Palaeontological survey and report for borrow pits in the Chris Hani district

Prepared for: Biotechnology and Environmental Specialist Consultancy cc
PO Box 8241, Nahoon, 5210, East

Compiled by: Robert Gess
Bernard Price Institute for Palaeontological Research
University of the Witwatersrand
(Research Associate of the Albany Museum)

c/o Box 40
Bathurst
6166
robg@imaginet.co.za

August 2011

Contents:

Background

The Department of Roads and Public works proposes to utilise borrow pits for upgrade/regravelling projects located throughout the Chris Hani District Municipality. BESC have been appointed to compile the Environmental Management plans for these borrow pits. All of the borrow pits are existing and most 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

Borrow pits in this area are situated in sedimentary strata belonging to the Balfour Formation (Adelaide Subgroup, Beaufort Group), Katberg Formation (Tarkastad Group), Burgersdorp Formation (Tarkastad Group) and Molteno Formation (Stormsberg Group), of the Karoo Supergroup. In addition many borrow pits exploit dolerite that crystalised from magma into underground dykes and sills during eruption of the Drakensberg Formation basalts. One borrow pit exploits Quaternary calcrete.

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 Permian **Koonap Formation**, **Middleton Formation** and **Balfour Formation** (**Adelaide Subgroup**, **Beaufort Group, Karoo Supergroup)**. Of these only the Balfour Formation is intercepted by borrow pits in the study area – in the vicinity of Cradock. In the Cradock – Pearston- Adelaide area lacustrine conditions are indicated for much of the Balfour Formation (Johnson, 1976, PhD Rhodes Univ.)

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 return to a meandering river system, possibly as a result of a recovery of vegetation cover is reflected in the mudstone dominated strata of the **Burgersdorp Formation** (**Tarkastad Subgroup, Beaufort Group, Karoo Supergroup**).

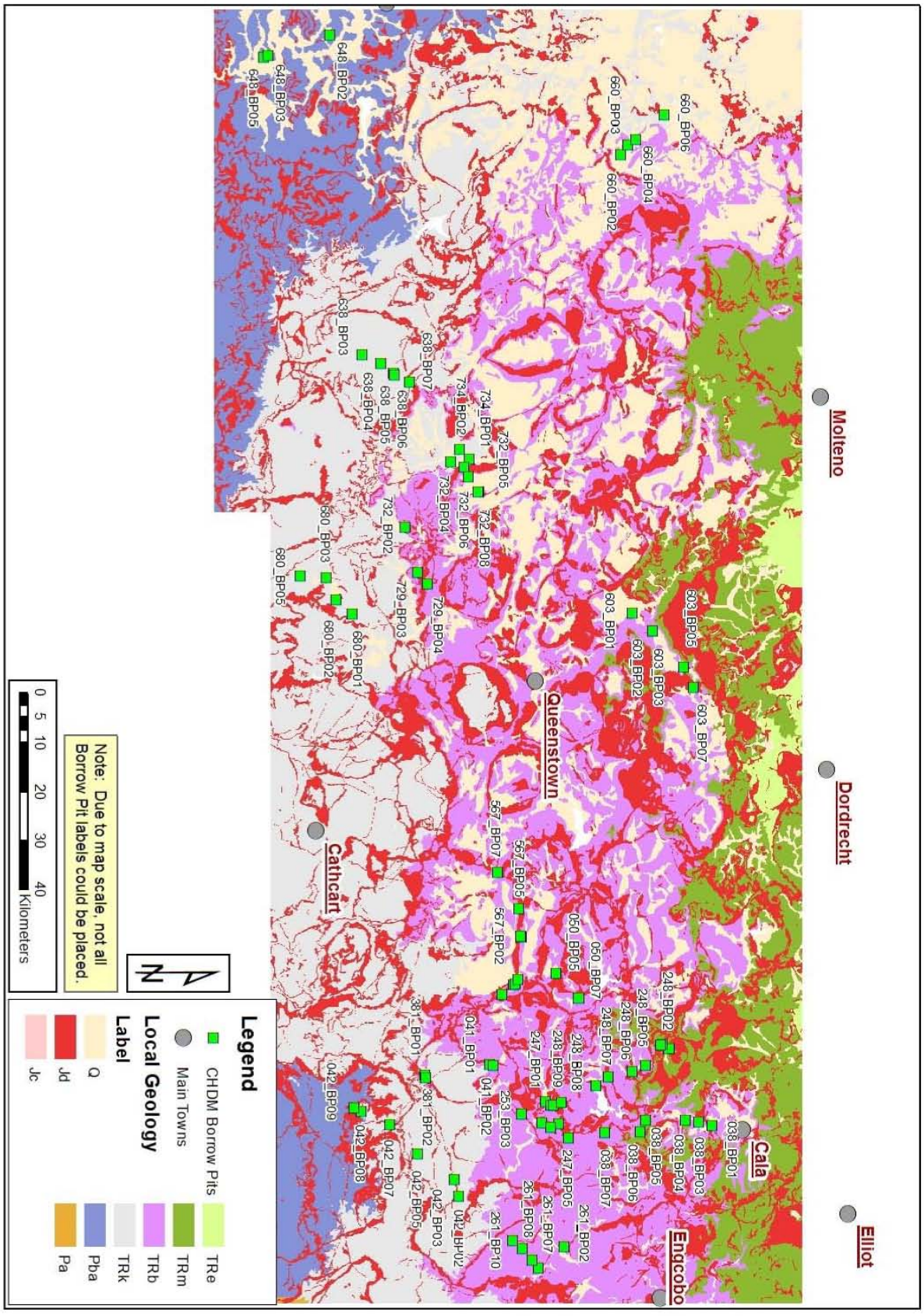
The Burgersdorp Formation is overlain (following a short discontinuity caused by regional uplift) by thick sandstones that constitute the **Molteno Formation** (lowermost member of the **Stormsberg Group, Karoo Supergroup**). These sandstones were deposited by large braided river systems, following uplift of the subcontinent and the onset of a cycle of increasing aridification. Occasional coal seams in the Molteno Formation represent localised swamps.

