# *PALAEONTOLOGICAL TECHNICAL REPORT FOR KWAZULU-NATAL*


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**EXECUTIVE SUMMARY**

The geological history of Kwazulu-Natal covers over 3100 million years of Earth history. Rocks, containing fossils or traces of fossils provide information about the palaeo-environments that existed in the past and the fossil history is therefore part of the Natural Heritage of the Province. The aim of this report is to ensure a better understanding of the fossil heritage in South Africa and to make it clear that fossils are not restricted to the Main Karoo Basin. Although metamorphic provinces are usually non-fossiliferous, low grade meta-sediments of a localized occurrence in the Pongola Group contain good examples of bio-sedimentary stromatolites.

Most fossils are hidden in the bedrock and developers will only be able to assess specific reference to fossils once the topsoil has been removed and excavation has exposed the bedrock. The report presented here must be used in conjunction with published geological maps and as such can be used by heritage and environmental assessment practitioners as well as private developers, to evaluate the potential impact of proposed developments on fossil heritage of the province. Rock units are ranked in terms of its palaeontological sensitivity according to a three-point scale, from which the appropriate action to be taken (if any) before or during development can be inferred.

Present legislation makes provision for the protection of fossil heritage as part of the National Heritage legislation. Despite the comparatively good legal protection offered to palaeontological heritage in South Africa by the current legislation, hitherto this aspect of natural heritage has been largely ignored by developers and professional heritage managers alike, mainly due to confusion between palaeontological and archaeological heritage. The National Heritage Resources Act of 1999 (pp 12-14) and the KwaZulu Natal heritage Act of 2008 protects a variety of heritage resources.

The geological foundation of Kwazulu-Natal is represented by the Kaapvaal Craton and the Natal Metamorphic Province, the ancient foundations of Kwazulu-Natal. The overlying Pongola Supergroup, with specific reference to the lower Nzuse Group, contains fossils of stromatolites. The Pongola Supergroup is overlain by the Natal Group sediments which in turn are followed by the Dwyka Group tillites, Ecca Group, Beaufort Group and Stormberg Group sedimentary sequences, culminating in the Jurassic volcanic deposits of the Drakensberg Formation and Lebombo Group with associated dolerite intrusions.

The Jurassic geology of KwaZulu-Natal is unconformably overlain by younger sediments of the Mzamba Formation, Cretaceous Zululand Group sediments and Tertiary to Quaternary formations of the Maputuland Group.

In the older formations of KwaZulu-Natal, fossils are associated with the Nsuze Group of the Pongola Supergroup. No fossils have been described from the Natal Group, but trace fossils have been recorded in the overlying Dwyka Group. The Ecca Group is not known to contain body fossils of vertebrates, but trace and plant fossils have been described from the group. Only trace fossils are known from the Pietermaritzburg Formation whereas the Vryheid Formation is well-known for the occurrence of coal

beds that resulted from the accumulation of plant material over long periods of time. Plant fossils described by Bamford (2011) from the Vryheid Formation are; *Azaniodendron fertile, Cyclodendron leslii, Sphenophyllum hammanskraalensis, Annularia sp., Raniganjia sp., Asterotheca spp., Liknopetalon enigmata, Glossopteris > 20 species, Hirsutum 4 spp., Scutum 4 spp., Ottokaria 3 spp., Estcourtia sp., Arberia 4 spp., Lidgetonnia sp., Noeggerathiopsis sp. and Podocarpidites sp.* The bivalve *Megadesmus* is described from the Late Permian Volksrust Shale Formation in the north-eastern Karoo Basin, South Africa; this is the first reported discovery of this genus in Africa.

The Permian to Triassic Beaufort Group records one of the most important extinction events in geological history. The lower Adelaide Subgroup, Estcourt and Normandien formations contain fossils characteristic of the *Cistecephalus, Dicynodon* and *Lystrosaurus* assemblage zones, and plant fossils of the *Glossopteris* Assemblage are also described from these sediments. Recent research confirms that the Emakwezini Formation in the eastern part of KwaZulu-Natal contains a fossil assemblage of animal traces, insects, molluscs, arthropods, fish and plants. Previously, only *Glossopteris* leaves and *Phyllotheca australis* had been described from this formation, on the basis of a few very small, scattered and poorly provenanced collections.

The Upper Beaufort Tarkastad Subgroup contains sediments of the lower Katberg Formation (correlated with the Verkykerskop Formation in the north), which is associated with the *Lystrosaurus* Assemblage Zone, and the upper Burgersdorp Formation (correlated with the Driekoppen Formation in the north), which is associated with the Cynognathus Assemblage zone.

The Stormberg Group consisting of the Molteno, Elliot and Clarens formations is fossiliferous and the Molteno Formation is considered to be one of the most productive deposits of Triassic plant fossils of *Dicroidium* assemblages in the world. At their peak development, during the Late Triassic, these seed ferns inhabited a variety of ecological niches, including riverine forests, wetlands and open woodland. The open woodland was dominated by cycadeoids, ginkos and conifers. Rich assemblages of insects are also recorded from these sequences. Although no vertebrate remains have been described from the Molteno Formation several sightings of dinosaur tracks are described from the formation.

In general, the Elliot Formation is globally recognized for the abundance of early dinosaur and mammal fossils, including the remains of dinosaur eggs containing embryos. The Clarens Formation contains dinosaur body fossils and footprints as well as invertebrate burrows.

The Jurassic Drakensberg and Lebombo Groups and associated dolerite intrusions have no palaeontological significance due to the igneous nature of the rocks.

The basal sandstone of the Mzamba Formation contains charred wood fragments (bored by *Teredo*, a gastropod), shark teeth and vertebrate remains. During deposition of the Zululand Group sediments, large snail-like animals up to one metre in size, called ammonites, thrived in the warm ocean. Their shells are common in almost all exposures of Cretaceous rocks, such as along the shorelines surrounding Lake St Lucia. The Makatini Formation contains large fossil logs that are pervasively drilled by *Teredo*

wood boring organisms. The overlying Mzinene Formation consists of glauconotic siltstone and sandstone with a rich invertebrate fauna, including bivalves, gastropods, ammonites, nautiloids and echinoids. Concretions bored by *Lithophaga*, are also common. Fossil logs, bored by *Teredo*, are commonly found in the formation. The upper St Lucia Formation is more fossiliferous than the underlying Mzinene Formation and contains an abundance of echinoid, bivalve, gastropod and cephalopod remains as well as fossil logs, plant fragments, reptile bones and at least 62 ostracod species.

The Maputuland Group forms a thin blanket of Tertiary and Cretaceous successions that extend from Durban northwards into Mozambique. The less detailed subdivision of Wolmarans and Du Preez (1986) are mapped on the scale of this project and is, for reasons of simplicity, preferred to the more detailed subdivision of Johnson et al (2006).

The main portion of the Uloa Formation comprises about 5 metres of unbedded calcirudite, locally known as the “Pecten Bed”, due to the abundance of the bivalve *Aeqipecten uloa.*

Gastropods, brachiopods, coralline algae, corals, polyzoa, foraminifera and echinoids are also present, as well as isolated teeth of the extinct giant shark *Carcharodon megalodon* (Johnson et al, 2006). The depositional environment is interpreted as a response to at least three transgressive events superimposed on a first-order regression during the Neogene. No fossils have been recorded from the Muzi Formation.

The Port Durnford Formation comprises a succession of carbonaceous muds and sand, containing fossils of terrestrial vertebrates such as hippopotamus, buffalo, antelope, rhinoceros and elephant as well as marine fossils including crustaceans and fish, foraminifera, marine moluscs and fragments of turtles and crocodiles.

The Bluff Formation has local fossiliferous zones whereas the Berea Formation, as well as the Masotcheni Formation and recent alluvial and sand deposits, do not contain significant fossil remains.

**GLOSSARY**

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| **ammonites or ammonoid** | any taxa belonging to a group of cephalopods of the subclass Ammonoidea, which appeared in the lower Devonian and were extinct by the end of the Cretaceous Period. They typically have an external chambered shell, planispirally coiled and often ornamented with ribs and knobs. Ammonoids are important index fossils because of their rapid evolution and wide geographical distribution in shallow marine waters. |
| **basalt** | dark coloured, fine-grained basic (low silica [45-52%] and relatively high calcium, iron and magnesium) volcanic rock, composed mainly of the minerals calcium plagioclase and pyroxene, usually augite, with or without olivine. |
| **basalt lava** | the most abundant lava type - it forms the upper layer of the oceanic crust, and is the chief constituent of intraplate oceanic islands. Varieties of basalt are found in island arcs and at active continental margins, and vast amounts of continental flood basalts have been erupted, associated with tension and rifting of the continents (e.g. Karoo flood basalts, southern Africa and Deccan flood basalts of India). |
| **basaltic crust** | the crust is the outermost layer of the Earth, the lower boundary of which is called the mohorovcic discontinuity or 'moho'. Part of the crust is termed ‘continental’ (an assemblage of igneous, sedimentary and metamorphic rocks rich in elements such as silicon and potassium), the other part, ‘oceanic’. Oceanic crust is much younger and thinner (5-10 km) than the continental crust (25-90 km). Oceanic crust is constantly being generated at mid-ocean ridges, and destroyed as it moves to a subduction zone. Basalts are the main material of the upper oceanic crust. |
| **basement** | the geological basement, the surface beneath which sedimentary rocks are not found; the igneous, metamorphic, granitised or highly deformed rock underlying sedimentary rocks. |
| **basins** | a depression of large size, which may be of structural or erosional origin. The Karoo Basin extended across much of southern Gondwana and records 120 million years of geological history, being the site of sediment deposition for that length of time. |
| **breakup (Gondwana)** | the splitting up of a continent or supercontinent (in this case the supercontinent Gondwana) into smaller continental blocks or fragments. |
| **burrow** | a pipe-like structure in sedimentary rock, made by an animal that lived in the soft sediment. Often filled with clay or sand, they may be along the bedding plane or may penetrate the rock. |

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| **Cambrian** | The oldest period of the Palaeozoic Era, having a duration of about 85 million years and beginning about 590 million years ago. Rocks of the Cambrian system are the oldest in which fossil remains are sufficiently abundant and distinct, because of hard parts, to provide reliable geological information. |
| **clay** | a smooth, earthy sediment or soft rock composed chiefly of clay-sized (less than 0.004 mm in diameter) or colloidal particles and a significant content of clay minerals. |
| **collision zone** | the zone or belt where two pieces of continental crust collided after closure of an intervening ocean. |
| **conglomerate** | coarse-grained clastic sedimentary rock, composed of more or less rounded fragments or particles at least 2 mm in diameter (granules, pebbles, cobbles, boulders), set in a fine-textured matrix of sand or silt, and commonly cemented by calcium carbonate, silica, iron oxide, or hardened clay. |
| **continental blocks** | separate or geologically unique blocks or rock masses that together form a continent - these would have formed independently of one another, having different geological histories and ages. |
| **craton** | a part of the continental crust that has been stable for at least 1000 million years. Cratons are typically formed of Lower to Middle Precambrian igneous and metamorphic rocks with a subdued surface relief which in places are overlain by largely undeformed Upper Precambrian or younger sedimentary rocks. |
| **Cretaceous** | the interval of geological time that began about 140 million years ago, and lasted about 75 million years. It is the final period of the Mesozoic Era, and precedes the Tertiary Period. |
| **crustaceans** | any arthropod of the subphylum Crustacea, characterized chiefly by two pairs of antenna-like appendages in front of the mouth and three behind it. Present groups are represented by shrimp, crabs, lobsters, copepods and isopods; most forms are marine. |
| **deformed** | having undergone deformation - the alteration, such as faulting, folding, shearing, compression and extension of rock formations by tectonic forces. |
| **desertification** | is the slow expansion of the world's deserts, either due to gradual climate change, and currently also due in part to rain falling in the desert margins, and the land being heavily farmed and overgrazed, allowing soil to dry out completely. |
| **dinosaur** | Any taxon of that particular group of reptiles that dominated or were prominent among Mesozoic life forms. They are divided into two forms on the basis of pelvic structure: the Saurischia with a reptile pelvis structure, and the Ornithischia, in which the pelvis resembles that of a bird. They ranged in size from 30 cm to 26 m. They were carnivorous, herbivorous, bipedal or quadrupedal. Most were terrestrial, but there were also aquatic and semi-aquatic representatives. |

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| **dolerite** | a medium-grained intrusive igneous rock of basaltic composition, composed of the minerals pyroxene, plagioclase and iron-titanium oxides. Preserved as dykes and sills in the field - feeding magma to form basalt lava flows. |
| **dyke** | a tabular body of intrusive igneous rock that cuts across the layering or structural fabric of the host rock. It may be a composite or comprise multiple intrusions. |
| **erosion** | the wearing away of any part of the Earth's surface by natural agencies. These include mass wasting and the actions of waves, wind, streams and glaciers. Fundamental to the process of erosion is that material must be picked up and carried away by such agents (transportation). |
| **estuarine** | originating in an estuary - formed where a deeply cut river mouth is drowned following a land subsidence or a rise in sea level. Fresh water intermixes with seawater and tidal effects occur. |
| **extinction** | the dying-out of a plant or animal species. This may have arisen from a variety of causes, for example increased competition for certain niches, variation in the physical environment such as climatic change or fluctuations in sea-level, which affect the range of habitats available. |
| **faulting** | the action or process of fracturing and displacement that produces a fault - a fracture in earth materials, along which the opposite sides have been relatively displaced parallel to the plane of movement. The surface along which movement takes place is known as the fault plane, or fault surface. Faulting may mark the walls of the fault plane with slickensides - a striated and polished surface from the grinding and sliding of two rock masses against one another. |
| **glacial pavement** | bedrock surface with fine-cut parallel or near-parallel lines made by rock fragments carried in a glacier which travelled over the bedrock. |
| ***Glossopteris*** | a late Palaeozoic genus of fossil plant (tongue-ferns) found throughout the glaciated regions of the Southern Hemisphere. *Glossopteris* flora bore clusters of simple spatulate leaves. |
| **gneiss** | a foliated metamorphic rock formed under conditions of high grade regional metamorphism. It is usually coarse-grained and characterised by a layered appearance due to the segregation of ferromagnesian from quartzo-feldspathic minerals in discontinuous layers or lenticles. |
| **Gondwana** | the southern supercontinent taking its name from the Gondwana system of India, dating to the late Palaeozoic and early Mesozoic, and containing glacial tillites below coal measures. Similar rock sequences of the same age, containing identical fossil flora (*Glossopteris*) show connections of the southern continents of Antarctica, Africa, Madagascar, South America, Australia and India. |

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| **granite** | a light coloured medium to coarse-grained plutonic(of deep seated origin) igneous rock composed mainly of quartz and feldspar with biotite and/or hornblende as the commonest ferromagnesian minerals. |
| **greenstone belt** | embedded in the ancient granite and gneiss terrains of South Africa and Australia. They are islands of ancient deformed rock, metamorphosed from basaltic lava and topped by sediments. They are between 2.5 and 3.5 billion years old. As greenstone belts contain pillow lavas, they are considered to be ancient pieces of oceanic crust that formed under the sea in back-arc basins as the continents grew larger. |
| **igneous rock** | a rock that has solidified from molten rock material (magma) which was generated deep within the Earth. Igneous rocks are one of the three main groups of rocks that comprise the Earth's crust (the others being sedimentary and metamorphic). |
| **ilmenite** | a black or dark brown rhombohedral mineral FeTiO3, a major ore of titanium; it occurs in compact or granular aggregates. |
| **intruded** | intrusion, also called injection, is the emplacement of magma into pre-existing rock. It can take place either by deformation of the involved rock, or along some structural channels such as bedding planes, cleavages or joints. |
| **kimberlite** | a porphyritic, ultrabasic intrusive igneous rock containing abundant olivine and mica of the phlogopite variety in a serpentine and carbonate-rich matrix. Host rock of diamond. |
| **lava** | molten rock (or magma) that issues from openings at the Earth's surface or on the ocean floor. Such openings may be located in craters or along flanks of volcanoes, or in fissures not associated with volcanic cones. |
| **limestone** | a sedimentary rock composed almost entirely of calcium carbonate mainly as the mineral calcite. Organic limestones consist of shell remnants or of calcite deposits precipitated by certain algae, e.g. coral limestone, crinoidal limestone, chalk. Chemically precipitated limestones form mainly in warm shallow seas. |
| ***Lystrosaurus*** | *Lystrosaurus* lived in Africa, Antarctica, India, Laos China and Russia approximately 250 million years ago. The discovery in the 1960's of a *Lystrosaurus* specimen in Antarctica was evidence to support the idea of continental drift. |
| **magma** | molten, mobile rock material that is a naturally occurring high temperature solution of silicates, water and gases. Suspended solids such as crystals and rock fragments may or may not be included. Magma is generated deep within the Earth's crust or upper mantle as a result of partial melting, and is the sources of igneous rocks. |
| ***Melanorosaurus*** | large quadrupedal, herbivorous sauropod dinosaur from Triassic rocks, specifically the Elliot Formation of South Africa. |

