Palaeontological Heritage Impact Assessment for Road works on the Waterloo Farm road cutting on the N2 road bypass outside Grahamstown

Prepared for: South African National Road Agency Limited (SANRAL)

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Summary

The Waterloo Farm road cutting contains a fossil site that has, over the last twenty Years, proven to be of enormous international importance, being the only worthwhile site of its age in Africa. It has demonstrated a diverse fauna and flora, and continues to produce additional taxa, as well as additional specimens of previously noted but incompletely understood taxa. It is currently the subject of a joint research project involving the University of the Witwatersrand and the University of Chicago, funded by PAST and the National Research Foundation. It was intended to develop an educational and tourism facility at this locality with funding from the Department of Science and Technology.

Heavy rainfall during 2006 has, however, led to extreme structural failure of the road-cutting, necessitating the closure of this section of the road for extensive road works, including the removal of a huge quantity of rock - in order to reduce the unstable (shale rich) portion of the road cutting to a one in three slope.

Detailed recommendations are made for Mitigation of the inevitable destruction of a site of high heritage value.

These include,

1: *Rescue of shale samples from the (collapsing) most important locality, their transport and storage for future excavation.*

2: *Possible exposure and preservation in situ of an adjacent portion of this horizon.*

3: *Ongoing monitoring throughout the road works and the rescue of important material uncovered in the less fossil rich portions of the black shale horizon.*

4: *Rescue or preservation in situ of any newly discovered localities of extreme palaeontological significance*

Contents

Physical and stratigraphic character of the road cutting

The above road cutting, orientated roughly east-west, is approximately 500 metres long and 20 to 30 metres high and cuts through strata of the Witpoort Formation of the Witteberg Group. These strata dip northwards and slightly westwards.

The eastern portion of the cutting intersects the stratigraphically lowest portion of the sedimentological sequence, consisting of alternating beds of grey quartz arenite separated by thin shales. These are interpreted as having been deposited in shore face and barrier-island depositional environments.

The central to western portion of the road cutting intersects the middle portion of the sedimentary sequence, consisting of laminated black carbonaceous shale, up to 6 metres thick. This is interpreted as having been deposited in a semi-stagnant back-barrier lagoonal environment.

This, in turn, is overlain by whitish shoreface-derived quartz arenites, containing a number of small black shale lenses, - which overly the black shale along the length of its exposure, and compose the westernmost portion of the road cutting, beyond the point where the black shale dips down to below the level of the road

Palaeontological overview

The shoreface arenites, lowest in the stratigraphic sequence, have revealed lycopod axes of the *Haplostigma* and *Leptophloem* types. These include a channel lag deposit of mixed stems and mud chips (presumed to have resulted from a more landward bank collapse), in which the only two known *Leptophloem* stems, displaying their subterranean root base structures, are preserved. A large block of this material has been excavated and is on display in the Albany Museum fossil gallery.

Plant material, including *Archaeopteris* fronds, has been recovered from very fine shale interbeds between beds of arenite, about five metres below the black shale. Trace fossils, including infaunal feeding burrows, *Cruziana* and *Rusophycos* are preserved as sole marks in the finely interbedded shales and arenites immediately stratigraphically underlying the black shale, and have been collected laterally to the east thereof.

Carbonised tree trunks appear to be present in the arenites overlying the black shale. It is, however, **in the black shale that the richest and most significant fossil remains** have been uncovered. Plant fossils are sparsely distributed throughout this black band, with some significant plant specimens having been recovered from the laterally middle portion of the outcrop.

By far the most palaeontologically important portion of the road cutting is **the most easterly exposed 10 metres of the black shale** horizon. The shale, at this point, pinches out against the barrier island deposits and is clearly more fine grained and carbon rich than the rest of the exposed horizon. It is also more finely bedded and is interpreted as having accumulated in the shallows, adjacent to the lagoonal shoreline.

Here dead organic matter was concentrated and buried in fine, acidic, anaerobic mud. This included aquatic plants and algae that may have lived within this environment, transported terrestrial plant material, aquatic arthropods and fish.