During the formation of the volcanic **Drakensberg Group (Stormsberg Group, Karoo Supergroup)**, during the Jurassic, 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.

In more geologically recent (Quaternary) times the poor drainage of the low gradient plains of the northern Karoo has resulted in deposition of isolated calretised palaeosols associated with former brak pans.

Figure 1. (below)

Geological map of the study area, combining Geological Survey data with borrow pit positions.
Q = Quaternary cover,
Jd = Jurassic dolerite,
TRe = Elliot Formation (Stormsberg Group, Karoo Supergroup)
TRm = Molteno Formation (Stormsberg Group, Karoo Supergroup)
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),


Molteno
Dordrecht
Elliot
Cala
Engcobo
Queenstown
Cathcart
Legend
CHDM Borrow Pits
Main Towns
Local Geology
Label
Q
Jd
Jc
TRe
TRm
TRb
TRk
Pba
Pa
Note: Due to map scale, not all Borrow Pit labels could be placed.
0 5 10 20 30 40
Kilometers
N

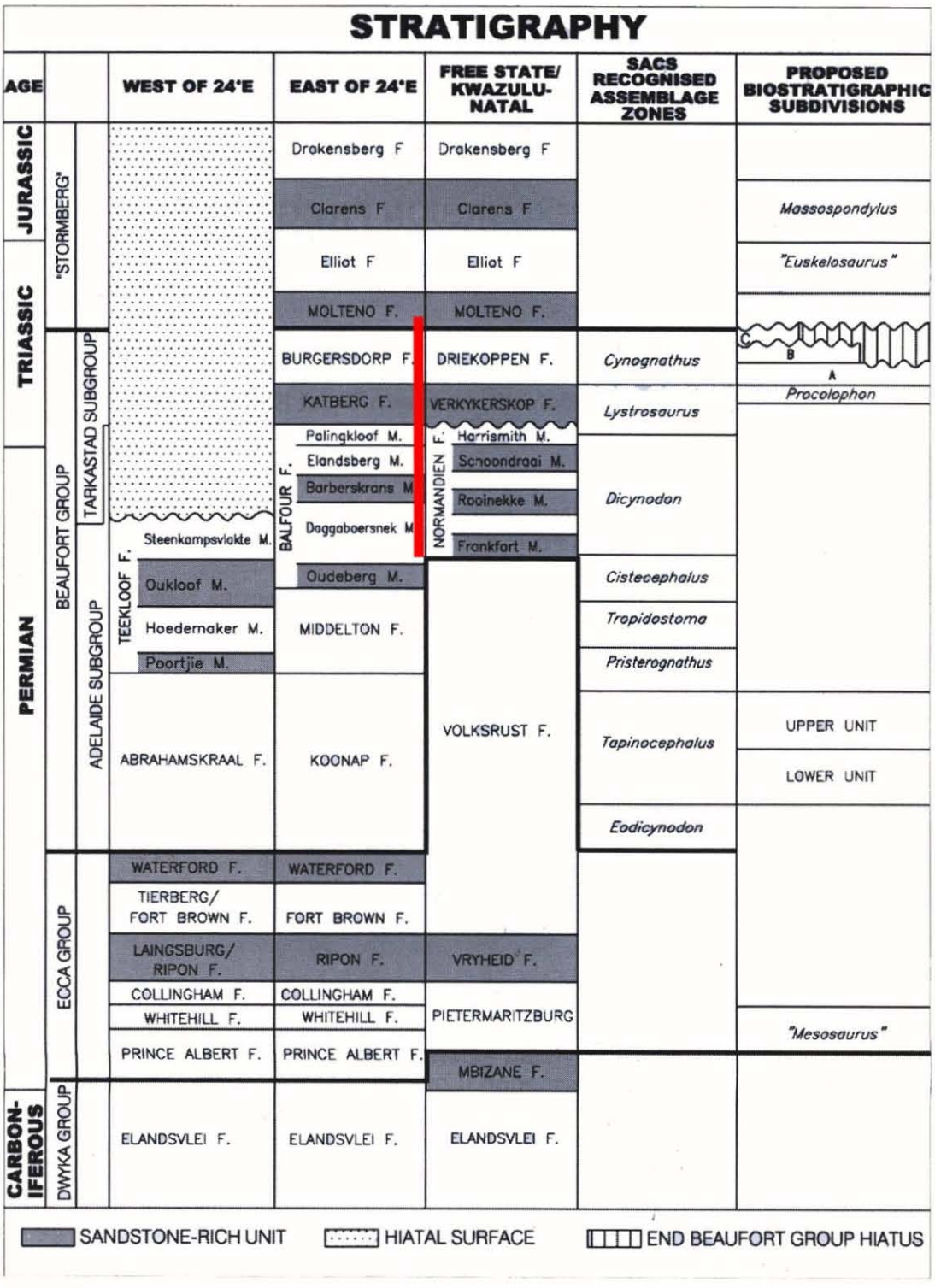


Figure 2. Stratigraphic column and corresponding biostratigraphy of the Karoo Supergroup (modified after Rubidge, B.S. 2005. *South African Journal of Science*. 108: 135-172). Red line indicates probably range of strata affected by the development)

Palaeontology

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 lower units are not represented in this area.

Though including the upper *Cistephalus* Assemblage Zone and possibly the 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 taxa 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 **Katberg Formation** (**Tarkastad Subgroup, Beaufort Group, Karoo Supergroup**) falls entirely within the *Lystrosaurus* Assemblage Zone. A marked faunal change occurs between the *Dicynodon* and *Lystrosaurus* Assemblage Zones approaching the top of the Balfour Formation. This corresponds to the major extinction event associated with the Permo-Triassic boundary.
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.

Though including the uppermost level of the *Lystrosaurus* Assemblage Zone, the Burgersdorp Formation largely corresponds to the *Cynognathus* Assemblage Zone. Synapsid therapsid diversity does not demonstrate recovery between the *Lystrosaurus* and *Cynognathus* assemblage zones. The Dicynodontia, *Lystrosaurus* and *Myosaurus* are replaced by *Kombuisia* and the giant *Kannemeyeria*. Therocephalia exhibit a turnover of taxa at generic level, but an overall reduction in diversity. Cynodontia (Therapsida, Synapsida) alone amongst synapsids demonstrate a slight increase in genera. These include the small advanced Cynodont, *Cynognathus*, which together with the Cynodont *Diademodon* and the Dicynodont *Kannemeyeria,* characterise this assemblage zone. Eosuchid and captorhinid Reptilia are moderately common, though showing no generic continuity with taxa of the underlying zone. Amphibia remain diverse, though they are not as gererically diverse as in the *Lystrosaurus* Assemblge Zone and likewise demonstrate no genus level continuity therewith. Fossil fish reach their greatest known Karoo Supergroup diversity in the Burgersdorp Formation (*Cynognathus* Assemblage Zone). Plants (*Dadoxylon, Dicroidium* and *Schizoneura*), trace fossils (including both vertebrate and invertebrate burrows) and a freshwater bivalve (*Unio karooensis*) have also been recovered.