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| **metamorphosed** | having undergone metamorphism - the processes which produce structural and mineralogical changes in any type of rock in response to physical and chemical conditions differing from those under which the rocks originally formed. Changes brought about by near-surface processes such as diagenesis and weathering are excluded. |
| **mudstones** | commonly used synonym for mudrock, a fine-grained sedimentary rock composed chiefly of particles in the silt-clay size range. Mudrock is a general term that can be used to distinguish the finer-grained sedimentary rocks from sandstones or limestones. |
| **pillow lavas** | hot, fluid magma rapidly cooled into pillow structures when coming into the sea or water saturated sediments. |
| **pillow structures** | spherical or ellipsoidal structures usually composed of basaltic lava, generally about 1 m in diameter. These are the result of the rapid cooling of hot, fluid magma that comes into the sea or into water saturated sediments. |
| **rhyolite** | one of a group of extrusive rocks (those extruded at the Earth's surface) commonly showing flow texture, and typically porphyritic, with phenocrysts of quartz and potassium feldspar in a glassy to microcrystalline groundmass. Rhyolite is the extrusive equivalent of granite. |
| **rift** | a zone where two tectonic plates are pulling apart, often forming a mid-ocean ridge with the associated upwelling of hot magma. |
| **rutile** | a yellow, red, brown or black tetragonal mineral, $TiO_2$, an important ore of titanium. Rutile occurs as a very common accessory mineral in intrusive igneous rocks, or dispersed through quartz veins. |
| **sandstone** | a sedimentary rock composed of sand-sized grains in a matrix of clay or silt, and bound together by a cement that may be carbonate. Quartz forms about 65% of the detrital fraction of the average sandstone, and feldspars about 10 to 15%. Most sandstones originate as underwater deposits, usually marine; many sandstones were originally beach deposits. |
| **sea level** | the level corresponding to the surface of the sea half way between mean low and high tide. |
| **sedimentary rocks** | rocks formed by the consolidation of sediment settled out of water, ice or air and accumulated on the Earth's surface, either on dry land or under water. Sediments are consolidated into a rock mass by lithification. Sedimentary rock is typically stratified or bedded, beds can vary greatly in thickness. |
| **shales** | fine-grained sedimentary rock formed by the compaction of silt, clay, or sand that accumulates in deltas and on lake and ocean bottoms. It is the most abundant of all sedimentary rocks. Shales may be black, red, grey or brown. |
| **sill** | a tabular igneous intrusion with boundaries conformable with the planar structure of the surrounding rock. |
| **silt** | a detrital particle, finer than very fine sand and coarser than clay, in the range of 0.004 to 0.062mm. |

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| **Striation directions** | the direction (compass) of one of many thin lines or scratches, generally parallel, incised on a rock by some geological agent such as a glacier or stream. See glacial pavement. |
| **stromatolites** | laminated calcareous sedimentary formations produced by lime-secreting cyanobacteria. Living stromatolites are in the shape of stony cushions or massive columns. Fossilized stromatolites (silicified) dating back to the Precambrian are found in the Gunflint Chert of Lake Superior, in cherts of Africa and Australia, and in calcareous sediments. |
| **subduction** | the movement of one crustal plate under another so that the descending plate is "consumed". |
| **supercontinent** | a collection of many smaller continents to form one giant landmass. |
| **tillite** | a sedimentary rock formed by the compaction and cementation of till. Till is generally not layered and deposited directly by glacial ice. It is poorly sorted with a wide range of grain sizes from clay to boulders. Clasts are usually angular because they have undergone little or no water transport. |
| **transport** | the carrying away (transportation) of sediment by the agents of waves, wind, streams and glaciers. *See erosion*. |
| **unconsolidated sediments** | sediments which have not yet been compacted and cemented to form rock |
| **uplift** | process by which regions of the Earth's crust is raised above sea-level. This process is most commonly associated with rifting and collision of continental crust. |
| **weathering** | destructive natural processes by which rocks are altered with little or no transport of the fragmented or altered material. Mechanical weathering occurs with the freezing of confined water and the alternate expansion and contraction due to temperature changes. Chemical weathering produces new minerals. The main chemical reactions are oxidation, hydration and solution. |
| **Witwatersrand rocks** | rocks belonging to the 3000 million year old Witwatersrand Supergroup, which outcrop around Johannesburg and south into the Free State. The Witwatersrand rocks are significant in that more than half of all the gold produced has been extracted from these rocks. |
| **zircon** | silicate mineral, $ZrSiO_4$, an important ore for zirconium, hafnium and thorium; some varieties are used as gemstones. Zircon is a typical accessory mineral of acidic igneous rocks and their metamorphic derivatives. It also occurs as a detrital mineral. |

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# 1 INTRODUCTION

The geological history of Kwazulu-Natal covers over 3100 million years of Earth history. Rocks, containing fossils or traces of fossils provide information about the palaeo-environments that existed in the past and the fossil history is therefore part of the Natural Heritage of the Province. Surface exposure of fresh, un-weathered rock is the optimal source of well-preserved fossils. Due to the climatic conditions prevailing in Kwazulu-Natal, freshly exposed rock is limited to badly eroded areas where topsoil has been removed by weathering and erosion. Areas of high significance for fossil remains are therefore limited to areas along the coast as well as areas in the hinterland where erosion is prolific. For this reason the discussion on the fossil heritage of the Province will not be discussed according to site specific localities, but more related to fossil bearing Groups, Formations and Members that are related to mapped units on a scale of up to 1:250 000.

Present legislation makes provision for the protection of fossil heritage as part of the National Heritage legislation. Despite the comparatively good legal protection offered to palaeontological heritage in South Africa by the current legislation, hitherto this aspect of natural heritage has been largely ignored by developers and professional heritage managers alike, mainly due to confusion between palaeontological and archaeological heritage.

The aim of this report is also to ensure a better understanding of the fossil heritage in South Africa and to make it clear that fossils are not restricted to the Main Karoo Basin. Although metamorphic provinces are usually non-fossiliferous, low grade meta-sediments of a localized occurrence in the Pongola Group contain good examples of bio-sedimentary stromatolites.

The well-known fossils of therapsids (ancient ancestors of mammals) have been described from various localities in the foothills of the Drakensberg and the association with specific formations and members are described in this report. Plant fossils of the well-known *Glossopteris* assemblage are described from the Middle Ecca Vryheid Formation and the Beaufort Group, whereas the exceptional variety of plant and insect fossils from the Molteno Formation is also well represented in collections now housed at the Bernard Price Institute for Palaeontological Research (BPI) at the University of the Witwatersrand in Johannesburg.

# 2 DOCUMENT OVERVIEW

The core purpose of the AMAFA palaeotechnical report is to briefly introduce the reader to palaeontological heritage of the KwaZulu-Natal Province. The report is presented in 6 sections.

In Section 3 there is a brief summary of the legislation regarding the palaeontological heritage within South Africa and the KwaZulu Natal Province. Section 4 provides the reader with a brief summary of the geology of the KwaZulu-Natal Province, making specific reference to the major geological formations in the province. Section 5 provides a summary of the significant palaeontological information available for

the province and Section 6 forms the core of the report providing summaries of the known and predicted fossil heritage in all the major fossiliferous stratigraphic units (members, formations and groups) that crop out within the province.

The report presented must be used in conjunction with published geological maps and as such can be used by heritage and environmental assessment practitioners as well as private developers, to evaluate the potential impact of proposed developments on fossil heritage of the province. Rock units are ranked in terms of its palaeontological sensitivity according to a three-point scale, from which the appropriate action to be taken (if any) before or during development can be inferred.

The databases provided are not site specific but refer to well-defined stratigraphic units that are mostly sedimentary successions. Site specific information is not appropriate because research is based on regional inspection of formations and specifically where good outcrops of productive (fossil-bearing) units are encountered. Most fossils are hidden in the bedrock and developers will only be able to assess specific reference to fossils once the topsoil has been removed and excavations have exposed the bedrock. A good example of the discovery of fossils in newly exposed bedrock was found during excavations for the Bedford Dam of the Ingula Pumped Storage Scheme in the Free State Province.

Emphasis on fossil sites (*e.g.* map showing all known localities) would be counterproductive since it would give the misleading impression that areas between known sites are less palaeontologically sensitive than the sites themselves. Furthermore, a site specific database could not be made freely available since it would undoubtedly endanger localities of scientific importance.

## 3 PERTAINING LEGISLATION

The National Heritage Resources Act of 1999 (pp 12-14) and the KwaZulu Natal heritage Act of 2008 protects a variety of heritage resources. These resources are defined as follows:

1. **"**For the purposes of this Act, those heritage resources of South Africa which are of cultural significance or other special value for the present community and for future generations must be considered part of the national estate and fall within the sphere of operations of heritage resources authorities.
2. Without limiting the generality of subsection (1), the national estate may include -
    2.1. Places, buildings, structures and equipment of cultural significance;
    2.2. Places to which oral traditions are attached or which are associated with living heritage;
    2.3. Historical settlements and townscapes;
    2.4. Landscapes and natural features of cultural significance;
    2.5. Geological sites of scientific or cultural importance;
    2.6. Archaeological and palaeontological sites;
    2.7. Graves and burial grounds, including—
    2.8. Ancestral graves;
    2.9. Royal graves and graves of traditional leaders;
    2.10. Graves of victims of conflict;

2.11. Graves of individuals designated by the Minister by notice in the Gazette;
2.12. Historical graves and cemeteries; and
2.13. Other human remains which are not covered in terms of the Human Tissue Act, 1983 (Act No. 65 of 1983);

3. Sites of significance relating to the history of slavery in South Africa;
   3.1. Movable objects, -
4. Objects recovered from the soil or waters of South Africa, including archaeological and palaeontological objects and material, meteorites and rare geological specimens;
   4.1. Objects to which oral traditions are attached or which are associated with living heritage;
   4.2. Ethnographic art and objects;
   4.3. Military objects;
   4.4. objects of decorative or fine art;
   4.5. Objects of scientific or technological interest; and
   4.6. books, records, documents, photographic positives and negatives, graphic, film or video material or sound recordings, excluding those that are public record as defined in section 1(xiv) of the National Archives of South Africa Act, 1996 (Act No. 43 of 1996).
5. Without limiting the generality of subsections (1) and (2), a place or object is to be considered part of the national estate if it has cultural significance or other special value because of—
   5.1. Its importance in the community, or pattern of South Africa's history;
   5.2. Its possession of uncommon, rare or endangered aspects of South Africa's natural or cultural heritage;
   5.3. Its potential to yield information that will contribute to an understanding of South Africa's natural or cultural heritage;
   5.4. Its importance in demonstrating the principal characteristics of a particular class of South Africa's natural or cultural places or objects;
   5.5. Its importance in exhibiting particular aesthetic characteristics valued by a community or cultural group;
   5.6. Its importance in demonstrating a high degree of creative or technical achievement at a particular period;
   5.7. Its strong or special association with a particular community or cultural group for social, cultural or spiritual reasons;
   5.8. Its strong or special association with the life or work of a person, group or organisation of importance in the history of South Africa; and
   5.9. sites of significance relating to the history of slavery in South Africa"

# 4 GEOLOGICAL HERITAGE OF KWAZULU-NATAL

The geological history of KwaZulu-Natal is adapted from an internet publication from the University of KwaZulu Natal, compiled by Reinardt (2006) [The website was designed and compiled by Dr. G. Whitmore, Ms D. Meth and Dr. R. Uken (modified by T. Reinhardt.)]

## 4.1 The Kaapvaal Craton and Natal Metamorphic Province

The geological foundation of Kwazulu-Natal is represented by the **Kaapvaal Craton** and the **Natal Metamorphic Province**, the ancient foundations of Kwazulu-Natal (Figure 4.1). These form separate continental blocks that have influenced the scenery and economic potential of the region. The most ancient crustal block, the Archaen Kaapvaal Craton is estimated at 3000 million years old and was formed when the Earth's basaltic crust was intruded by granite. The basalts are 3500 million years old and are preserved as greenstone fragments within the granite.

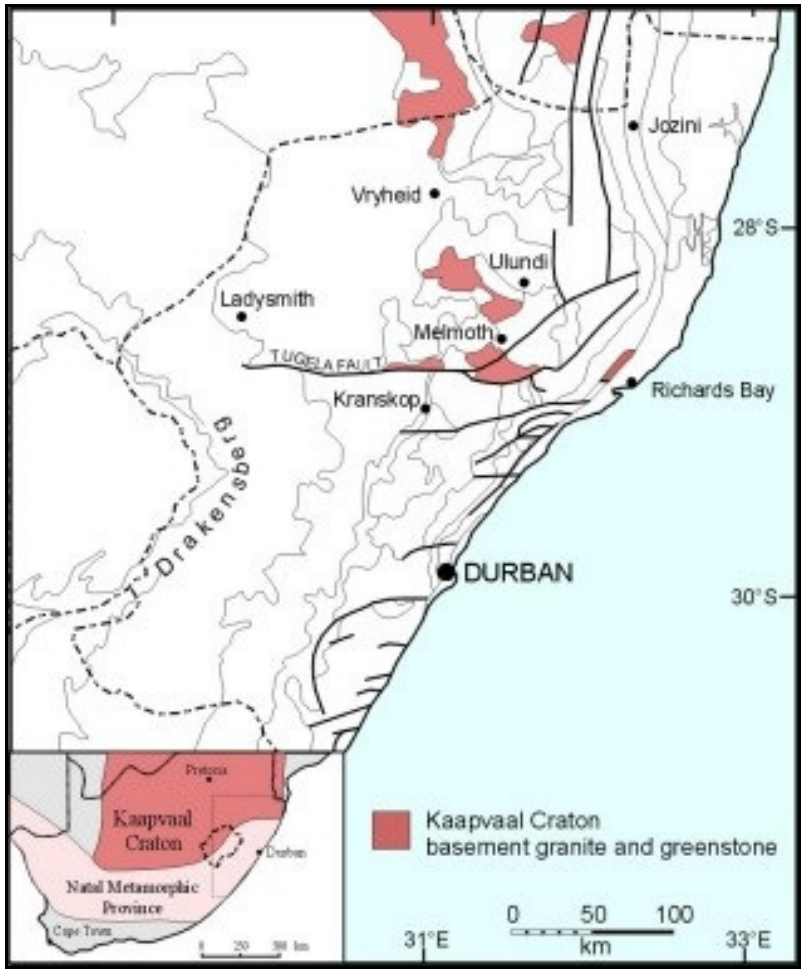



**Figure 4.1 Outcrop areas of the basement rocks in KwaZulu-Natal**

Granite can be seen in the valley between Melmoth and Vryheid, and at quarries inland of Richards Bay. Basalt of the Nondweni Greenstone Belt south of Vryheid preserves ancient 'pillow structures'. These are identical to the structures seen today where basalt lava erupts into the sea.