Collecting and research at this sub-locality, over the past 20 years, has produced (in addition to a range of trace fossils), the remains of 7 species of charophyte algae, approximately 20 types of plants, at least two types of arthropod and 17 species of fish. These are of varying abundance and are known from specimens of diverse quality of preservation. Of particular significance, from a global point of view is the fine preservation of soft tissues (of algae, plants and fish) sometimes preserved in these strata.

Material collected has already provided the type material of four new species of charophyte algae (*Octochara crassa, Octochara gracilis, Hexachara setacea* and *Hexachara riniensis*), representing the world's oldest reconstructable charophytes, two new species of thallophyte algae (*Hungerfordia fionae* and *Yeaia africana*), an early progymnosperm (*Archaeopteris notosaria*), three species of placoderm fish (*Bothriolepis africana, Groenlandaspis riniensis* and *Africanaspis doryssa*), a shark (*Plesioselachus macracanthus*) an acanthodian chondrichthyan (*Diplacanthus acus*) and, most recently, the worlds oldest fossil lamprey fish (*Priscomyzon riniensis*).

Over one and a half thousand additional specimens are the subject of a project involving international scientific collaboration between the University of the Witwatersrand and the University of Chicago. Many new species are currently being described, whilst ongoing excavations continue to reveal additional species, in addition to more complete examples of, as yet, undescribed species.

General Palaeontological context

The Witpoort Formation rocks, of which the cutting is comprised, form the bottommost subdivision of the Lake Mentz subgroup of the Witteberg Group. They are Late Devonian (Fammenian) in age and marginal marine in character.

During the Devonian Period (417-354 Ma) important biodiversity changes occurred as plants and aquatic vertebrates diversified into a wide range of orders and the colonisation of land by both plants and vertebrates began.
From very small and simple taxa, at the beginning of the Devonian, plants evolved into a wide range of taxa, reaching the size of trees within sphenopsid, lycopod and various branches of the progymnosperm stock by the end of the period. The evolution of bryophytes, and pteridophytes (ferns) also occurred during this Period. With the exception of the angiosperms, the major divisions of the plant kingdom, as we see them today, were established by the end of the Devonian.

Fish reached their broadest ordinal diversity during the Devonian as many ancient orders, which would become extinct towards the end of the Period, co-existed with emergent new orders. As a result, the Devonian is often referred to as 'the age of fishes'.

Important biogeographic changes occurred during the Devonian. During the Early and Middle Devonian there was marked global biological provincialism, whilst toward the end of the Devonian there was a move to global cosmopolitanism, in both plants and fish. Palaeontologists view this, in part, as a symptom of the coalescence of the landmasses currently forming north America with those of current north western Europe, to form Laurussia, during the Middle Devonian and the probable closure of the Iapetus sea between Laurussia and Gondwana towards the Late Devonian, which was accompanied by climatic and sea level changes, increasing exchanges of taxa, and many extinctions.

During the Devonian, South Africa's southern margin formed one of the shores of the semi-enclosed, high latitude, Agulhas Sea, which was also bounded by portions of what are now South America and Antarctica.

Extensive studies of marine invertebrates from the Early and Mid Devonian Bokkeveld Group of South Africa, and the contiguous strata of South America and the Falkland Islands has led to the definition of a distinct Malvinokaffric cold water fauna of Early and Mid Devonian invertebrates, dominated by brachiopods. Preliminary surveys of the depauperate Bokkeveld fish taxa, suggests that in addition to its unique invertebrate fauna the Malvinokaffric realm also had a unique combination of vertebrate taxa. This fauna, which was dominated by arthrodire placoderms, acanthodians and sharks, has closest affinities with those from East Gondwana.

At the Late Devonian Frasnian-Famennian boundary, a major extinction event led to widespread extinctions amongst plants, followed by a new radiation of taxa. It has been suggested that this was precipitated by continental movements that brought Gondwana into the antarctic region, leading to its extensive glaciation – which may have lowered global temperatures, and sea levels. Alternately a model has been proposed which suggests that lowered global temperatures, may have resulted from reduced atmospheric carbon dioxide levels, due to the rapid spread of *Archaeopteris* forests during the Frasnian. This led to increased levels of fixed carbon entering drainage systems, perhaps helping to account for the global frequency of carbon rich anaerobic sediments during the Famennian.