Coaly and mudstone units within the **Molteno Formation** (**Stormsberg Group, Karoo Supergroup**) have provided an incredible view of late Triassic gymnosperm diversity. On an ordinal level, this appears to have been far greater than modern gymnosperm diversity, extensive reduction in taxa having later occurred during an extinction event towards the end of the Triassic. Plant fossils are associated with a remarkable record of contemporary insect life. The Molteno Formation has, as yet, produced no record of tetrapod life, though rare fish have been recorded.

Dolerite, being of magmatic origin, contains no fossils.

Calcrete hardpans may contain the remains of Quaternary mammal species (from the last few hundred thousand years) differing from those of today. In addition such Quaternary deposits have the potential to contain the remains of early *Homo sapiens*. The Hofmeyer skull, discovered in a donga near Hofmeyer in 1955 has recently been dated to 36 000 years ago (towards the end of the Middle Stone Age), making it the only reasonably preserved human skull from southern Africa from between 20 000 and 70 000 years ago

Whereas the Karoo Supergroup strata of the Karoo Basin have 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 there from will be valuable.

Site visit

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

Figure 3. Borrow pit 603 BP02 at the time of the survey.

Shales of the **Balfour Formation** (**Adelaide Subgroup, Beaufort Group, Karoo Supergroup**), occur in borrow pits of the 638 series south of Cradock. These borrow pits reveal that the Balfour Formation here consists of fine grained dark green mudstones compatible with a lacustrine setting. Plant drag marks and invertebrate traces were observed on some surfaces. Although no Glossopteris leaves were found, the sedimentary environment indicated would have lent itself to the preservation of leaves and it is quite likely that they will be found with excavation of fresh material.

Figure 4. Balfour Formation: Dark green finely laminated mudstones at 648 BP05

Figure. 5. Plant drag marks on a bedding surface at 648 BP05

A number of borrow pits within this study area expose mudstones and sandsones of the **Katberg Formation** (**Tarkastad Subgroup, Beaufort Group, Karoo Supergroup**). These include 042 BP05, 381 BP01 and BP02, the 680 series, the 638 series, possibly 660 BP06, 734 BP01, 734 BP02 and 732 BP04

Whilst significant fossils were not found in the 042 and 381 borrow pits it should be noted that these borrow pits are situated within an area that is proving one of the most productive for vertebrate palaeontological studies in the Transkei. During the Amathole District borrow pit survey (done back to back with this one) an extremely important vertebrate burrow site was discovered just south east of this area. Somewhat north east of this, about 20km south of Engcobo on the R408, Bordy and colleagues have also reported vertebrate burrows (proceedings of the 2010 PSSA conference). In addition, Bordy *et al*. (proceedings of the 2010 PSSA conference) have collected the skulls of a *Lystrosaurus* and a *Thrinaxodon* at Tsomo, not far from 042 BP05. Exposure of fresh material in this area is therefore not unlikely to disturb further

material.