After its formation, the Kaapvaal Craton was uplifted and exposed to the atmosphere. This resulted in weathering, erosion and transport of sediment into shallow basins. Both the Pongola Supergroup and the similar gold-rich Witwatersrand rocks were deposited in these early basins.

### 4.2 The Pongola Supergroup

The lower part of the **Pongola Supergroup** (Nsuze Group) is a succession of basalt, sandstone and minor limestone. North of the Tugela Fault the Pongola Supergroup rocks are gently dipping and relatively unaltered. Near the Tugela Fault these rocks are folded and deformed during collision of the basement. The Nsuze Group is overlain by the Mozaan Group, with intrusive Pongola Granites also present.

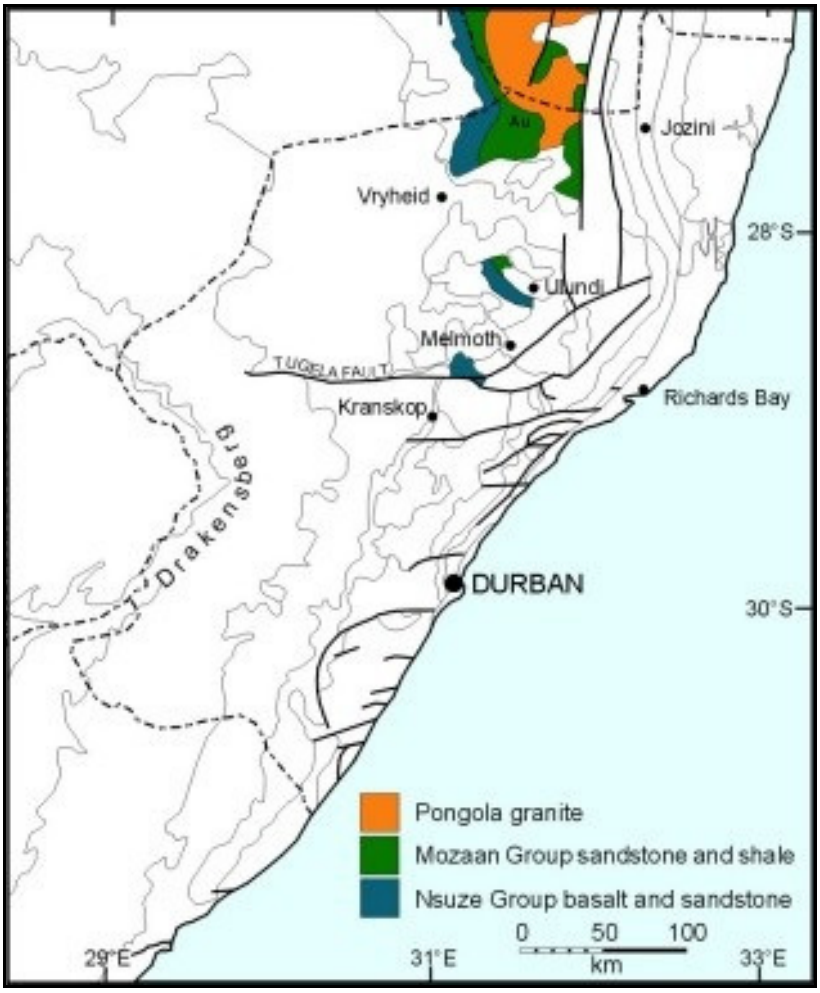



**Figure 4.2 Outcrop of Pongola Supergroup rocks in KwaZulu-Natal**

### 4.3 The Natal Group

The first sedimentary sequence deposited on the new basement was the Cambrian to Ordovician **Natal Group** (490 million years ago).

Structures preserved in these sandstones indicate that the sediments were transported and deposited by rivers that drained highlands to the northeast. Close to their source, in northern KZN, deep valleys were in-filled with thick accumulations of boulders and pebbles.

Further south the sediment is finer grained and forms resistant sandstone cliffs. These give rise to the table top topography seen in the Valley of a Thousand Hills and Oribi Gorge near Port Shepstone.

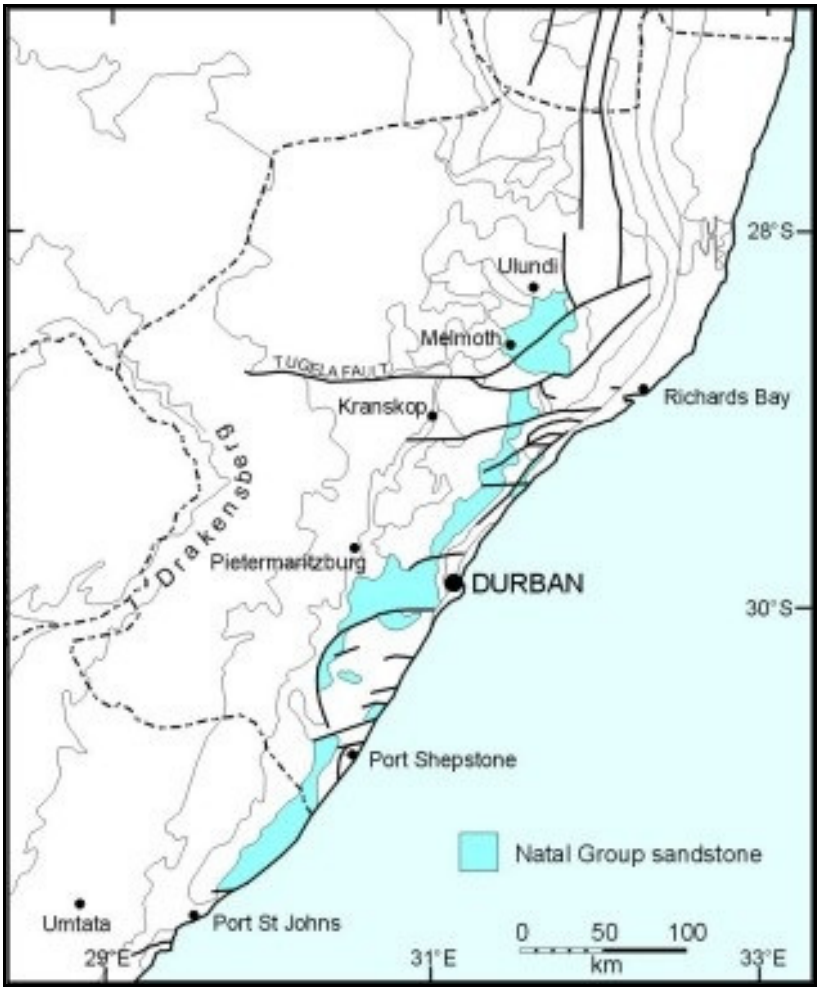



**Figure 4.3 Outcrops of Natal Group sandstones in KwaZulu-Natal**

### 4.4 The Dwyka Group

The rocks overlying the Natal Group is a thick unit of tillite that was deposited in a glacial environment by retreating ice sheets about 300 million years ago.

At this time South Africa was part of the supercontinent Gondwana, which was situated near the South Pole and covered with ice. Rocks imbedded in the slowly moving ice sheets scoured and polished the underlying older rocks giving rise to glacial pavements. Striation directions indicate that ice flow was from north to south - valuable information when it comes to reconstructing Gondwana.

The **Dwyka Group** forms the lowermost and oldest deposit in the Karoo Supergroup basin. The Karoo Basin extended across much of southern Gondwana and records 120 million years of geological history.

The tillite in KZN often weathers to a characteristic yellowish colour. In the Durban area, cliffs near the mouth of the Umgeni River, and quarries in the Westville area offer the best exposures of tillite.


**Figure 4.4** **Outcrop of Dwyka Group sediments in KwaZulu-Natal**

## 4.5 The Ecca Group

### 4.5.1 Pietermaritzburg Formation

As Gondwana moved north towards the equator, thick clay and silt beds were laid down in a large sea that occupied the Karoo B**asin**, leading to the deposition of the **Ecca Group**. These sediments deposited in deep water now form shales of the **Pietermaritzburg Formation**. The shales are easily weathered and often present slope stability problems.

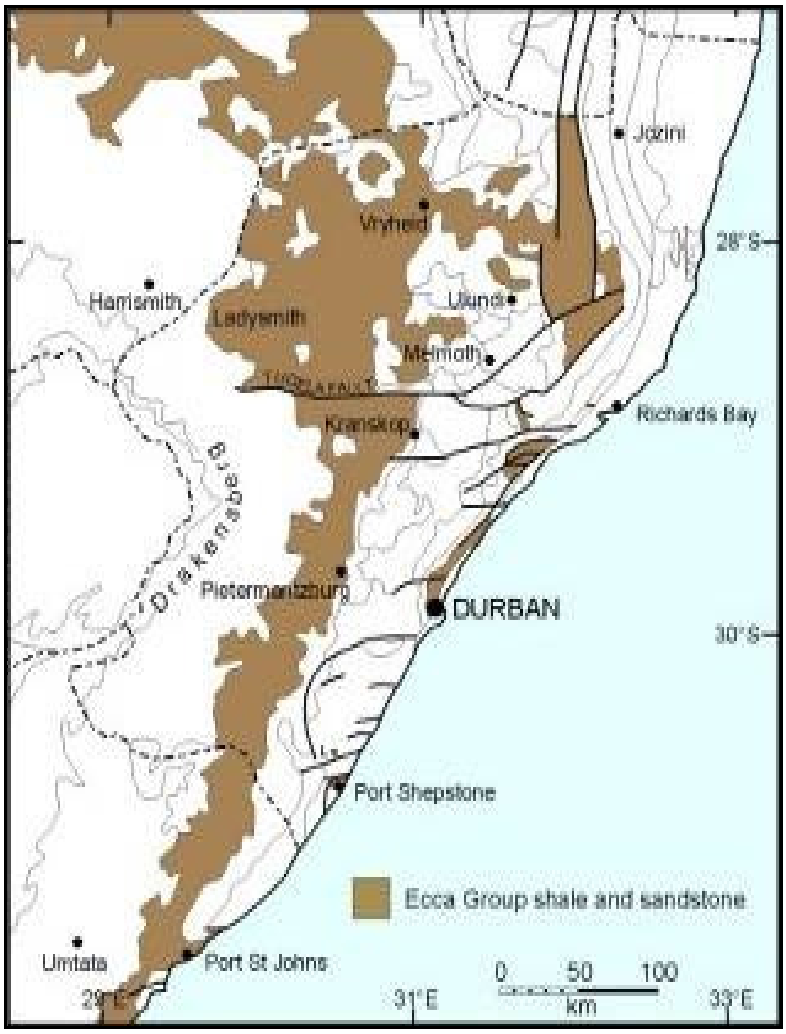



**Figure 4.5 Outcrop of Ecca Group sediments in KwaZulu-Natal**

### 4.5.2 Vryheid Formation

Overlying the shale is a thick sequence dominated by light grey sandstones, called the **Vryheid Formation**. These sandstones were deposited along ancient sandy shorelines behind which lay vast swamplands. Burial of vegetation in the swamps eventually formed coal which is mined in the Vryheid area.

### 4.5.3 The Volksrust Formation

The Vryheid Formation is overlain by the **Volksrust Formation** which represents a deep water dark grey deposit of siltstone.

## 4.6 The Beaufort Group

**Beaufort Group** mudstones and sandstones form the foothills of the Drakensberg Escarpment as well as isolated outcrops in eastern Kwazulu-Natal along the Lebombo Mountains. The red, green and purple coloured mudstones which characterize this group were deposited in a steadily drying swampland (MacRae, 1999; Rubidge , 1995; Johnson et al. 2006; McCarthy and Rubidge, 2005).

### 4.6.1 Geology of the Beaufort Group along the Drakensberg Escarpment

SACS (South African Committee for Stratigraphy) still needs to publish a formal note on the lithostratigraphy of the Escarpment at Harrismith. The most recent formal academic study of the complete section was done by Groenewald (1984, 1989).

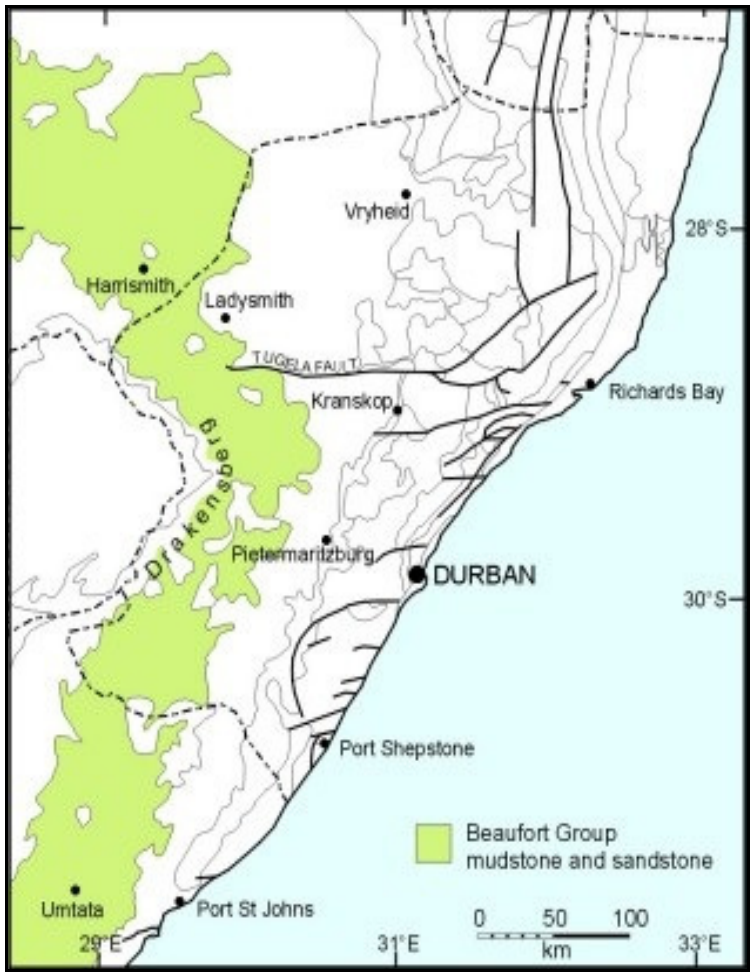


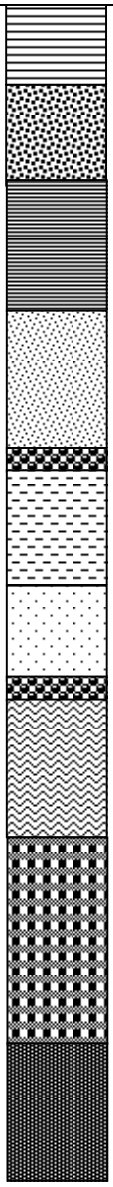

**Figure 4.6 Outcrop of Beaufort Group sediments in KwaZulu-Natal**

The Beaufort Group is subdivided into a lower Adelaide Subgroup and upper Tarkastad Subgroup. Correlation of these units from the Southern Karoo Basin into this northern part of the basin is contained in a comprehensive regional study of the Upper Karoo Supergroup (Groenewald, 1996).

#### 4.6.1.1 The Adelaide Subgroup/Formation

The Adelaide Subgroup comprises the lower part of the Beaufort Group along the Drakensberg Escarpment and on some 1:250 000 sheets is referred to as the Adelaide Formation. In most of the outcrop areas in KwaZulu-Natal the Adelaide Subgroup consists primarily of a lower deltaic facies, mostly referred to as the Estcourt Formation and an upper fluvial facies referred to as the Normandien Formation (Groenewald, 1984; Johnson et al 2006).