A number of minor extinction peaks occurred during the Famennian, culminating in a major event at the end of the Famennian. This was characterised by extensive extinction amongst marine organisms, possibly triggered by widespread marine regression, or environmental consequences of the rapid diversification and spread of seed-bearing plants into relatively dry habitats.

The post-Devonian world would be radically different from the Devonian one, characterized by verdant, botanically diverse terrestrial environments inhabited by insects, arthropods and tetrapod vertebrates, with the waters dominated by a new diversity of fish. Yet the first appearances of the taxonomic groups that characterise the post-Devonian world (such as angiosperm plants and tetrapod vertebrates) are to be found in latest Devonian (Frasnian and Famennian) rocks, where they co-inhabited with those groups that would shortly become extinct, or greatly reduced.

Late Devonian fish and plant communities previously studied, from around the world, were preserved in strata deposited in lower latitude, often tropical, environments. In contrast palaeomagnetic studies place the South African Devonian strata at about 75 degrees south, at a time of global cooling and ice cap formation.

In South Africa, therefore, the Fammenian, represented by the Witpoort Formation rock sequence, was laid down at far higher latitude than most known fossil localities of this important age. It can therefore give unique insights into the world in which the earliest tetrapods arose.

The Waterloo Farm locality, in the aforementioned road cutting is, however, the only significant locality of this age in Africa.

A brief history of the Waterloo Farm road cutting

The construction of a road bypass around Grahamstown in 1985 followed a route through the deeply valleyed terrain to the south of the town. This required the excavation of extensive road cuttings and the deposition of rubble to build viaducts across the intervening valleys.

That immediately to the north of Waterloo Farm intercepted arenites and extensive black shale of the Witpoort Formation. Sampling of this shale horizon by Robert Gess, Norton Hiller and Billy de Klerk revealed both plant and fish fragments of greater diversity and completeness than any previously known from South Africa, of this age.

In 1991 Norton Hiller asked Fiona Taylor to carry out a study of the cuttings, in particular the fossiliferous one, for her honours project. A volume of sedimentary data was collected and processed. Fiona Taylor and Robert Gess conducted a small excavation at the eastern end of the black shale. The results of this work were published in two short papers (see reference list).

Due to the roadwards dip of the strata, and the huge weight of jointed quartzites atop the inclined "soapy" horizon of black shale, the road cutting was already experiencing structural failure by 1990, with the metal road barrier collapsing under the weight of avalanching material.

In 1993 Norton Hiller obtained funding which allowed Robert Gess to conduct extensive excavations at the site between 1993 and 1995 (when funding ceased with Hiller's emigration). Gess collected over a thousand specimens which are housed in the Albany Museum. These revealed the presence of a large diversity of algal, plant, arthropod and fish material. Preliminary reports on this material formed the basis of a further seven scientific publications.

In 1994, due to concern for the safety of motorists utilising the bypass, road engineers made some attempts to stabilise the cutting. Following discussions with Gess and Hiller a plan to cap unstable areas, including the fossil locality, was curtailed, and instead a concrete barrier wall was constructed at the base of the cutting.

By 1999, however, continued slumping had resulted in the near permanent closure of one traffic lane, leading the National Roads Agency to call for tenders for it's upgrading. After Gess had notified them of the important site's existence, they made funds available for emergency rescue efforts, and the preservation of a portion of the outcrop (with a wide terrace beneath for it to slump onto). The rest of the cutting was terraced and capped with soil and vetivier grass.

As much of Gess' original excavation site was to be cut back to create a terrace he spent two weeks with the assistance of a team of labourers, clearing off the overburden, chiselling the shale into blocks of varying sizes, and stacking these on more stable ground nearby. About thirty cubic metres were thus prepared. They then laid a thin bed of sand on the back of a flat bed truck and utilised it, over three days, trucking the blocks to a safe locality. The blocks were transported one layer deep to prevent them from crushing one another. On arrival they were stacked, and a shed roof was constructed over them to slow their decay.

Excavation of these blocks is a slow and meticulous process, conducted with a pen knife, with which the blocks are gradually split apart into small flakes to reveal the, often minute and faint, fossils.

Since 1999 part time work on the saved sample, in addition to material collapsing onto the terrace at the road cutting, revealed that much new and important material could still be brought to light through systematic work.