Katberg Formation deposits throughout this district were found to commonly contain thick maroon mudstone sequences interbedded between sandstone layers. These mudstones generally exhibit mud crack surfaces and bedding planes of closely spaced small vertical invertebrate burrows. Small sandstone beds often contain rippled layers or layers of ripped up mud clasts. One layer containing ripped up mud clasts at 638 BP04 was also found to contain a vertebrate coprolite (fossil dropping). A bone fragment was found in purplish mudstone at 638 BP03.

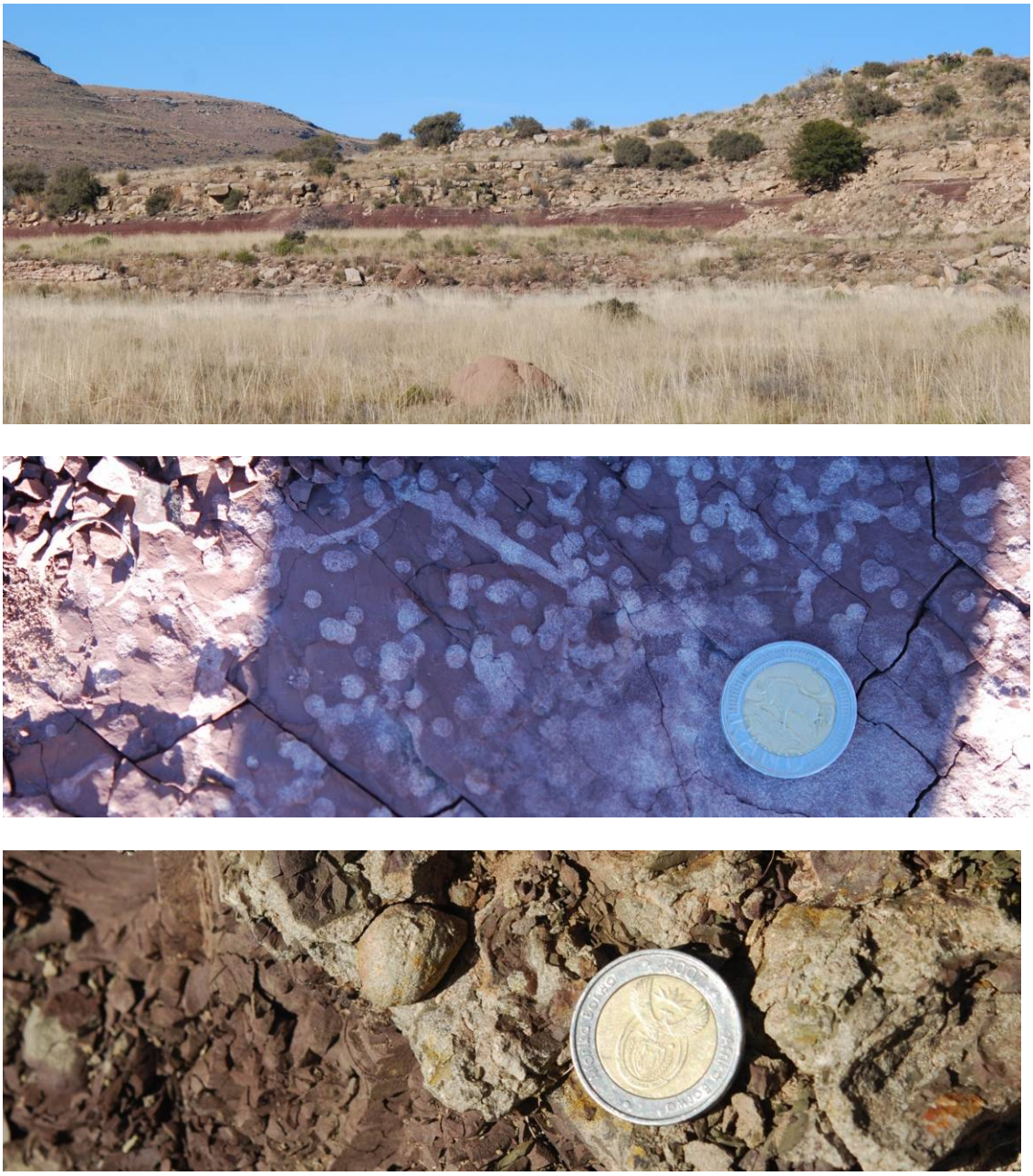


Figure 6. Katberg Formation: Borrow pit 638 BP04: Mudstone interbed exposed by borrow pit (*top*), casts of mud cracks and small invertebrate burrows (*middle*), vertebrate coprolite (dropping) preserved in a mud chip conglomerate to left of R5 coin (*bottom*).

Figure 7: Katberg Formation: Borrow pit 638 BP03: Current soutcrop of shale (*above*), fragment of bone preserved in mudstone (*below*).