**Table 4.1 Summary of the Geology of the Beaufort Group at the Drakensberg Escarpment**

| | |
|---|---|
|  | Burgersdorp/Driekoppen Formation. Red mudstone and thin yellow-brown sandstone. Cynognathus Assemblage Zone vertebrate fossils and trace fossils. |
| | Katberg/Verkykerskop Formation. Coarse-grained sandstone with manganese enriched conglomerates – Braided River Fluvial deposit. No record of fossil finds to date. |
| | Harrismith Member – Normandien Formation. Brightly coloured siltstone – highly dissipating and expansive. Concretions with numerous fossils of Lystrosaurus Assemblage Zone material and vertebrate burrows |
| | Schoondraai Member – Normandien Formation. Fine to medium-grained sandstone with prominent conglomerate of granitic pebbles at the base. Large scale petrified tree fossils of Glossopteris and very thin coal beds. |
| | Green and grey mudstone and siltstone with prominent concretions of Calcium and Gypsum. Fossils of plants and coal beds in upper layers and very productive vertebrate fossil layers of the Dicynodon Assemblage Zone. |
| | Rooinek Member – Normandien Formation. Coarse-grained fluvial feldspathic sandstone with basal conglomerates, fossil trees of Glossopteris and coal beds. |
| | Green and grey mudstone and siltstone with thin coal beds. Fluvial crevasse splay deposits with micro cross-bedding in silt deposits. Trace fossils abundant on sandstone bedding planes. (Fossil remains of Rhachiocephalus recorded towards the west where weathering is not as severe as along the escarpment). |
| | Frankfort Member – Normandien Formation - Dark grey shale and siltstone, interbedded with lenses of deltaic very coarse-grained feldspathic sandstone deposits of up to 20 m thick. Lenses of sandstone discontinuous over 500 m. Plant fossils of Glossopteris abundant. Prominent but discontinuous coal beds and abundant trace fossils on bedding planes of sandstones, siltstones and mudstones. No vertebrate remains recorded to date. |
| | Volksrust Formation – Ecca Group. Dark grey shale – deep water sedimentary deposits with very little recorded evidence of vertebrate life. Trace fossils recorded in the upper part of the formation. |

#### 4.6.1.1.1 Estcourt/Normandien Formation

Referring to Table 4.1, the geological history of the Drakensberg Escarpment region represents the final sedimentation into the Ecca Sea about 260 million years ago. Deltaic deposits of the Estcourt Formation contain evidence of an abundance of marine and probably estuarine invertebrates that left a wealth of trace fossils in the rock record (MacRae, 1999; McCarthy and Rubidge, 2005). The overlying fluvial deposits of the Normandien Formation (Groenewald, 1989; Johnson et al 2006) with prominent sandstone members (Rooinek and Schoondraai Members) represent a progressive basin ward migration of the depositional system.

### 4.6.1.2 The Tarkastad Subgroup

#### 4.6.1.2.1 Katberg/Verkykerskop Formations

The Katberg Formation is defined as the lower sandstone-rich unit of the Tarkastad Subgroup and consists of fine-grained sandstone with a main provenance to the southeast. The Verkykerskop Formation is a time equivalent of the Katberg Formation, but consists predominantly of coarse-grained sandstone with a provenance to the northeast (Groenewald, 1996; Johnson et al, 2006).

#### 4.6.1.2.2 Burgersdorp/Driekoppen Formations

The Katberg and Verkykerskop formations are overlain by red mudstones of the Burgersdorp and Driekoppen formations (Groenewald 1996; Johnson et al, 2006).

## 4.6.2 The Geology of the Beaufort Group along the Lebombo Mountains

### 4.6.2.1 The Adelaide Subgroup

#### 4.6.2.1.1 The Emakwezini Formation

The Emakwezini Formation (Adelaide Subgroup, Beaufort Group, Karoo Supergroup) crops out in a narrow strip just inland of the eastern coast of South Africa in northern KwaZulu-Natal. It is an actively mined coal-bearing succession characterised by fining-upward successions of coarse- to fine-grained sandstones together with mudstones.

With sediments sourced from a north-easterly continental interior, the Emakwezini Formation was deposited rapidly in a fluviolacustrine setting under moist conditions capable of supporting an abundant and diverse biota. The permanently moist environment in which the Emakwezini Formation was deposited contrasts with that of the time-equivalent lower Beaufort Group units in the main Karoo Basin where environmental indicators suggest deltaic, lacustrine and meandering fluvial systems developed in a seasonally dry and more arid setting. Thus, within southern Africa, during the Middle to Late Permian, the environmental conditions, including climate, were varied leading to a mosaic of continental depositional settings (Prevec et al. 2009; Bordy and Prevec, 2009).

### 4.7 The Stormberg Group

The **Stormberg Group** overlies the Beaufort Group and is subdivided into three formations which preserve a record of gradual desertification.

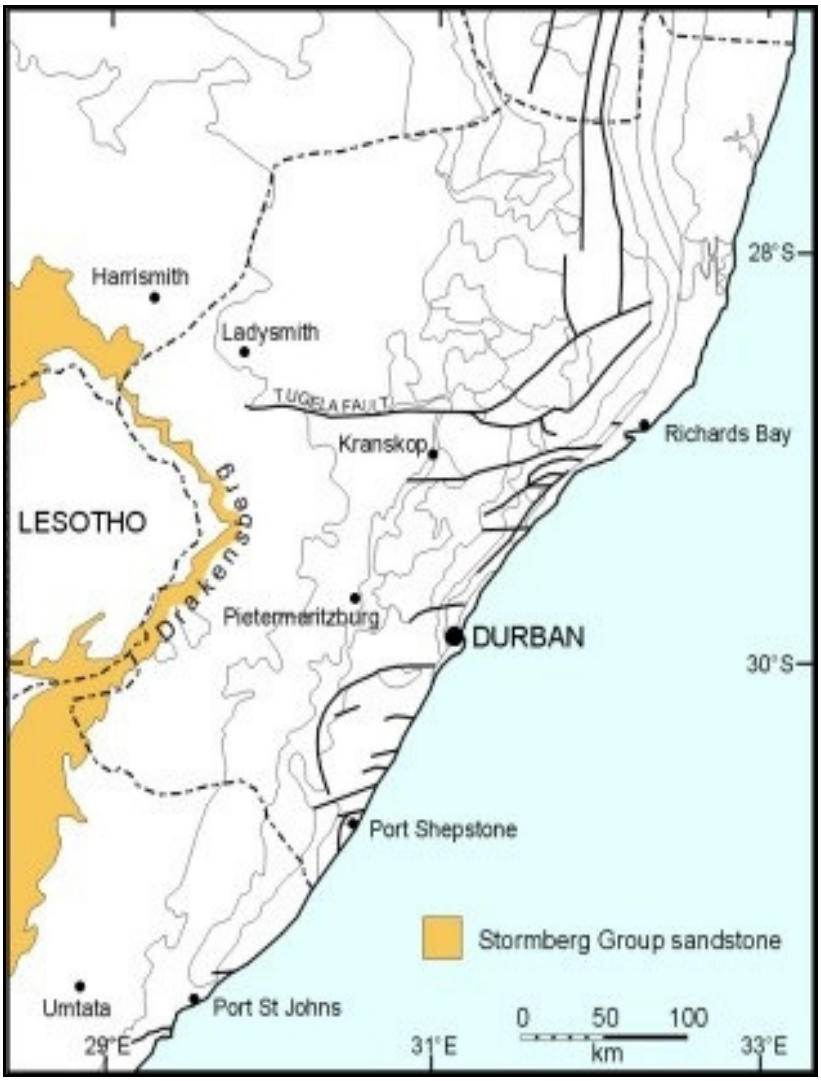



**Figure 4.7 Outcrop of Stormberg Group sediments in KwaZulu-Natal**

#### 4.7.1 The Molteno Formation

Sandstone of the lowermost **Molteno Formation** was formed by rivers in a wet environment. These are now exposed as small cliffs in the lower Drakensberg and can be easily recognised by their sparkling appearance. This is due to minute quartz crystals that coat and bind together the sand grains. The sandstone is interbedded with mainly khaki colored mudstone and siltstone that can be carbonaceous in places.

In Eastern Natal along the Lebombo Monocline the Emakwezine Formation is overlain by the **Ntabene** Formation which is roughly correlated with the Molteno Formation in the west.

### 4.7.2 The Elliot Formation

The Molteno Formation is in turn overlain by red mudstone and fine-grained sandstone of the **Elliot Formation**.

The **Nyoka** Formation that overlies the Ntabene Formation of Eastern KwaZulu-Natal is equated with the Elliot Formation in Western KwaZulu-Natal.

### 4.7.3 The Clarens Formation

The overhanging white cliffs of the middle Drakensberg are composed of **Clarens Formation** sandstone. These sandstones were deposited as large dunes in a desert environment and preserve large internal bedding structures called crossbeds. The Clarens Formation represents a time when most of Southern Africa was covered with dune sand and interspersed lakes similar to the Sossusvlei area in the Namib Desert of Namibia.

The **Clarens Formation** is directly correlated with similar deposits of Aeolian sandstones in Eastern KwaZulu-Natal, which are most probably equivalents of the Stormberg Group sediments in the Main Karoo basin.

## 4.8 The Drakensberg Group

The **Drakensberg Group** formed when dramatic outpourings of lava spread across much of Gondwana about 190 million years ago heralding the start of the Gondwana breakup. Remnants of these once extensive lavas now form the Lesotho highlands. The **Lebombo Group** of rocks in eastern Kwazulu-Natal is a time equivalent of the Drakensberg Group in the main Karoo Basin.

A 1.5 kilometer thick accumulation of Jurassic age basalt flows can be seen along the Drakensberg Escarpment. The magma (molten rock) made its way to the surface along a complex system of fractures.

Crystallisation of magma within these fractures formed dolerite sills and dykes. Sills are horizontal intrusions of igneous rock. Dolerite sills are common throughout inland KZN in sedimentary rocks of the Karoo Supergroup. The sills often form flat areas and weather to form a very dark red soil. The sills may also form resistant cliffs such as those at Howick Falls.

The final volcanic event produced rhyolite lava which now forms the Lebombo Mountains. These volcanic events were followed by uplift and faulting that eventually separated Africa and Antarctica.

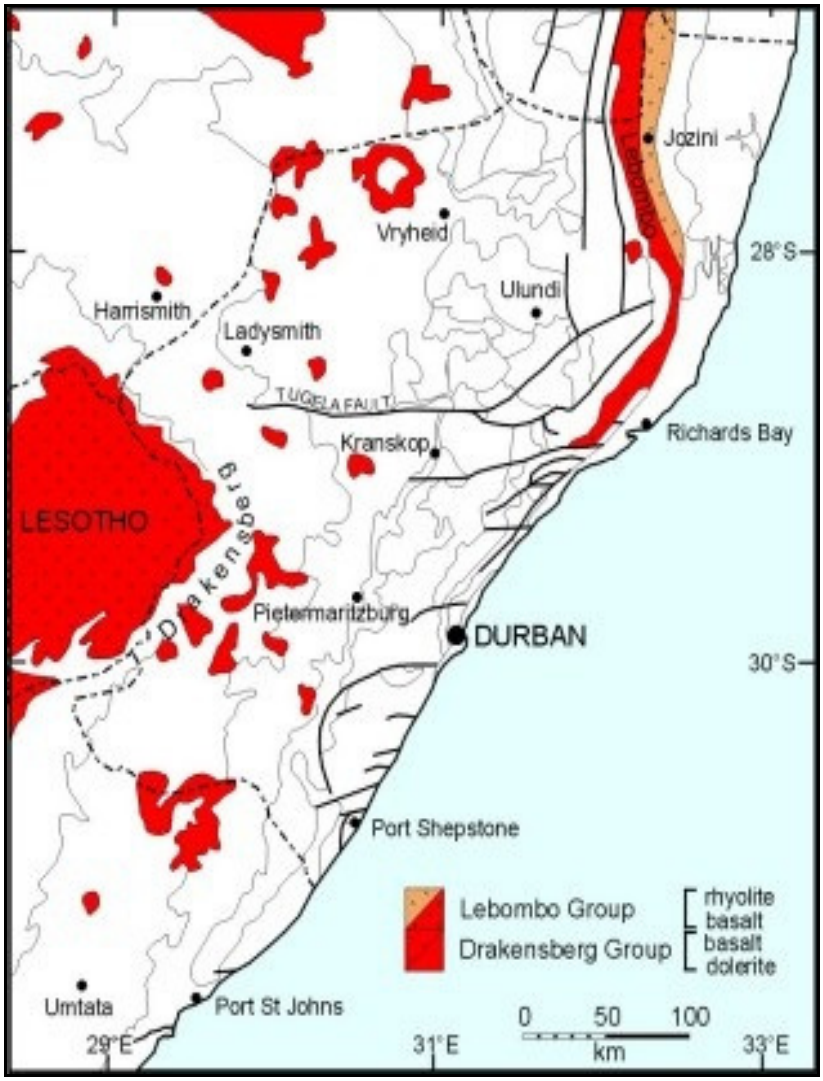



**Figure 4.8 Outcrops of Drakensberg and Lebombo Group Volcanics in KwaZulu-Natal**

### 4.9 The Mzamba Formation

The Mzamba Formation consists mainly of isolated outcrops along the coast of KwaZulu-Natal. The unit is approximately 20 m thick with a basal pebbly sandstone overlain by coquinoid sandstones and mudstone (Johnson et al, 2006).

### 4.10 Zululand Group

The **Zululand Group** of siltstones and sandstone are the first deposits that formed in the newly opened Indian Ocean and consist of silt- and sandstone of Cretaceous age (145-65 million years ago). These marine sediments were deposited when dinosaurs roamed the land (MacRae, 1999). The Zululand Group is divided into three formations.

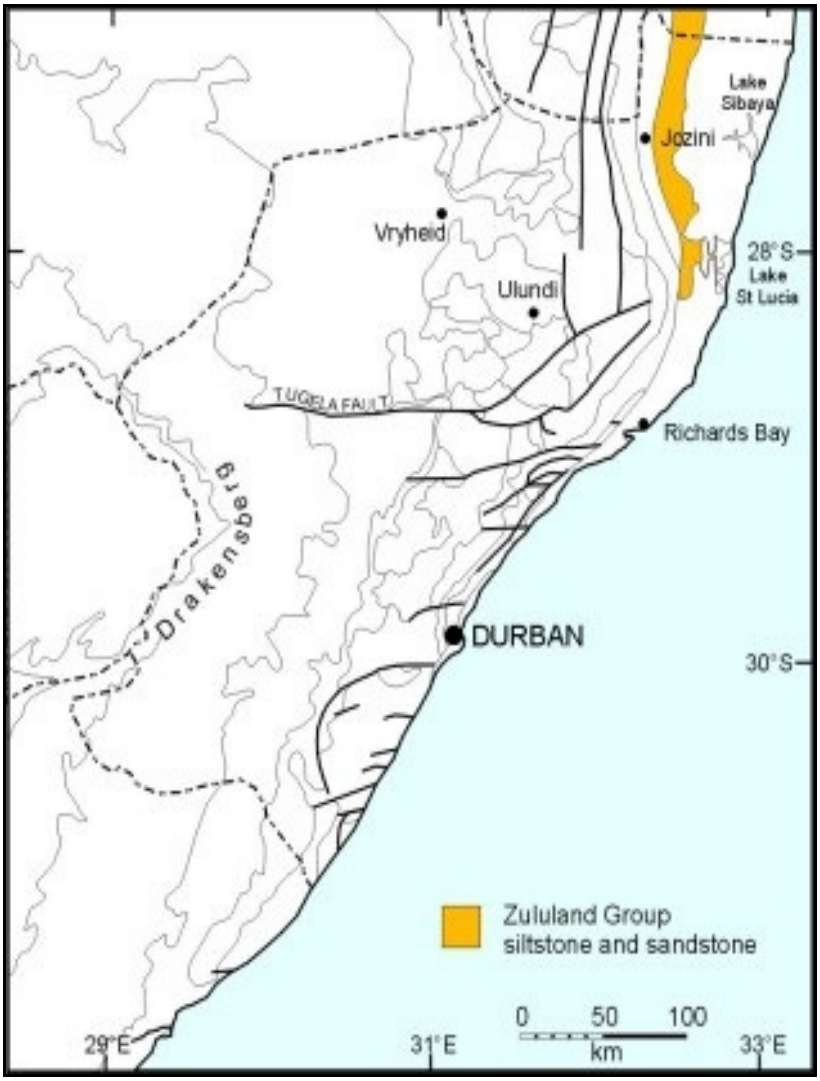



**Figure 4.9 Outcrops of Zululand Group sediments in KwaZulu-Natal**

### 4.10.1 The Makatini Formation

The Makatini Formation unconformably overlies much older Lebombo Group volcanic rocks and consists of a sequence of small pebble conglomerates, sandstone, siltstone and limestone up to 80 m in thickness (Johnson et al, 2006). The Makatini Formation is capped by a fossiliferous marine sandstone (Du Preez and Wolmamarans, 1986).

