaceous Period, that their palaeontological legacy has been entirely obliterated to a depth that would only be encountered in fairly deep excavations.

In the northern part of Brakkefontein the landscape is defined by a series of north-west to south east trending parallel folds that are overturned towards the north west. Erosion of the landscape has revealed the crests of upward folds in the Witpoort Formation which are more resistant than the overlying mudstones of the Lake Mentz Subgroup. These define parallel ridges, the troughs between which have been carved into two parallel valleys. Overlying mudstones in this region are less deeply leached relative to the current land surface. Those in the most northerly area belong to the Kweekvlei Formation.

Kweekvlei Formation shale includes that exposed in the small borrow pit that is proposed for expansion, despite it having originally been mapped as belonging to the more palaeontlogically sensitive Witpoort Formation. Careful examination of a large amount of shale currently exposed in this excavation site revealed no significant palaeontological material.

Likewise, Waaipoort Formation strata encountered in deep excavations in the main brick clay quarry were not observed to be notably fossiliferous.

The only interesting palaeontological material was observed in the Witpoort Formation quartzites. It is also to be expected, on the basis of previous excavations into the Botha's Hill – Governors Kop Ridge, that fossiliferous black shale horisons occur beneath the protective capping of overlying quartzites.

As the client's principal interest is the extraction of clay and shale it is unlikely that the Witpoort Formation will be seriously impacted. Should however a quartz quarry at any time be proposed on Brakkefontein recommendations in this regard should be obtained from a palaeontologist.

Further mining of kaolin clay will have no palaeontological impact, as its formative leaching has degraded any original palaeontological record. Should mines penetrate through the kaolin clay to bedrock a palaeontologist should be informed to evaluate its scientific interest.

Should any suspected palaeontological material be at any time encountered during mining of Kweekvlei Formation mudstones, a palaeontologist should likewise be immediately contacted to sample and record such occurrence.