More fossil bone material was found at borrow pit 660 BP06 (near Hofmeyer) which, according to Geological Survey maps, is situated in the upper part of the Katberg Formation. Presence of a coarse sandstone interbed with lag deposits of plant stems (represented by iron stained impressions) more closely resembles conditions in the Burgersdorp Formation. Based on fieldwork near Engcobo Bordy *et al*. (proceedings of the 2010 PSSA conference) has postulated a transitional boundary of several tens of meters thick between the Katberg and Burgersdorp Formations in that region . It is likely that 660 BP06 actually falls within this boundary between the Katberg and Burgersborp Formations.

This very large and significant borrow pit exposes a thick mudstone package in its lower section. This is associated with ripple marks and fossilised bones. These include a series of articulated vertebrae.

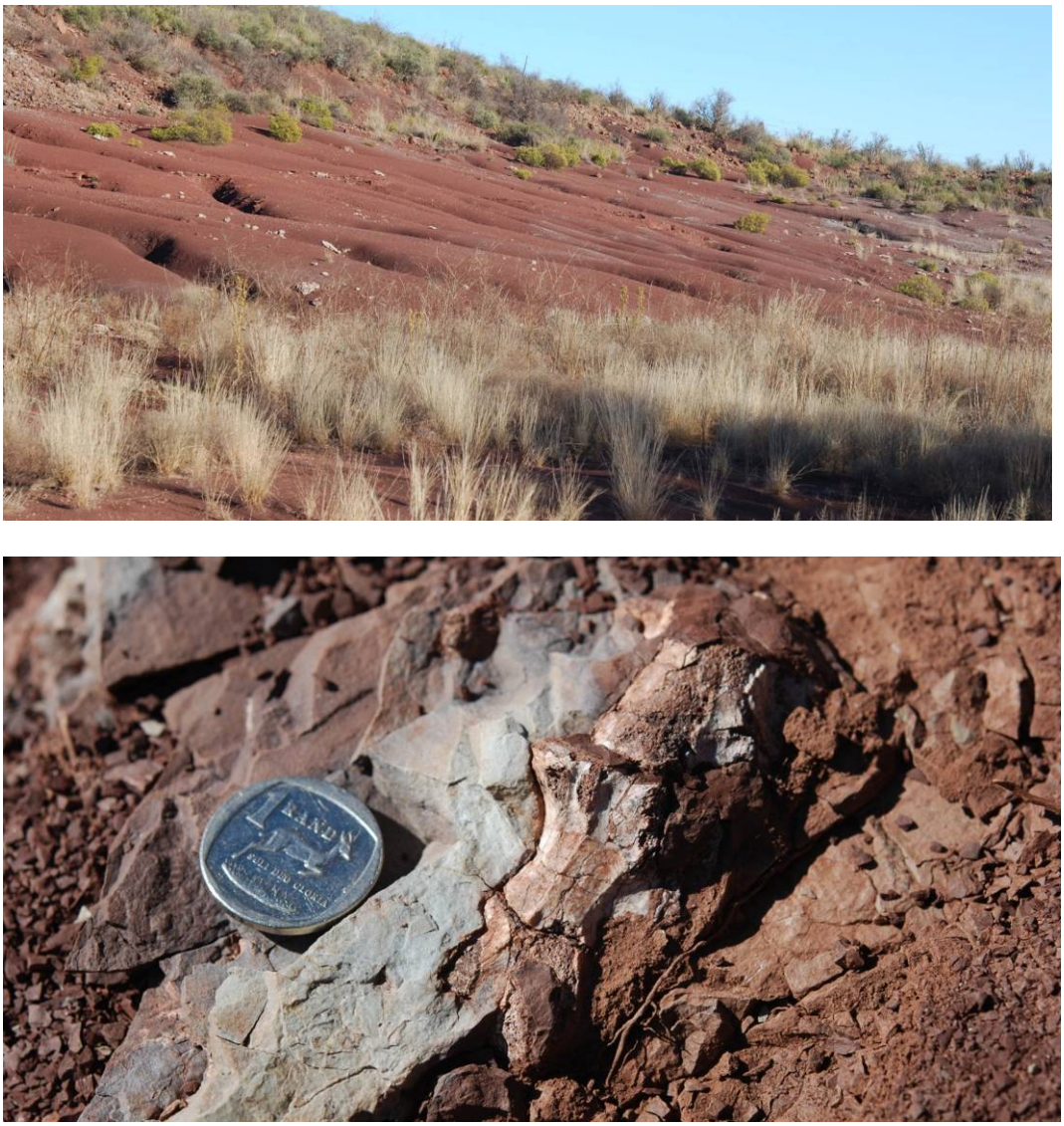


Figure 8: Uppermost Katberg Formation: Borrow pit 660 BP06: Thick package of mudstone in the lower part of the section (*above*), fossil vertebrae (*below*).

The upper portion of the section exposed at 660 BP06 contains a discontinuous layer of coarse greenish sandstone with lag deposits of plant stems of a variety of types. This layer also contains disassociated vertebrate remains.

Figure 9: Uppermost Katberg Formation: Borrow pit 660 BP06: Sandstone layer near top of section with field assistant sitting at point where vertebrate material was recovered.