### 4.10.2 The Mzinene Formation

The Mzinene Formation is mainly a glauconitic fossiliferous sandstone with well-defined *Teredo* – type hiatus concretions (Du Preez and Wolmarans, 1986). The Mzinene Formation is separated from the Makatini Formation by a hard ground or well indurated concretionary horizon bored by *Lithophaga*, a rock boring gastropod (Johnson et al, 2006).

### 4.10.3 St Lucia Formation

The St Lucia Formation is lithologically similar to the Mzinene Formation and is also separated from the underlying formation by a similarly bored hard ground (Wolmarans and Du Preez, 1986; Johnson et al, 2006).

## 4.11 The Maputuland Group

During the last glacial period, approximately 18 000 years ago, the Earth was much colder and sea level was more than 100 metres below present. The coastline at that time would have been far out to sea and many of the larger rivers cut deep valleys along the coast. As the earth warmed and the sea-level rose, these valleys were infilled with unconsolidated estuarine muds and shelly sands, grouped together into the Maputuland Group (65 million years ago to the present day). It is for this reason that many bridges along the coast require deep foundations to reach solid bedrock.

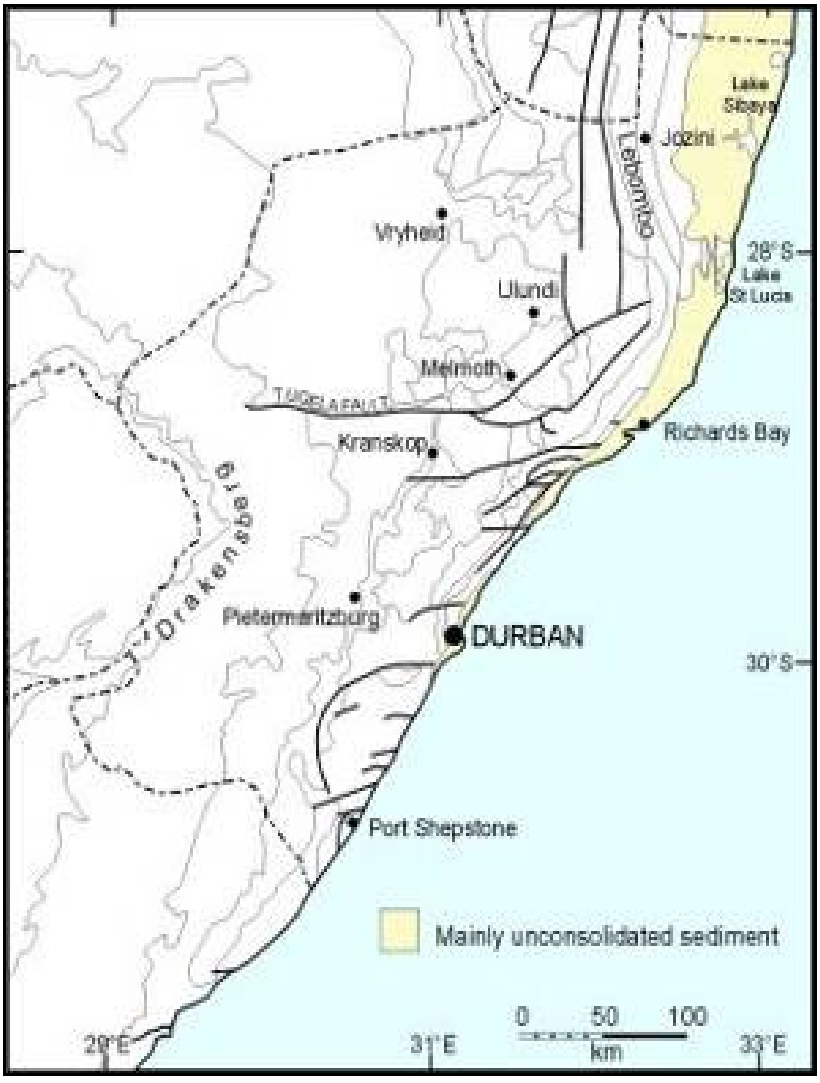



**Figure 4.10 Outcrop areas of Maputaland Group sediments in KwaZulu-Natal**

A series of large coast-parallel dune complexes developed along most of the KwaZulu-Natal coastline and constitutes the Maputuland Group of Johnson et al (2006). These Pleistocene sediments form a thin blanket on the Tertiary and Cretaceous successions of the coastal plain of KwaZulu-Natal (Wolmarans and Du Preez (1986).

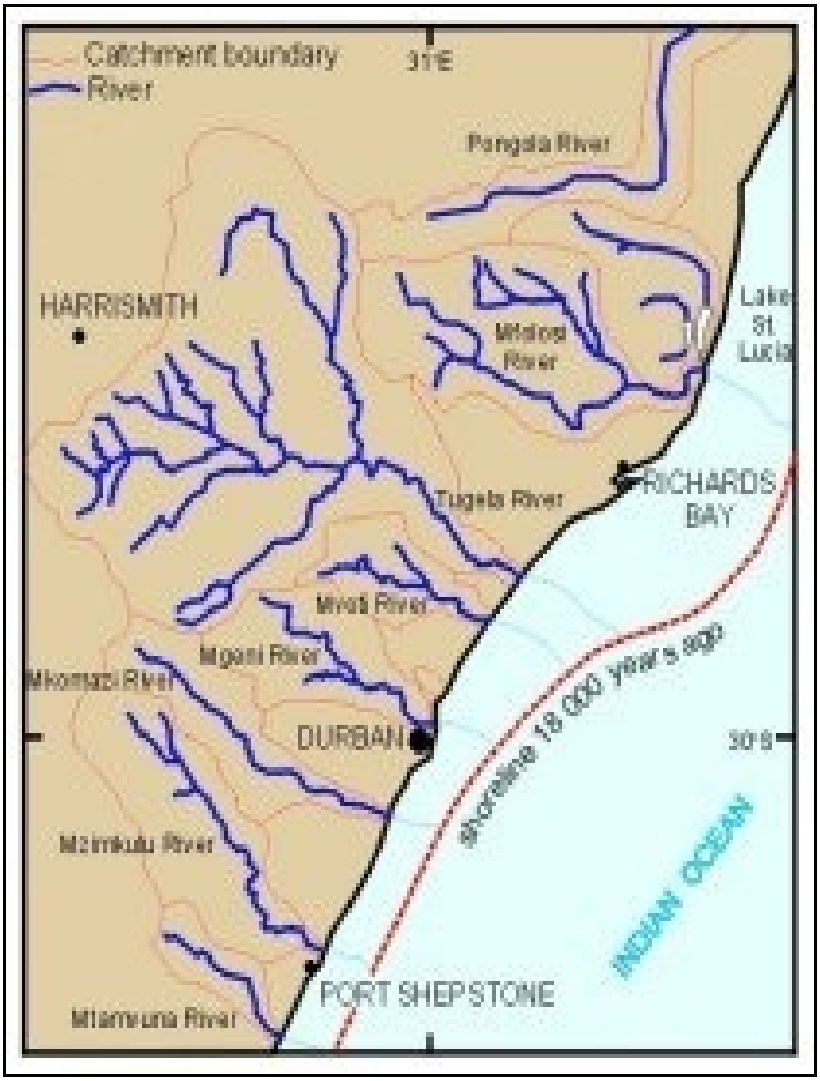



**Figure 4.11 Most recent rises in sea-level buried Cenozoic sediments of the Maputaland Group**

### 4.11.1 The Uloa Formation

During the Cenozoic Erathem, sea-level began to fall from the high levels experienced during the Cretaceous. The Tertiary Uloa Formation is a highly fossiliferous formation of calcrenite and thin limestone with a basal coquina that discordantly overlies the St Lucia Formation (Wolmarans and Du Preez, 1986; Du Preez and Wolmarans, 1986; Johnson et al, 2006).

### 4.11.2 The Muzi Formation

The Pleistocene sediments area divided into a lower Muzi Formation, which represents a vlei or swamp deposit consisting of mottled, brown clayey sand with few outcrops (Wolmarans and Du Preez, 1986).

### 4.11.3 The Port Durnford Formation

The Port Durnford Formation consists of mudstone, lignite clay and sand (Wolmarans and Du Preez, 1986).

### 4.11.4 The Bluff Formation

The Bluff Formation forms the core of the coastal dune cordons and is a pale brown sandstone deposit. In places it contains fossils of corals and a shelly limestone (coquina) probably associated with off-shore reefs (Wolmarans and Du Preez, 1986).

### 4.11.5 The Berea Formation

The Bluff Formation is overlain by the Berea Formation which consists of red, orange and yellow Aeolian sand, in the form of dune cordons along the coast of KwaZulu-Natal. The Berea Formation is interpreted as the weathering product of the Bluff Formation (Wolmarans and Du Preez, 1986).

In Durban these now form the Berea and Bluff Ridges. In most areas deep weathering of old dunes has produced dark red coloured sand called the Berea Red Sand.

## 4.12 Alluvium, Sand & Calcrete

In more recent times, fluctuations in sea-level have continued to shape the KwaZulu-Natal coastline. Recent coastal dunes contain economic concentrations of minerals such as ilmenite, rutile and zircon, which are mined near Richards Bay. The ilmenite and rutile is smelted to produce titanium metal and white pigments (mostly for paint). The zircon is used for glazing on tiles and pottery, and as a metal alloy.

## 4.13 The Masotcheni Formation

The Masotcheni Formation comprises palaeosols that represent local colluvial deposits of Cenozoic age in the interior of KwaZulu-Natal (Johnson et al, 2006).

# 5 PALAEONTOLOGY AND SIGNIFICANT GEOLOGICAL FORMATIONS IN KWAZULU-NATAL

## 5.1 Kaapvaal Craton and Natal Metamorphic Province

Due to the metamorphic character of these rocks they have no significance for fossils or palaeontology.

## 5.2 The Pongola Supergroup

Some limestone units in the **Nsuze Group** (Chobeni Formation, Linstrom, 1987 or White Mfolozi Formation, Johnson et al, 2006) contain beautifully preserved stromatolites - fossils of 2900 million year old algal colonies which thrived in a shallow, warm ocean (Johnson et al, 2006).

The photosynthesing bacteria (cyanobacteria) consumed carbon dioxide and caused the precipitation of calcium carbonate from the sea water, which stuck to the bacterial colonies. Gradually, layer upon layer of calcium carbonate was added, forming stromatolites.

The shape (cones, domes etc.) assumed by stromatolites depends on water depth, tidal range, and wave and current activity (MacRae, 1999).

## 5.3 The Natal Group

No fossils have been recorded from these units to date (Johnson et al, 2006; Thomas, 1988).

## 5.4 The Dwyka Group

Trace fossils have been recorded from the fine-grained shales of the Dwyka Group in KwaZulu-Natal (Linstrom, 1987; MacRae, 1999). All of the following could potentially be found in KwaZulu-Natal. Trackways, produced mostly by fish and arthropods (invertebrates), have been recovered in shales from the uppermost Dwyka Group. Other trace fossils include coprolites (fossilized faeces) of chondrichthyians (sharks, skates and rays).

Body fossils include aranaceous foraminifera and radiolarians (single-celled organisms), bryozoans, sponge spicules (internal support elements of sponges), primitive starfish, orthoceroid nautiloids (marine invertebrates similar to the living *Nautilus*), goniatite cephalopods (*Eoasinites* sp.), gastropods (marine snails such as *Peruvispira viperdorfensis*), bivalves (*Nuculopsis* sp., *Phestia* sp., *Aphanaia haibensis*, *Eurydesma mytiloides*), brachiopods (*Attenuatella* sp.) and palaeoniscoid fish such as *Namaichthys schroederi* and *Watsonichthys lotzi*.

Fossil plants have also been found, including lycopods (*Leptophloem australe*), moss, leaves and stems (possibly belonging to a proto-glossopterid flora). Fossil spores and pollens (such as moss, fern and horsetail spores and primitive gymnosperm pollens) as well as fossilized wood probably belonging to primitive gymnosperms have also been recorded from Dwyka deposits (MacRae, 1999; McCarthy and Rubidge, 2005).

## 5.5 The Ecca Group

### 5.5.1 Pietermaritzburg Formation

Fossils are generally absent from the Formation although trace fossils have been recorded from the upper layers of the Pietermaritzburg Formation by Linstrom (1987).

### 5.5.2 Vryheid Formation

The Vryheid Formation is well-known for the occurrence of coal beds that resulted from the accumulation of plant material over long periods of time. Plant fossils described by Bamford (2011) from the Vryheid Formation are; *Azaniodendron fertile, Cyclodendron leslii, Sphenophyllum hammanskraalensis, Annularia sp., Raniganjia sp., Asterotheca spp., Liknopetalon enigmata, Glossopteris > 20 species, Hirsutum 4 spp., Scutum 4 spp., Ottokaria 3 spp., Estcourtia sp., Arberia 4 spp., Lidgetonnia sp., Noeggerathiopsis sp. and Podocarpidites sp.*

According to Bamford (2011) "Little data have been published on these potentially fossiliferous deposits. Around the coalmines there is most likely to be good material and yet in other areas the exposures may be too poor to be of interest. When they do occur fossil plants are usually abundant and it would not be feasible to preserve and maintain all the sites, however, in the interests of heritage and science such sites should be well recorded, sampled and the fossils kept in a suitable institution.

Although no vertebrate fossils have been recorded from the Vryheid Formation, invertebrate trace fossils have been described in some detail by Mason and Christie (1985). It should be noted, however, that the aquatic reptile, *Mesosaurus*, which is the earliest known reptile from the Karoo Basin, as well as fish (*Palaeoniscus capensis*), have been recorded in equivalent-aged strata in the Whitehill Formation in the southern part of the basin (MacRae, 1999; Modesto, 2006). Indications are that the Whitehill Formation in the main basin might be correlated with the mid-Vryheid Formation. If this assumption proves correct, there is a possibility that Mesosaurus could be found in the Vryheid Formation (Catuneanu et al 2005).

The late Carboniferous to early Jurassic Karoo Supergroup of South Africa includes economically important coal deposits within the Vryheid Formation of Natal. The Karoo sediments are almost entirely lacking in body fossils but ichnofossils (trace fossils) are locally abundant. Modern sedimentological and ichnofaunal studies suggest that the north-eastern part of the Karoo basin was marine. In KwaZulu-Natal a shallow basin margin accommodated a prograding fluviodeltaic complex forming a broad sandy platform on which coal-bearing sediments were deposited. Ichnofossils include U-burrows (formerly *Corophioides*) which are assigned to ichnogenus *Diplocraterion* (Mason and Christie, 1985).

### 5.5.3 Volksrust Formation

Trace fossils have been described from the upper layers of the Formation.

The bivalve *Megadesmus* is described from the Late Permian Volksrust Shale Formation in the north-eastern Karoo Basin, South Africa; this is the first reported discovery of this genus in Africa. The fossil is large, 9 cm dorsally and 8.4 cm laterally, and both valves are articulated indicating minimum transport after death. The bivalve was encased in interbedded siltstone-shale that constitutes the distal sediments of a prograding delta at the Beaufort –Ecca Group boundary. *Megadesmus* is known from other continents (Australia, India, Siberia, South America and Tasmania) where its presence indicates exclusively marine conditions. The implication for the northeastern Karoo Basin during the Late Permian is that a marine enclave still existed in this geographic area and that terrestrial conditions did not yet prevail as in the southern basin region (Cairncross, 2005).