Resultant funding from the Palaeontological Society Trust (PAST) became available from 2005, whilst supplementary funding from the National Research Foundation (NRF), became available from the beginning of 2006, for Gess to continue excavations and prepare a Phd (through the Bernard Price Institute for Palaeontological Research (BPI) at the University of the Witwatersrand (Wits)) based on his exiting new finds. About half of the 30 cubic meter sample has so far been excavated, and it was hoped to return to the on-site excavation at the completion of this phase of the research.

It was further hoped to involve the Department of Science and Technology, in preparing a roofed Educational/Tourism live exhibit of an on site excavation of what is being revealed as a major National Heritage site of both national and international significance.

In 2006, however, heavy rains fell in the Eastern Cape, and beginning in August 2006 massive failure of large portions of the road cutting has occurred. In the west of the road cutting, water build up within the hill has led to crevassing of the entire cliff face, which has begun to shift forward in huge slices, sliding down the slippery dip surfaces and threatening to collapse the concrete barrier and slump onto the road. This section of the road has therefore been declared unsafe for traffic, both lanes of which have been rerouted around this section of the bypass.

The National Roads Agency has therefore declared the need for the rapid implementation of massive emergency road works. It is proposed to cut back the affected part of the cutting to a one in three slope, removing most of the black shale horizon.

Mitigation

There is no doubt that the massive road works envisaged by the National Roads Agency Limited are necessary to allow the continued use of the road. A number of mitigations may, however, be implemented to facilitate the benefit of palaeontological research.

1. The important, easternmost (10 meter) portion of the shale, partially preserved *in situ* in 1999, is collapsing and disintegrating down the slope below it, where chunks of it are becoming embedded in a mud flow. Before further disintegration of this material occurs, and before equipment and personnel begin work on the road cutting, a team of workers need to be employed to work under the consultant. Loose material needs to be recovered and stacked in a stable position. In addition the unstable, exposed, portion of the outcrop needs to be carefully removed and stacked with this material. This should then be transported, one layer deep, on a flatbed truck, and unloaded beside the material rescued from the 1999 road works. A shed roof should be constructed there over to prevent decay of the material whilst it awaits excavation (which is a time-consuming activity).
   Some material from this outcrop was also incorporated (January 2000) into a terrace, adjacent to the outcrop, and efforts should be made to recover this material, at this point.
   The removal of the material may be facilitated by preparing a route for the truck to drive onto the terrace behind the concrete barrier, from the east, and from there up the fairly stable inclined terrace that leads to the area below the outcrop. A small crane on the truck will facilitate the lifting and unloading of large slabs. For research purposes the material should be kept in the largest possible portions.

2. As the ‘fertile’ material is wedged onto the top of the relatively stable underlying arenites it may still be possible to preserve a previously unexposed extension thereof for future on-site excavation. The feasibility of this will only become apparent once the extensive overburden is removed according to the road-works plan. This is as:
   - **a.** The upwards trajectory (southwards) of the inclined strata is likely, at some point, to intersect the profile of the hill – and the strata may therefore be limited in further extent.
   - **b.** In addition, deep weathering of the shale has reduced it to a creamy white clay for some meters below the land surface – rendering it useless.
   - **c.** The exact orientation of the bed, and the line of the “palaeo-waters-edge” relative to the landscape cannot be easily predicted prior to earth movement.

   *Removal of overburden in this area should therefore only proceed in conjunction with the consultant.

   *Should a continuation of the richly fertile shale be located, this should be carefully exposed over a significant area and covered by an *in situ* cladded shed. (Funding will then be sought from other sources for the further development of this site).

* Loose material disturbed during this activity should either be accommodated in the proposed cladded shed, or removed for off-site preparation.

3. As has been noted, important plant fossils have been recovered from other portions of the black shale horizon. In addition, the extent and nature of the black shales within the hill are currently unknown.
It is probable that minor fossil occurrences will be intercepted during the extensive removal of rock involved in reducing the cutting to a one-in-three slope. Most of the voluminous black shale is to be removed from the central to western portions of the road cutting, allowing for extensive exploration.