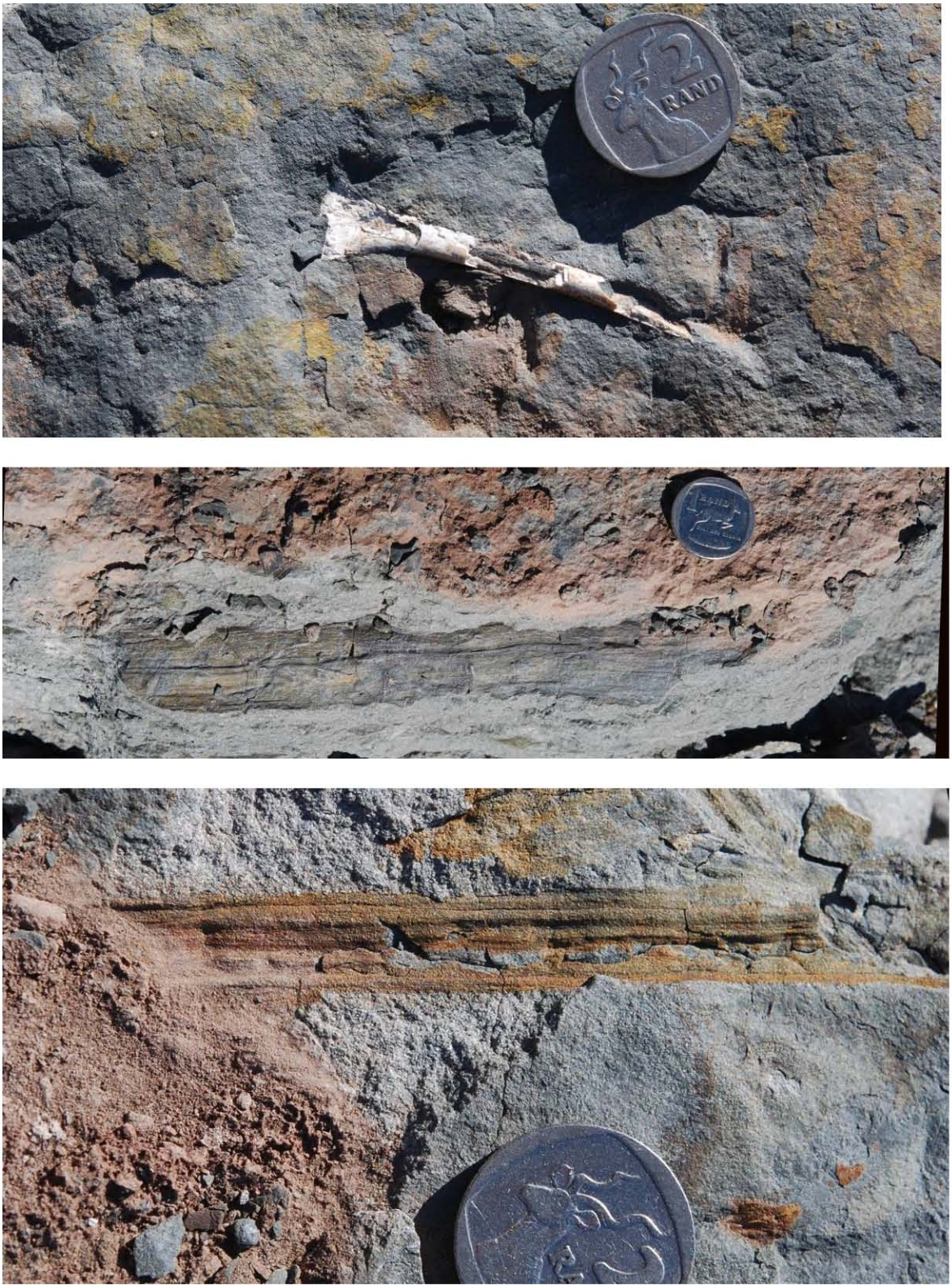


Figure 10: Uppermost Katberg Formation: Borrow pit 660 BP06: Bone and plant stem remains from lag deposit in sandstone near the top of the section (see Figure 9)

Borrow pits exposing strata of the **Burgersdorp Formation** (**Tarkastad Subgroup, Beaufort Group, Karoo Supergroup**) include 660 BP02-BP04, 732 BP06, BP08, 732 BP02, 729 BP03-BP04, 603 BP03, BP05, 050 BP01-BP05, BP07, 567 BP02-BP05, 247 BP01-BP02, BP04-BP05, 248 BP05-BP09, 253 BP03-BP05, 038 BP01, BP07, 041 BP01-BP02, 261BP07-BP10.

These borrow pits commonly comprise purplish and grey-greenish mudstones, (generally less red in colour than those of the underlying Katberg Formation). These contain medium grained sandstone interbeds. The mudstones contain mud cracks and layers of small vertical invertebrate burrows similar to those occurring in the Katberg Formation.

Some sandstones layers contain abundant plant impressions, particularly those of diverse plant stems. Particularly significant plant rich outcrops occur at borrow pits 567 BP03, 050 BP01, and 248 BP08.