## 5.6 Beaufort Group

These 250 million year old rocks record the largest known extinction event, the end-Permian mass extinction, in which most of the known species died out.

The Beaufort Group is well-known for its richness in fossils of vertebrates and also includes several recordings of unique vertebrate burrows. (Groenewald 1991; Johnson and Verster , 1994; Rubidge, 1995; Groenewald 1996; Groenewald et al, 2001 and; Johnson et al, 2006).

### 5.6.1 Adelaide Subgroup (In some areas mapped as the Adelaide Formation)

The Adelaide Subgroup overlies the Volksrust Formation of the Ecca Group and the transition from deep water deposits of the Volksrust Formation to pro-delataic and deltaic deposits of the Beaufort Group present fieldworkers with problems in mapping these units (Groenewald, 1984; Munitingh, 1989; Johnson and Verster, 1994; Johnson et al, 2006). The Adelaide Subgroup comprises the *Dicynodon* Assemblage Zone and possibly the underlying *Cistecephalus* Assemblage Zone.

#### 5.6.1.1 Normandien Formation

The Normandien Formation comprises all the sediments of the Adelaide Subgroup and includes the Estcourt Formation (Johnson and Verster, 1989)The Karoo Basin in South Africa is well known for the fact that it represents the most complete sequence of sedimentary history in Gondwana and contains the remains of most of the therapsids (ancient ancestors of mammals) that roamed the Earth during the Permian Period (Rubidge, 1995; MacRae, 1999; McCarthy and Rubidge, 2005). The most significant geological event recorded in this sequence is the end-Permian mass extinction event (EPME) that occurred 252.4 million years ago when much of all life on Earth was terminated. This event is probably associated with the Schoondraai Member of the Normandien Formation (see Section 4). The present excavations for the Bedford Dam of the Ingula Pumped Storage Scheme (Groenewald, 2011) provided a unique opportunity to collect vertebrate fossils, trace fossils of invertebrates (i.e. trackways, burrows) as well as plants from the rocks that were deposited during the Late Permian.

##### 5.6.1.1.1 Permian Vertebrates (255 to 252 million years ago)

Permian vertebrates from the *Cistecephalus* and *Dicynodon* assemblage zones in the main Karoo Basin include at least three genera of fish, four genera of amphibians, eight genera of

parareptiles (the sister group to true reptiles), three genera of diapsid reptiles (i.e. true reptiles) and 66 genera of therapsids (ancestors of mammals) (Rubidge 1995; Smith et al, 2012). Fish, amphibians, parareptiles and diapsid reptiles from these assemblage zones are relatively rare, both in terms of number of species and number of individuals. However, therapsid fossils are known by the hundreds and form the bulk of vertebrate fossils collected from these assemblage zones.

Dicynodonts ("Two Dog Toothed animals") are well-known herbivorous (plant-eating) therapsids from the Karoo Basin. They reached up to 4 metres in length and are characterized by a horny beak and tusks. Some of the oldest examples of this group have never been recorded from the Harrismith escarpment due to deep weathering of the mudstones. One such animal is the dicynodont *Rachiocephalus,* only recorded from Warden, far towards the west (Groenewald, 1984). However, at least 35 dicynodont genera are known from the Beaufort Group in South Africa and although only a few genera have been recorded from KwaZulu Natal strata, this is most likely due to a lack of collecting activity as the most intensive collecting has taken place in the main Karoo Basin. KwaZulu Natal strata however, have the potential to contain at least 21 dicynodont genera, which are known from the Permian *Cistecephalus* and *Dicynodon* assemblage zones in the main Karoo Basin, and these deposits are also preserved in KwaZulu Natal.

The most important indicator of the beginning of the largest and most severe mass extinction on Earth is the disappearance of almost all of the dicynodont therapsids. Only one dicynodont genus, *Lystrosaurus*, has been recorded from both sides of the Permo-Triassic boundary. After this bottle neck, however, the dicynodonts recovered and diversified during the Middle Triassic.

Although the dicynodonts were by far the most abundant vertebrates in South Africa during the Permian, other therapsids lived and often predated upon these herbivores. The gorgonopsians and therocephalians are such examples.

Gorgonopsians were one of the most fearsome predators to have roamed the Earth. These animals had unusually long canines nearly 20 cm in length (Figures 5.1 and 5.2). Gorgonopsians were the dominant predators during the Late Permian. They grew up to 5 metres in length and are often termed the 'sabred-toothed cats' of the Permian due to their exceptionally long canines. They were slightly more mammal-like compared to their ancestors and several key features in the skull and skeleton show that they had begun to move and feed similar to mammals. During the excavation of a gorgonopsian at Bedford Dam, a small skull of a dicynodont was found associated with its ribs, possibly representing the last meal of the predator. These unique finds are only possible if the palaeontologist is on site at all times during an excavation.

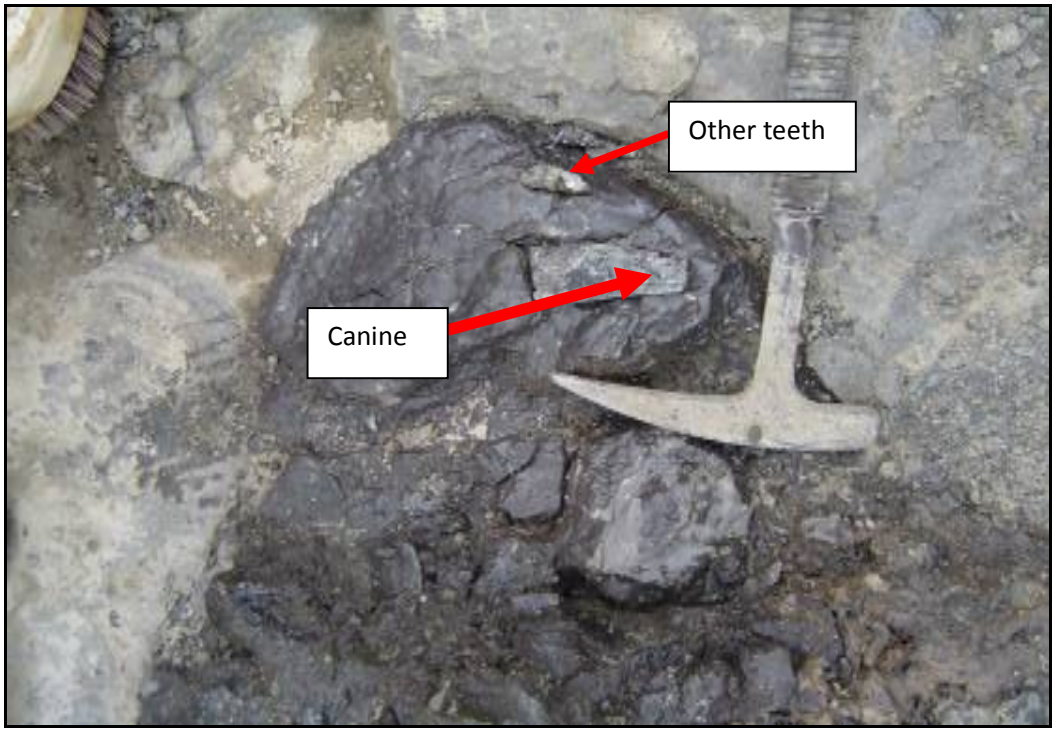



**Figure 5.1** **Remains of a Gorgonopsian snout discovered with a prominent canine exposed**

**Figure 5.2** **Reconstruction of the animals that roamed the Drakensberg Escarpment during the Late Permian**

At least 19 gorgonopsian genera are known from the *Cistecephalus* and *Dicynodon* assemblage zones of the main Karoo Basin, and thus there is a potential of finding this many genera in KwaZulu Natal as well. Gorgonopsian remains are relatively rare, being the top predators of the food web, and thus were not nearly as abundant as the herbivorous dicynodonts. Consequently, any recovery of a gorgonopsian fossil is a significant find. Another group of therapsids, the biarmosuchians, are closely related to gorgonopsians, but more primitive, and although exceptionally rare, have been recovered from the *Cistecephalus* and *Dicynodon* assemblage zones of the main Karoo Basin. Five genera (Smith et al, 2012) are currently known from these strata and could potentially be recovered from equivalent strata in Kwazulu Natal as well.

The other main group of predatory therapsids during the Permian were the therocephalians. They looked superficially similar to mammals and are one of the few vertebrate groups to have survived the end-Permian mass extinction relatively unscathed and are thus important specimens in Permo-Triassic research pertaining to the end-Permian mass extinction. Twenty-two therocephalian genera have been recovered from the *Cistecephalus* and *Dicynodon* assemblage zones of the main Karoo Basin (Smith et al, 2012), and have the potential to be preserved in equivalent strata in Kwazulu Natal.

Cynodonts are the most mammal-like therapsids and are the direct ancestors of living mammals. They are thus fundamental to research on the origin and evolution of mammals. At least 26 cynodont genera have been recovered from the main Karoo Basin, four of which are known from the Permian *Cistecephalus* and *Dicynodon* assemblage zones (Botha-Brink et al, 2012; Smith et al, 2012; Smith pers. Comm.. 2012), and may be potentially preserved in equivalent Kwazulu Natal deposits.

Large burrows, associated with the large dicynodonts *Daptocephalus* and *Lystrosaurus maccaigi* have also been discovered in the uppermost portion of the *Dicynodon* Assemblage Zone in the main Karoo Basin (Botha-Brink, pers. Comm., 2012) and have the potential to be preserved in equivalent strata in Kwazulu Natal.

#### 5.6.1.1.2 Plant and Insect fossils from the Permian Normandien Formation

The Normandien Formation is well known for rich assemblages of plant fossils, mainly *Glossopteris, Phyllotheca* and other flora including ferns, clubmosses, liverworts and true mosses (McCarthy and Rubidge, 2005). Insect remains have been recorded from several localities (Lacey et al, 1975; Johnson and Verster, 1994 and Michael Motovski, pers comm., 2012). Of special note is a locality near Bulwer that contains numerous plant and insect fossils. Insect families include Perlaria (including one holotype), Protorthoptera, Protelytroptera, Miomoptera (including one holotype), Psocoptera/Hemiptera, Homoptera, Neuroptera (including one holotype) and Mecoptera (including two holotypes). This site comprises one of the richest fossil insect sites in the world, but is currently unprotected and under constant destruction as was the case with localities at Mooi River, Lidgetton, Mount West, Balgowan, and Far End.

#### 5.6.1.1.3 Triassic Vertebrates (252 to 180 million years ago)

Numerous remains representing the survivors of the end-Permian mass extinction have been recovered from localities in the Free State and Eastern Cape Provinces in South Africa. Although no evidence of the extinction event is known from the Drakensberg Escarpment, survivors of the event are associated with the Early Triassic *Lystrosaurus* Assemblage Zone which is mostly represented by the Harrismith Member (Groenewald, 1989; Muntingh, 1989). *Lystrosaurus*, after which the assemblage zone is named, is the most abundant vertebrate found directly after the end-Permian mass extinction event. It is the only dicynodont genus found on either side of the Permo-Triassic boundary. Other Early Triassic vertebrates include large predators such as the archosauriform reptile *Proterosuchus* and the therocephalian therapsid *Moschorhinus*, as well as more relatively abundant cynodonts such as the insectivorous *Thrinaxodon* and *Galesaurus* (Rubidge et al, 1995; MacRae, 1999; Botha and Smith 2006). All vertebrates from this assemblage zone formed an important part of the recovery ecosystem following the end-Permian mass extinction and thus any finds from this zone are significant. Approximately one fish genus, 10 amphibian genera, five parareptile genera, five diapsid reptile genera, two dicynodont genera, seven therocephalian genera and four cynodont genera have been recorded from the *Lystrosaurus* Assemblage Zone, many of which have been recorded from the Harrismith Member in Kwazulu Natal.

The lower part of the *Lystrosaurus* Assemblage Zone is also well-known for preserving burrows of various sizes that may be associated with invertebrates (e.g. Katbergia) and vertebrates such as dicynodonts, therocephalians and cynodonts. These important trace fossils provide important information about the behavior of these animals (Botha and Smith, 2006; Modesto and Botha-Brink, 2010).

In Kwazulu Natal, there are 11 localities in the Bulwer, Bergville, Estcourt and Impendle districts that contain the dicynodont *Lystrosaurus curvatus* . This animal is restricted to the uppermost strata of the Permian *Dicynodon* Assemblage Zone and lowermost strata of the Triassic *Lystrosaurus* Assemblage Zone, and as such, acts as a biostratigraphic marker for the Permo-Triassic boundary (Botha and Smith, 2007). Thus, any locality that contains *Lystrosaurus curvatus* has the potential to contain a complete sequence marking the end-Permian mass extinction, and should thus be considered extremely sensitive.

### 5.6.2 Tarkastad Subgroup

#### 5.6.2.1 Katberg/Verkykerskop Formations

The Katberg and Verkykerskop formations are well-defined sandstone rich units along the Drakensberg Escarpment and the lower boundary of the Tarkastad Subgroup is mapped out over the entire escarpment. The Katberg and Verkykerskop Formations are associated with the middle and upper portion of the *Lystrosaurus* Assemblage Zone. Numerous vertebrate fossils have been found in these strata, including one fish genus, 10 amphibian genera, three parareptile genera, two diapsid reptile genera, two dicynodont genera, four therocephalian genera and three

cynodont genera (Smith et al, 2012), all of which formed an important part of the Early Triassic recovery ecosystem following the end-Permian mass extinction event (Botha and Smith 2006). Important trace fossils include large burrows similar to those found in the lower portion of the *Lystrosaurus* Assemblage Zone (Palingkloof and Harrismith Members) and generally associated with the dicynodont *Lystrosaurus* (Botha-Brink, pers. Comm., 2012).

#### 5.6.2.2 Burgersdorp/Driekoppen Formations

The Burgersdorp/Driekoppen formations are associated with the Middle Triassic *Cynognathus* Assemblage Zone (Rubidge, 1995). Current database information shows that no fossils from this time have been found in Kwazulu Natal, but the lack of fossils may be ascribed to a lack of intensive collecting, as numerous vertebrate fossils have been recorded from this formation in other areas (Rubidge 1995; Smith et al, 2012). These include seven fish genera, 16 amphibian genera, six parareptile genera, six diapsid reptile genera, four dicynodont genera, two therocephalian genera and 11 cynodont genera (Smith et al, 2012; Botha-Brink, pers. Comm. 2012). One of the most spectacular finds are casts of vertebrate burrows containing fossils of the cynodont *Trirachodon* near the town Clarens (Groenewald et al, 2001). Other burrows from the *Cynognathus* Assemblage Zone have been found associated with procolophonid parareptiles in the main Karoo Basin (Botha-Brink, pers. Comm. 2012).

### 5.6.3 Emakwezini Formation in eastern KwaZulu-Natal

Recent research confirms that the Emakwezini Formation contains a fossil assemblage of animal traces, insects, molluscs, arthropods, fish and plants. Previously, only *Glossopteris* leaves and *Phyllotheca australis* had been described from this formation, on the basis of a few very small, scattered and poorly provenanced collections.

However, recent regional-scale sedimentary facies analysis (based on field relationships, provenance studies, palaeocurrent and subsurface data) together with palaeobotanical studies of a newly discovered, well-preserved and diverse palaeoflora from the Emakwezini Formation, have permitted a more detailed interpretation of the depositional environment. The current investigation also revealed the first evidence of the plant fossils *Dictyopteridium flabellatum*, *Rigbya arberioides*, *Lidgettonia* spp., and *Trizygia speciosa* in the upper parts of the Emakwezini Formation, strongly supporting a Late Permian age based on correlation with floras from Upper Permian units in the main Karoo Basin. In the lower part of the unit, within the partings of actively mined coal seams, preliminary investigations also show the presence of a new flora including both the glossopterid fructification *Ottokaria* sp. (only known from the Lower Permian in South Africa) and the sphenopsid *Schizoneura gondwanensis* (typical of the Upper Permian in South Africa).