*All road works personnel should, therefore, be familiarised with the appearance and importance of fossiliferous material and be encouraged to be on the lookout therefore.
*Twice weekly site inspections should be conducted by the consultant to ascertain whether important material is being disturbed, and to facilitate sampling thereof.
* Sample blocks will be accumulated in a stable area for later removal and off-site storage, adjacent to other material.

4. It is not improbable that formally unenvissaged areas of highly concentrated fossil material may be encountered with the cutting back of the hill. These may be importantly different from previously encountered material, as the palaeogeography of the lagoon (in 3D) is not known. Other areas of the lagoon margin may be intercepted, which may furnish different suites of material. For example:

a. a still lagoon embayment in closer proximity to the vegetated landward banks of the lagoon would be expected to yield better preserved terrestrial plant material, including fructifications of early gymnosperms and, perhaps, well preserved terrestrial invertebrate remains.
b. A still lagoon embayment adjacent to a freshwater inlet would be expected to provide the remains of fresh water fish faunas and invertebrates, in addition, perhaps to **early tetrapod remains**.

Both these possibilities would be of immense international scientific importance.

* The road workers and the consultant should be continually on the lookout for these types of occurrences.
* Should such occurrences be located towards the "back" (south) of the portion of hill to be removed, provision should be made for their *in situ* preservation.
* Should *in situ* preservation be precluded for structural engineering reasons, substantial samples of such fossil concentrations should be removed and trucked to a site adjacent to material rescued in 1999, where a shed roof should be constructed to preserve blocks for later, systematic, excavation.

5. All important material will, in time, be curated into the Albany Museum collection.

Appendix 1: Publications regarding the Waterloo Farm Road Cutting

Anderson, H.M., Hiller, N. and Gess, R.W. (1995). *Archaeopteris* (Progymnospermopsida) from the Devonian of southern Africa. *Botanical Journal of the Linnean Society* **117**: 305-320.
Anderson, M.E., Hiller, N. and Gess, R.W., (1994). The first *Bothriolepis*-associated Devonian fish fauna from Africa. *South African Journal of Science* **90**: 397-403.

Anderson, M.E., Long, J.A., Gess, R.W. and Hiller, N., (1999). An unusual new fossil shark (Pisces: Chondrichthyes) from the Late Devonian of South Africa. *Records of the Western Australian Museum* **57**: 151-156.

Gess, R.W. (2001). A new species of *Diplacanthus* from the Late Devonian (Famennian) of South Africa. *Annales de Paléontologie* **87**: 49-60.

Gess, R.W. (2002). Important new chondrichthyan material from the Witpoort Formation of the Devonian Witteberg Group. *Palaeontological Society of Southern Africa, 12th Biennial Meeting, Abstracts,* National Museum, Bloemfontein: 16.

Gess, R.W. (2002). *The palaeoecology of a coastal lagoon of the Witpoort Formation (Upper Devonian, Famennian) in the Eastern Cape Province, South Africa.* MSc thesis, University of Fort Hare.

Gess, R. W. (2004). A large Cyrtoctenid Eurypterid from a Witpoort Formation (Upper Devonian, Famennian) exposure near Grahamstown in the Eastern Cape. *Geoscience Africa 2004, Abstract Volume*, University of the Witwatersrand, Johannesburg, South Africa: 219.

Gess, R.W. and Hiller, N. (1995a). A preliminary catalogue of fossil algal, plant, arthropod, and fish remains from a Late Devonian black shale near Grahamstown, South Africa. *Annals of the Cape Provincial Museums (Natural History)* **19**: 225-304.

Gess, R.W. and Hiller, N. (1995b). Late Devonian charophytes from the Witteberg Group, South Africa. *Review of Palaeobotany and Palynology* **89**: 417-428.

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Hiller, N. and Gess, R.W. (1996). Marine algal remains from the Upper Devonian of South Africa. *Review of Palaeobotany and Palynology* **91**: 143-149.

Long, J.A., Anderson, M.E., Gess, R.W. and Hiller, N. (1997). New placoderm fishes from the Late Devonian of South Africa. *Journal of Vertebrate Palaeontology* **17:** 253-268.
Taylor, F.F. and Hiller, N. (1993). A new Devonian fossil plant locality in the eastern Cape Province, South Africa. *South African Journal of Science* **89**: 565-568.