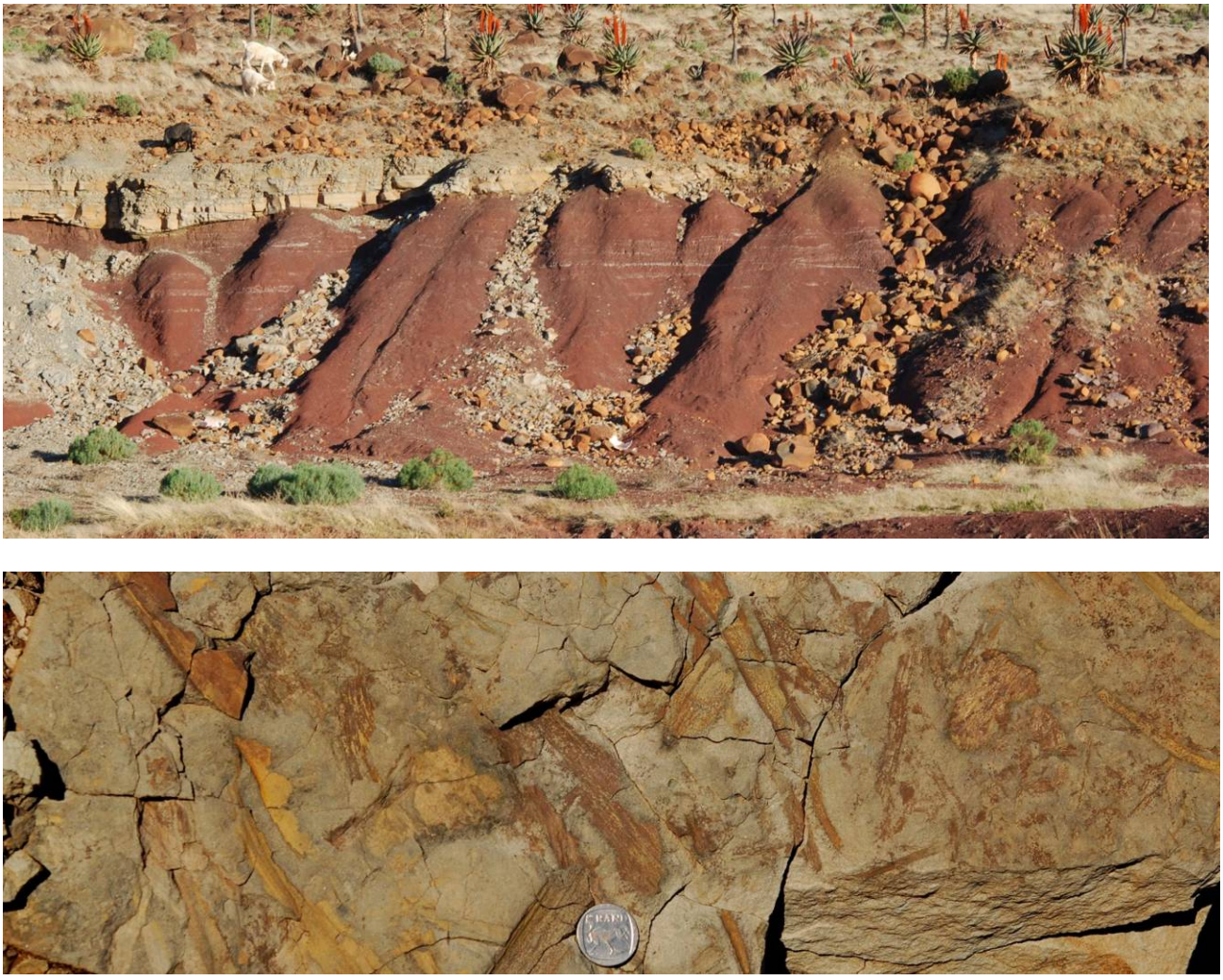


Figure 11. Burgersdorp Formation: Borrow pit 567 BP03 showing sandstone overlying mudstone (*above*), Layer crowded with plant remains (*below*).