## 5.7 The Stormberg Group

### 5.7.1 Molteno Formation (Ntabene Formation in eastern KwaZulu-Natal)

This sequence of sediments is rated as some of the most productive deposits of Mesozoic plant fossils of *Dicroidium* assemblages in the world. At their peak development during the Late Triassic

these seed ferns inhabited a variety of ecological niches, including riverine forests, wetlands and open woodland. The open woodland was dominated by cycadeoids, ginkos and conifers. Rich assemblages of insects are also recorded from these sequences. A rich plethora of early gymnosperms are also recorded from outcrops in KwaZulu-Natal, notably Little Switzerland, Kannaskop, Umkomaas and Bird River. These deposits are seen by scientists as examples of one of the richest plant histories and the clearest window into the Late Triassic plant and insect communities in the world (Mac Rae, 1995; McCarthy and Rubidge, 2005). Although no vertebrate remains have been described from the Molteno Formation several dinosaur tracks have been described from the formation.

### 5.7.2 Elliot Formation (Nyoka Formation in eastern KwaZulu-Natal)

Outcrops of the Elliot Formation are restricted to badly eroded regions in the foothills of the Drakensberg. Due to these areas mainly falling in protected reserves, outcrops are not as abundantly present as in the more western part of the basin. In general the Elliot Formation is globally recognized for its abundance of early dinosaur and mammal remains (MacRae, 1995; McCarthy and Rubidge, 2005), including dinosaur eggs containing embryos from the Golden Gate Highlands National Park in the Free State Province, which represent the oldest dinosaur embryos in the world (Reisz et al, 2005, 2012). At present, one fish genus, two amphibian genera, 10 non-dinosaurian reptiles, at least 17 dinosaur genera, seven cynodont genera and two mammalian genera are known from this formation. Importantly, *Australochelys*, the oldest known fossil turtle is also known from the Elliot Formation (Smith et al, 2012).

The Elliot Formation also contains the Triassic-Jurassic boundary, an important marker, which represents the end-Triassic mass extinction. This extinction resulted in a massive faunal turnover (Tanner et al, 2004), the reasons for which are still under debate.

### 5.7.3 Clarens Formation

The Clarens Formation has produced some dinosaur remains and footprints as well as invertebrate burrows (Linstrom, 1981). The fish genus, *Semionotus*, has also been recovered from the Clarens Formation (MacRae, 1999).

## 5.8 The Drakensberg Group (Lebombo Group in eastern KwaZulu-Natal)

Due to the volcanic nature of these rocks, fossils are absent.

## 5.9 The Mzamba Formation

The basal sandstone of this formation contains charred wood fragments (bored by the gastropod *Teredo*), shark teeth and vertebrate remains (Johnson et al, 2006).

## 5.10 Zululand Group

During this time, huge snail-like animals called ammonites, which are similar to the living *Nautilus* and reached up to one metre in size, thrived in the warm ocean. Their shells are common in almost all exposures of Cretaceous rocks, such as along the shorelines surrounding Lake St Lucia (Wolmarans and

Du Preez, 1986; Kennedy and Klinger, 1975; MacRae, 1999; McCarthy and Rubidge, 2005, Johnson et al, 2006).

A wide range of evidence indicates that 65 million years ago a large meteorite impact at Chicxulub, Mexico resulted in a worldwide extinction of many organisms including the ammonites and dinosaurs.

### 5.10.1 The Makatini Formation

The Makatini Formation contains large fossil logs that are pervasively drilled by *Teredo* wood boring organisms (Johnson et al, 2006). Interfingering fine-grained sediments contain bored fossil tree trunks, smaller plant fragments and marine invertebrates.

Palaeo-environments are interpreted as mainly braided rivers that emerged from the foot of a steep escarpment, flowing eastwards onto a narrow coastal plain where they merged with tidal flats (Johnson et al, 2006).

### 5.10.2 The Mzinene Formation

The Mzinene Formation consists of glauconotic siltstone and sandstone with a rich invertebrate fauna, including bivalves, gastropods, ammonites, nautiloids and echinoids. *Lithophaga*, i.e. bored concretions, are common. Fossil logs, bored by *Teredo* are frequently found in the formation (Johnson et al, 2006). The palaeo-environment is interpreted as shallow-marine.

### 5.10.3 The St Lucia Formation

The St Lucia Formation is more fossiliferous than the underlying Mzinene Formation and contains an abundance of echinoid, bivalve, gastropod and cephalopod remains as well as fossil logs, plant fragments, reptile bones and at least 62 ostracod species (Johnson et al, 2006).

## 5.11 The Maputuland Group

The Maputuland Group forms a thin blanket of Tertiary and Cretaceous successions that extend from Durban northwards into Mozambique. The less detailed subdivision of Wolmarans and Du Preez (1986) are mapped on the scale of this project and is, for reasons of simplicity, preferred to the more detailed subdivision of Johnson et al (2006).

### 5.11.1 The Uloa Formation

The Uloa Formation is a succession of calcarenite and thin limestone with a basal coquina, shelly conglomerate, low-angle stratified boulder/cobble conglomerate, sandstone and siltstone, deposited in the littoral zone on palaeoshorelines along the Lebombo foothills and closer to the present coastline from Mtunzini to Port Edward (Johnson et al, 2006; Wolmarans and Du Preez, 1986; Du Preez and Wolmarans, 1986). A main portion of the formation comprises about 5 metres of unbedded calcirudite, locally known as the “Pecten Bed” on account of the abundance of the bivalve *Aeqipecten uloa.*

Gastropods, brachiopods, coralline algae, corals, polyzoa, foraminifera and echinoids are also present, as well as isolated teeth of the extinct giant shark *Carcharodon megalodon* (Johnson et al, 2006). The depositional environment is interpreted as a response to at least three transgressive events superimposed on a first-order regression during the Neogene.

### 5.11.2 The Muzi Formation

The clayey nature and mottled appearance with root-like structures leads to the interpretation of a swamp or vlei deposit for this unit (Wolmarans and Du Preez, 1986). No other fossils are described from this unit.

### 5.11.3 The Port Durnford Formation

The Port Durnford Formation comprises a succession of carbonaceous muds and sand, containing fossils of terrestrial vertebrates such as hippopotamus, buffalo, antelope, rhinoceros and elephant as well as marine fossils including crustaceans and fish remains, foraminifera, marine moluscs and fragments of turtle and crocodile (Johnson et al 2006).

### 5.11.4 The Bluff Formation

The Bluff Formation occurs in an almost continuous outcrop zone along the coast and significant fossils have been described from small deposits of coral limestone at False Bay (Wolmarans and Du Preez, 1986).

### 5.11.5 The Berea Formation

No significant vertebrate fossils have been recorded from the Berea Formation (Wolmarans and Du Preez, 1986). Petrified wood with fossil wood, flattened *Syzigium* logs, have been described from the Formation.

## 5.12 Alluvium, Sand & Calcrete

Large areas of the coastal plain of KwaZulu-Natal are covered in a blanket of alluvial sand and no significant fossils have been described from these sediments (Wolmarans and Du Preez, 1986; Johnson et al, 2006).

## 5.13 Masotcheni Formation

Large areas of the coastal plain of KwaZulu-Natal are covered in a blanket of alluvial sand and no significant fossils have been described from these sediments (Wolmarans and Du Preez, 1986; Johnson et al, 2006).

## 6 GEOLOGICAL BASE MAPS USED

The KwaZulu-Natal Province is covered by 10 maps at a scale of 1:250 000 (Table 6.1). These maps are published by the Council for Geoscience, Pretoria and each map sheet is accompanied by a separate sheet explanation. Some of the explanations are only available in Afrikaans.
The level of attention paid to palaeontology varies between sheet explanations, depending on the interest and priorities of the compilers and the stratigraphic units present in the areas mapped.

The layout of the sheets is depicted in the official 1:250 000 sheet catalogue. The only maps with substantial palaeontological data are sheet 2632 Kosi Bay and 27(.5)32 St Lucia.

**Table 6.1 1:250 000 scale Geology Sheets and Sheet explanations**

| Sheet Name and Number | Mapping status | Sheet explanation | Palaeontology coverage |
|---|---|---|---|
| 2632 Kosi Bay | Published 1986 | Du Preez and Wolmarans1986 | 27 sites described with fossil identification and age |
| 2728 Frankfort | Published 1989 | Muntingh DJ, 1989 | Moderate |
| 2730 Vryheid | Published 1987 | Linstrom W, 1987 | Moderate |
| 27(.5)32 St Lucia | Published 1986 | Wolmarans and Du Preez, 1986 | 71 fossil sites described with fossil identification |
| 2828 Harrismith | Published 1994 | Johnson MR and Verster PSJ, 1994 | Poor |
| 2830 Dundee | Published 1987 | Linstrom, W. 1987 | Moderate |
| 2928 Drakensberg | Published 1981 | Linstrom,W. 1981 | Moderate |
| 2930 Durban | Published 1987 | Linstrom, W. 1987 | Poor |
| 3028 Kokstad | Published 1981 | De Decker, RH. 1981 | Poor |
| 3030 Port Shepstone | Published 1988 | Thomas, RJ. 1988 | Absent |

# 7 STRATIGRAPHIC UNITS WITH ASSOCIATED FOSSILS

This section forms the core of the document and must be read in conjunction with the sensitivity map (Figure 7.1) and the 1:250 000 scale geological maps of the KwaZulu-Natal Province (10 maps available from the Council for Geoscience in Pretoria). The palaeontological sensitivity is presented in tabular format, and the classification of sensitive areas is presented in three classes, with colour coding red, orange and green.

The tables are arranged according to the age of the geological groups, formations and members as provided on the most recent geological maps. The youngest geological formations are presented at the top and the oldest at the bottom.

## 7.1 Palaeo Sensitivity Classes

Red colouration indicates a very high possibility of finding fossils of a specific assemblage zone. Fossils will most probably be present in the areas and the chances of finding fossils during the construction phase are very high. These geological formations will need at least a Phase I palaeontological Impact Assessment, with a very high possibility for the need of a palaeontologist being on site during the construction phase of the project.

Orange colouration indicates a moderate possibility of finding fossils of a specific assemblage zone and the chances of finding fossils during the construction phase are possible. These geological formations will require at least a desk top survey, with a high possibility of the need for a Phase I palaeontological assessment.

Green colouration indicates that there is no possibility of finding fossils in those sections. Due to the scale of mapping (1:250 000) it is recommended that at least a desktop survey be conducted by a professional palaeontologist to confirm that the specific locality falls on non-fossiliferous strata.

**Table 7.1 Palaeontological Sensitivity for Cenozoic Era**

| ERA | System | Supergroup or Sequence | Group | Subgroup | Formation | Member | Lithology | Fossil Record |
|---|---|---|---|---|---|---|---|---|
| Cenozoic | Quaternary | | | | m m m m m | | Recent alluvial sediments | None |
| | | | | | Qs | | Dune sand from extensive reworking of the Kosi Bay Formation on the Northern Natal coastal plain that resulted from marine regressionand dry periods when dune formation was wide spread. Yellowish red grey and white dune sands with local pockets of calcareous clays | Local peat deposits up to 4m thick |
| | | | | | Δ Δ Δ Δ Δ | | Debris | None |
| | | | | | Masocheni (Qm) | | Thin sedimentary deposit on hillsides and in valley floor, on floodplains of rivers | Fossil plant roots preserved as silcrete around original roots |
| | | | | | Berea (Qb / Qbe) | | Rocky shoreline along the Bluff in Durban. Basal aeolianites, truncated by calcified beach and dune deposits of the Last Interglacial-age | Oyster beds are present in karst potholes and an elephant tusk was collected at the Umlaas Canal outfall, associated with the Last Interglacial beach |

| ERA | System | Supergroup or Sequence | Group | Subgroup | Formation | Member | Lithology | Fossil Record |
|---|---|---|---|---|---|---|---|---|
| | | | | | Bluff (Qbl / Qb) | | Composite units comprising dune sand under inland dune system and forming core unit of coastal dune cordon. Lignite unit in the formation is interpreted as an inland lake deposit. | Fossil wood, flattened *Syzigium* logs |
| | | | | | Port Durnford (Qp) | | Comprises a succession of carbonaceous muds and sand. Estuarine and lacustrine mud and clayey carbonaceous sand | Basal bio-turbation containing *Ophiomorpha nodosa* burrows. Variety of fossils including crustaceans and fish remains, foraminifera, marine molluscs, fragments of turtles and crocodiles. Mammalian fossils include hippopotamus, buffalo, antelope, rhinoceros and elephant |
| | | | | | Muzi (Qm) | | Cross-bedded aeolianite of up to 25m, characteristically overlying a stratified shallow marine calcarenite. Upper surface commonly karst-weathered, decalcified and rubified to form a thick covering of Berea-type red sand | None |
| | Tertiary | | | | Cornelia (T-Qc) | | Well defined kompact klei and highly erodable sandy clay layers and gravel with carbonate concrections | Rich in fossils of animals such as *Stylochoerus compactus, "Gazella" helmoedi, Connochaetes laticornutus* and *Megalotragus eucornutus* |

| ERA | System | Supergroup or Sequence | Group | Subgroup | Formation | Member | Lithology | Fossil Record |
|---|---|---|---|---|---|---|---|---|
| | | | | | Uloa (Tu1 / Tu2) | | Calcified coquina, shelly conglomerate low angle stratified boulder conglomerate, sandstone and siltstone. Deposited in littoral zone on palaeoshorelines along the Lebombo foothills and closer to the present shoreline from Mtunzini to Port Edward | Shallow marine coquina. Mainly 5m of unbedded calcirudite coquina, locally known as the "Pecten Bed" due to abundance of the bivalve *Aeqipecten uloa.* Gastropods, brachiopods, coraline algae, corals, polyzoa, foraminifera and echinoids as well as isolated teeth of the giant shark *Carcharodon megalodon* |

**Table 7.2 Palaeontological Sensitivity for Mesozoic Era**

| ERA | System | Supergroup or Sequence | Group | Subgroup | Formation | Member | Lithology | Fossil Record |
|---|---|---|---|---|---|---|---|---|
| Mesozoic | Cretaceous | | Zululand | | St. Lucia (K-Ts) | | Lithologicaly similar to Mzinini Formation. Separated along slight unconformity by bored hardground above which the formation consists of repetitive sequence of bored concretions, shelly glauconitic sandstones and bioturbated siltstones | Even more fossiliferous than underlying Mzinene Formation, abundance of echinoid, bivalve, gastropod and cephalopod remains as well as fossil logs, plant fragments, reptile bones and at least 62 ostracod species. |
| | | | | | Mzinene (Kmz) | | Directly on Lebombo Group lavas or overlying the Makatini Formation, glauconitic siltstone, cross-bedded sandstone and with characteristic hardground [concretionary horizon bored by *Lithophaga* (rock drilling gastropod)]. | Rich invertebrate fauna including bivalves, gastropods,ammonites, nautiloids and echinoids. *Lithophaga*-bored concretions, fossil logs bored by *Teredo.* Arthropod burrows in finer silty horizons |
| | | | | | Mzamba (Km) / Makatini (Km) | | Small pebble conglomerates sandstones siltstone and limestone | Fossil wood, bored extensively, plant fragments and marine invertebrates |
| | Jurassic | | | | Nxwala (Jn) / Ntabankosi (Jnt) | | Rhyolitic tuff and perlite | None |
| | | | | | Bumbeni Complex (Jb) | | Syenite microsyenite | None |
| | | | | | Fenda (Jf) | | Rhyolitic lava and pyroclastic rocks | None |
| | | | | | Msunduze (Jms) | | Conglomerate and sandstone | None recorded |

| ERA | System | Supergroup or Sequence | Group | Subgroup | Formation | | Member | Lithology | Fossil Record |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Quartz porphyry | | | Dykes | None |
| | | Karoo | | | Dolerite (Jd / Jk / Jn) | | | Dolerite and related intrusive igneous rocks | None |
| | | | Drakensberg / Lebombo | | Drakensberg (Jdr / Jdb) | Movene (Jm) / Jozini (Jj) / Letaba (Jl) / Mpilo (Jm) | | Picritic (Olivine rich) and silicic volcanic rocks | None |
| | Triassic | | Stormberg | | Clarens (Trc) | | | Fine-grained aeolian sandstone deposit. Arid environment with isolated salt pans | Fossillised fish remains, dinosaurs and tracks of dinosaurs. Trace fossils of invertebrates. |
| | | | | | Elliot (Tre) | Nyoka (Trny) | | Red Mudstone with interbedded yellow brown sandstone lenses in meandering river environment | Reptilian (mainly dinosaur) and fish fossils. Lower *Euskelosaurus* range zone and upper *Massospondylus* range zone, *Tritylodon* Acme zone in *Massospondylus* range zone. Dinosaurs consisting of Ornithishia and Saurischia, as well as Thecodontia and Crocodilia are well represented. |
| | | | | | Molteno (Trm) | Ntabene (Trn) | | Coarse-grained, glittering sandstone. Interbedded khaki coloured mudstone | *Dicroidium* ferns and most diverse plant and insect assemblages in the Gondwana Geological Terrain |
| | | | Beaufort | Tarkastad | Tarkastad (Trt) | | | Fluvial sandstone and red mudstone. Lower part always more sandstone rich. | *Lystrosaurus* and *Cynognathus* assemblage zones. Fish, amphibians, reptiles, therapsids and trace fossils such as foot prints and burrows. |

| ERA | System | Supergroup or Sequence | Group | Subgroup | Formation | | Member | Lithology | Fossil Record |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Burgersdorp | Driekoppen | | Red Mudstone with interbedded yellow brown sandstone lenses in meandering river environment | *Cynognathus* Assemblage Zone. Fish, amphibians, reptiles and therapsids. Vertebrate burrows with remains of *Trirachodon.* |
| | | | | | Katberg | Verkykerskop | | Braided river environments Katberg mainly fine-grained horizontally bedded sandstone; Verkykerskop Formation very coarse-grained sandstone with prominent manganese enrichment at base | *Lystrosaurus* Assemblage Zone. Fish, amphibians, reptiles, therapsids and trace fossils such as foot prints and burrows. |

**Table 7.3 Palaeontological Sensitivity for Palaeozoic Era**

| ERA | System | Supergroup or Sequence | Group | Subgroup | Formation | Member | Lithology | Fossil Record |
|---|---|---|---|---|---|---|---|---|
| Palaeozoic | Permian | Karoo | Beaufort | Adelaide | Adelaide (Pa / Pne) | | Deltaic and fluvial sequences of sandstone and green-grey mudstone | *Dicynodon* and *Lystrosaurus* assemblage zones. Fish, amphibians, reptiles, therapsids and vertebrate burrows |
| | | | | | Normandien (Pn) | Harrismith | Lacustrine environment. Fine-grained brightly coloured siltstone | *Lystrosaurus* Assemblage zone. Fish, amphibians, reptiles, therapsids and vertebrate burrows |
| | | | | | | Schoondraai | Meandering river channel sandstone | *Dicynodon* Assemblage Zone |
| | | | | | | Rooinek | Meandering river channel sandstone | *Glossopteris* tree fossils and insect wings |
| | | | | | Estcourt (Pe / Pes) / Emakwazini (Pem) | | Deltaic Coarse-grained sandstone and shale | Trace Fossils, including areas in the Estcourt Area, plant fossils of *Glossopteris* |
| | | | Ecca | | Volksrust (Pvo) | | Dark Grey Shale | Trace Fossils |
| | | | | | Vryheid (Pv) | | Light grey coarse- to fine-grained sandstone and siltstone. Dark coloured siltstone due to presence of carbon enrichment and coal beds | Abundant plant fossils of *Glossopteris* and other plants. Trace fossils. The reptile *Mesosaurus* has been found in the southern part of the Karoo Basin |
| | | | | | Pietermaritzburg (Pp) | | Dark Grey Shale | Trace Fossils |
| | Carboniferous | | | | Dwyka (C-Pd / Pd) | | Tillite, diamictite | None recorded in KwaZulu-Natal to date. the basin |

| ERA | System | Supergroup or Sequence | Group | Subgroup | Formation | Member | Lithology | Fossil Record |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | Devonian | | | | | | | |
| | Silurian | | Natal (O-Sn) | | | | Reddish brown arenaceous rocks with interbedded mudrock and conglomerate units | None |
| | Ordivician | | | | | | | |
| | Cambrian | | | | | | | |

**Table 7.4 Palaeontological Sensitivity for Swazian, Randian, Vaalian, Mokolian and Nambian Eras**

| ERA | System | Supergroup or Sequence | Group | Subgroup | Formation | Member | Lithology | Fossil Record |
|---|---|---|---|---|---|---|---|---|
| Namibian | | Natal Structural and metamorfic province | Mapumulo<br>Matigulu<br>Tugela<br>Ntingwe<br>Mfongosi | | Nmz, Nmk, Ns, Ne, Nmn, Nml, Nmg, Nmc, Nmi, Nh, Nma, Nly, No, Nss, Nsm, Ni, Nb, Na, Ns, Ncg, Nhg, Ngg, Ng, Nn, Nm, Nmh, Nl, Nt, Nmu, Nmp, Nq, Nh, Nbi, Nmg, Nsg, Nmg, Nsg, Nw, Nta, Ndg, Nnt | | Various formations of intrusive and metamorphic rocks, comprising mainly of granite, gneises and amphibolite | None |
| Mokolian | | | | | Intrusive Rocks (M) | | Intrusive rocks consisting of Granite and Gneiss | None |
| Vaalian | | | | | Intrusive Rocks (Vg, Vgp) | | Granite | None |
| Randian | | Venters dorp | Klipriviersberg | | Edenville | | Basaltic Lava | None |
| | | | | | Intrusive rocks (Rg, Rh, Rp, Rd) | | Various intrusive rock formations consisting of Biotite, Granophyre, Granite Diorite, Quartz, Gabbro and Diabase | None |

| ERA | System | Supergroup or Sequence | Group | Subgroup | Formation | | Member | Lithology | Fossil Record |
|---|---|---|---|---|---|---|---|---|---|
| Swazian | | Pongola | Mozaan | | Qwasha (Rqs) | | | Lower arenaceous and upper argillaceous units | None |
| | | | | | Mpunga (Rms) | | | | |
| | | | | | Mandeva (Rmq) | | | | |
| | | | Nsuze | | Taka (Rtq) | Mankane (Rml) | | Ferrugenous shale and quartzite | None |
| | | | | | | Vutshini (Rv) | | | |
| | | | | | Bivane (Zbl) | Qudeni (Zqb) | | Basaltic and amygdaloidal lava, quartzite and minor conglomerate | None |
| | | | | | | Mdlelanga (Zmd) | | | |
| | | | | | Chobeni (Zc) | Msukane (Zmp) | | Quartzitic Dolomite and dolomitic sandstone carbonate-bearing siltstone | Stromatolites in the vicinity of the White Mfolozi River |
| | | | | | | Dlabe (Zd) | | | |
| | | | | | Thembeni (Zts) | Mome (Zmo) | | Various formations consisting of Lava, Granite, Quartzite and Gneisses | None |
| | | | | | Nhlebela (Znl) | Mabaleni (Zma) | | | |
| | | | | | Bomvu (Zbq) | Hlathini (Zh) | | | |
| | | Baberton Sequence (Zk, Za) | | | | | | Quartzitic Chert and Schist | None |

| ERA | System | Supergroup or Sequence | Group | Subgroup | Formation | | Member | Lithology | Fossil Record |
|---|---|---|---|---|---|---|---|---|---|
| | | | Nondweni / Empangeni metamorfic suite | | Nkandla (Znq) | Ngweni (Zna) | | Quarzite, Schist, Basaltic lava and Amphibolite | None |
| | | | | | Mhlatuze (Zmh) | Lubana (Zl) | | | |

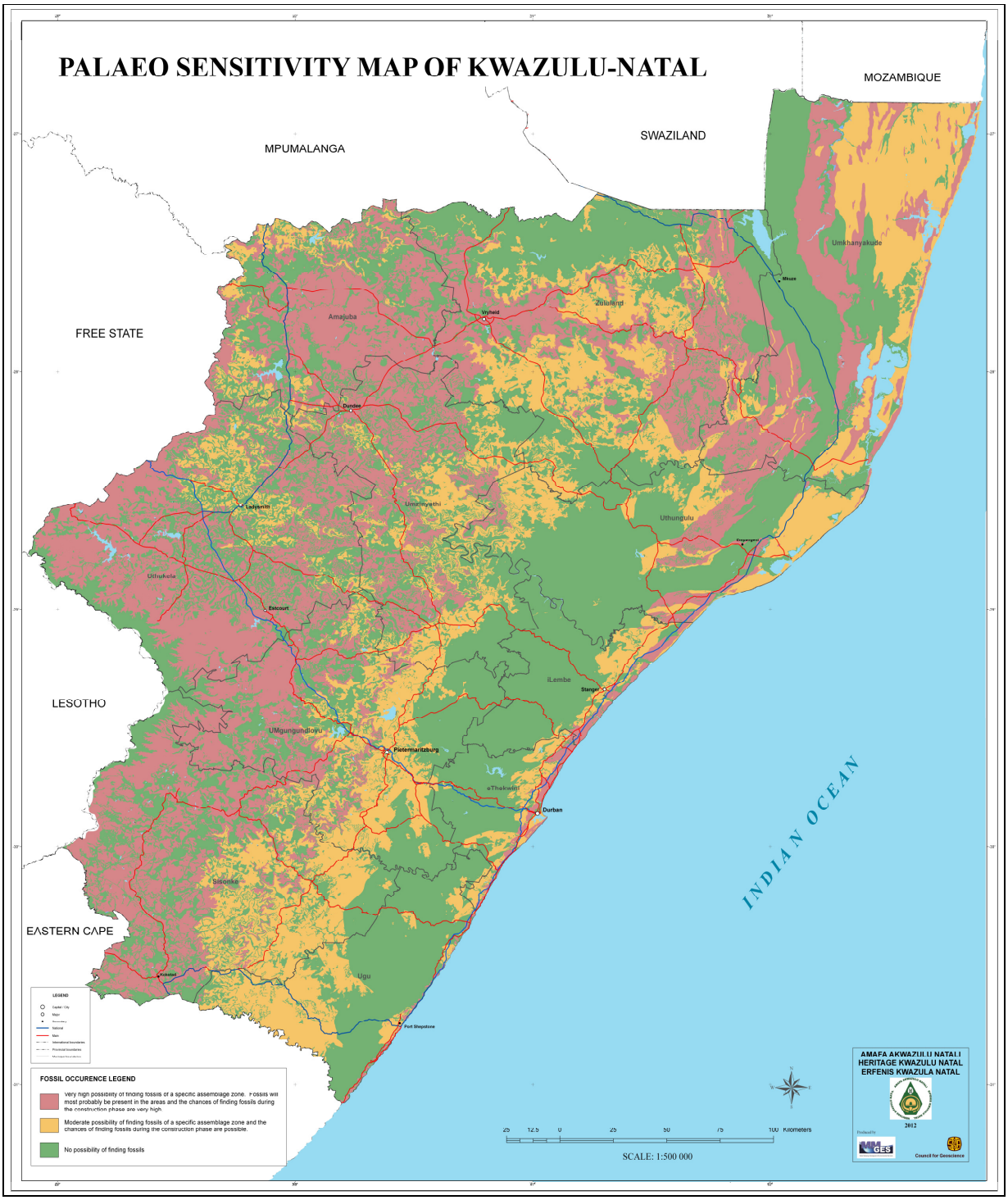



**Figure 7.1** **Palaeontological Sensitivity Map for KwaZulu-Natal Province**

# 8 KNOWN FOSSIL COLLECTIONS OF KWAZULU NATAL

According to the present information available the following institutions have collections of KwaZulu-Natal Province fossils.

## 8.1 University of KwaZulu-Natal

The University of KwaZulu-Natal is currently updating their collection information. They listed approximately 430 specimens in their database. However, localities are not recorded in detail.

Contact Person: Dr Tanja Reinhardt, Coordinator: Science and Technology Education Centre
Tel: 031 2602524. Email: reinhardtt2@ukzn.ac.za

## 8.2 KwaZulu-Natal Museum

The KwaZulu-Natal Museum has a collection of approximately 1660 specimens in their database. Most of the specimens is not identified and consist of small bone fragments. Localities are also not recorded in detail.

Contact Person: Dr Mike Mostovski, Assistant Director: Dept of Natural Sciences
Tel: 033 3451404 (Switchboard), E-mail: mmostovski@nmsa.org.za

## 8.3 Durban Museum

The Durban Museum has some specimens that were donated from various individuals and other sources. Amateur palaeontological volunteers are in the process to sort and record these collections. No formal database is currently available.
General information desk: Tel: 031 3112226/7

## 8.4 Iziko (South African Museum) Cape Town

No information was received from Iziko after numerous inquiries.
General information desk: Tel 021 4813800

## 8.5 Bernard Price Institute of Palaeontological Research, WITS University

A comprehensive database of the vertebrates palaeontology of the Karoo Basin has been developed by the Bernard Price Institute of Palaeontological Research at Wits University. Access to this database is available to institutions and researchers pending compliance to certain protocols.
Contact Person: Prof Bruce Rubidge. Director BPI Palaeontology
Tel: 011 7176682

## 8.6 Council for Geoscience, Pretoria

A comprehensive database of the vertebrates palaeontology of Southern Africa has been maintained by the Council for Geoscience in Pretoria. This collection was started during the early 1980's. Access to this database is available to institutions and researchers pending compliance to certain protocols.
General Reception Tel: 012 8411911

## 9 CONCLUSION

The document presented is aimed at providing the reader with a summary of the geology of KwaZulu-Natal and to relate the geology to the sensitivity of a specific unit (Group, Formation or Member) for palaeontological finds.

The geology of KwaZulu-Natal represents an evolution of geological events from the Archaeozoic to the Present. The oldest evidence of life is in the Pongola Supergroup. Evidence of soft bodied organisms is recorded in the Dwyka Group for the first time, with evidence of plant life, and specific reference to a rich accumulation of *Glossopteris* flora remains in the Ecca Group. The Beaufort Group contains remains of Permian *Glossopteris* flora and remains of the first vertebrate remains in the Estcourt and Normandien formations of the Adelaide Subgroup. An assemblage of plant fossils is also recorded from the Emakwazini Formation in Eastern KwaZulu-Natal. The Adelaide Subgroup contains the important end-Permian extinction event. Therapsids, the ancient ancestors of mammals, are preserved in the Tarkastad Subgroup. The Triassic Molteno Formation provides a unique window into the plant and insect life on Earth of that time, with specific reference to the *Dicroidium* flora. The Elliot Formation contains remains of the first dinosaurs and the Clarens Formation is known to contain remains and tracks of dinosaurs.

Following the Drakensberg and Lebombo Group volcanic events during the Jurassic, marine fossil rich deposits are represented by the Mzamba Formation, the Zululand Group and the Maputaland Group sediments.

The sensitivity map for palaeontological heritage in KwaZulu-Natal has been compiled by the Council for Geoscience and, used in conjunction with the tables presented in Section 6 as well as published 1:250 000 geological maps, presents the reader with a tool to assist both officials of AMAFA and potential developers to assess the possible impact of a development on the palaeontological heritage of the Province.

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