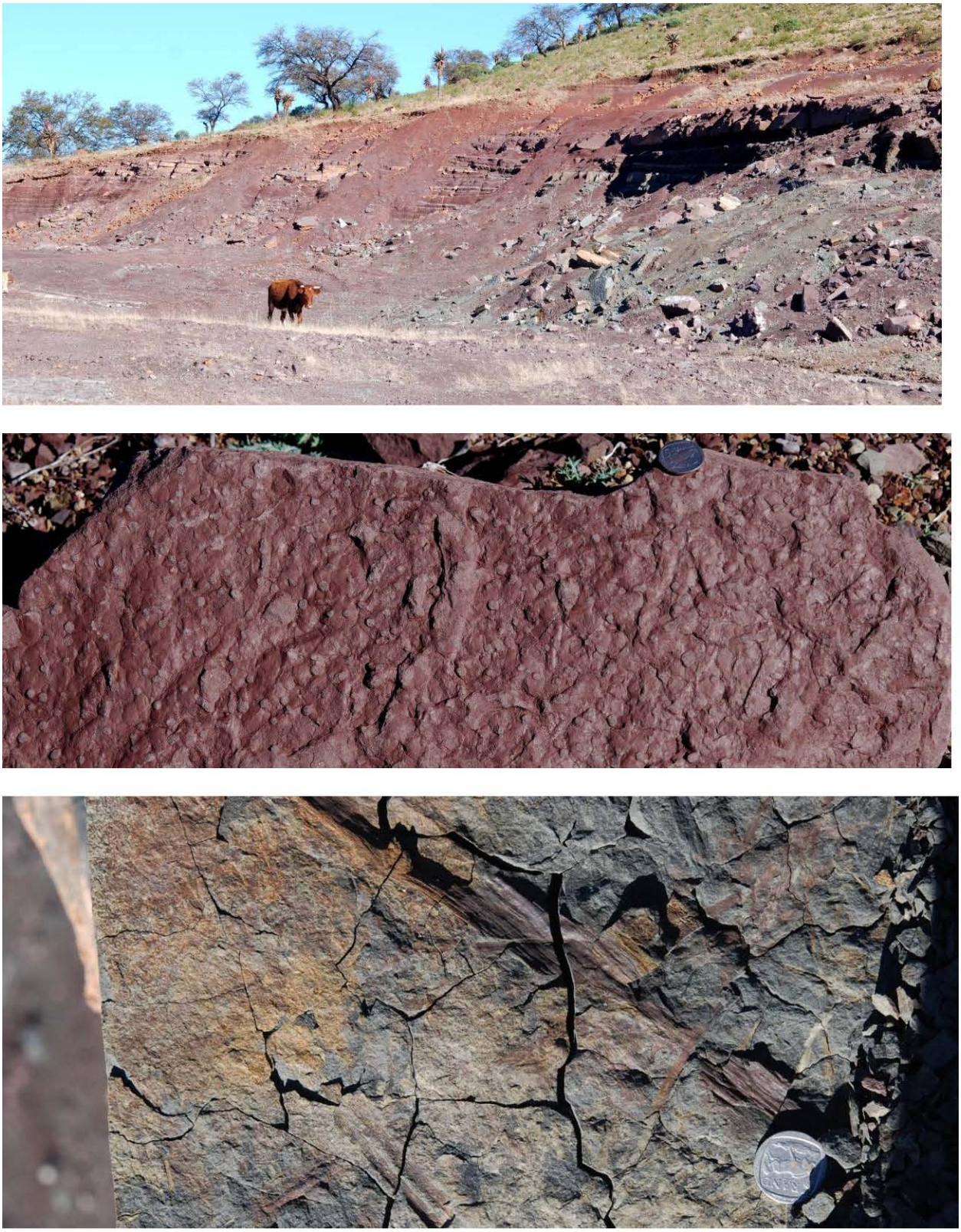


Figure 12. Burgersdorp Formation: Borrow pit 050 BP01: strata (*above*), impression of mud cracks and crowded vertical invertebrate burrows (middle) sandstone crowded with plant stems (bottom).

Figure 12. Burgersdorp Formation: Borrow pit 248 BP08: view (*above*), impression of *Lepidopteris* sp. (sead fern frond) (*middle, left*), large stem (*middle, right*), natural internal cast of sphenophyte stem (*bottom*).

Strata of the **Molteno Formation** (**Stormsberg Group, Karoo Supergroup**) occur in few borrow pits. These are 248 BP01, 248 BP02 and 248 BP03. All of these contained plant matter. That at BP01 was hardly recognisable, that at BP03 included sphenophyte stems whearas material at 248 BP02 was well preserved and most diverse. In this borrow pit, creamish mudstones have been slightly baked due to the close proximity of a dolerite dyke. Particularly well preserved material was found in a test pit a little to the north of the main working.

Figure 13. Molteno Fm: Test pit on northern edge of 248 BP02 (*top*), plant 'cone' c.f. *Sewardistrobus* sp. (*mid left*), unidentified leaf (*mid rt.*), sphenophyte stems (*bottom*)

Quaternary calcrete is exposed in 660 BP02 where it forms a broad band overlying decayed purplish Burgersdorp Formation mudstone. The calcrete layer is overlain by a river terrace or erosional residue deposit of weathered lydianite stones, some of which show middle stone age working. A spring based vlei currently occupies the borrow pit. The outcrop was carefully examined but no fossil bone material was found.

Figure 14. Quaternary calcrete: Borrow pit 660 BP02 with calcrete layer exposed in back wall and spring deposit in foreground (*top left*), stony lydianite rich layer overlying calcrete (*middle, left)*, middle stone age tools amongst stones (*bottom left*), middle stone age tools (*right*).

Conclusions and Recommendations

This survey was partially conducted in an area with a palaeontological heritage which has not been well studied for historical reasons (former Ciskei and Transkei). 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.

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. A palaeontologist is required to visit sensitive borrow pits shortly after removal of aggregate is resumed. This will permit 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 during the duration of excavations, on one side). This would comprise fossil bones or slabs of plant material.

   Sensitive borrow pits include 248 BP02 in the Molteno Formation;
   248 BP08, 050 BP01 and 567 BP03 in the Burgersdorp Formation and
   660 BP06, 638 BP04, 638 BP03, 381 BP01, BP02, 042 BP05 in the Katberg Formation;

2. 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.

3. Discovery of fossil bones or fossil leaves in any borrow pit during excavations should be reported to a palaeontologist.