GEOLOGY FOR FIELD GUIDES

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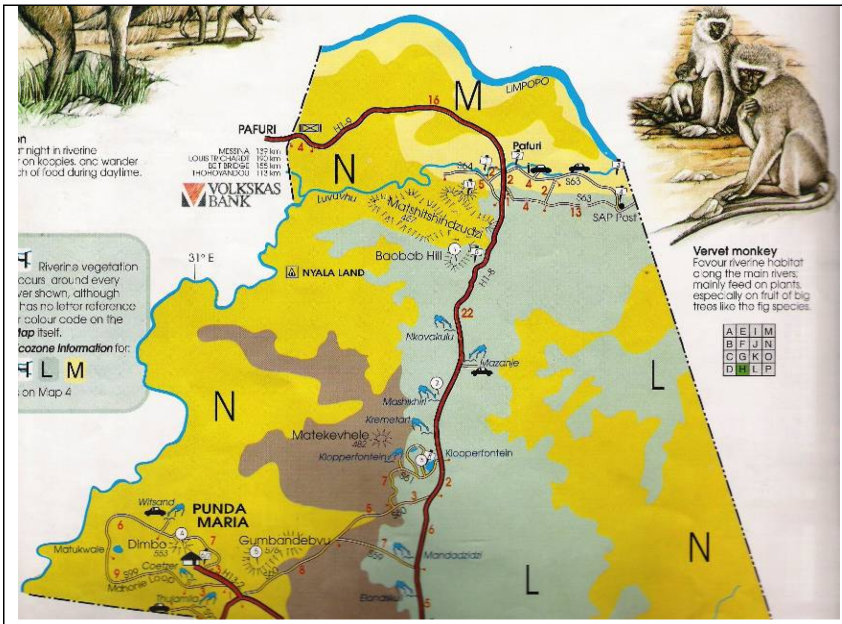
PREFACE

These notes seek to give Field Guides a deeper understanding of the processes that have shaped the landscape and created soils through geological history and affect the distribution of wild plants, animals and birds today. The idea of preparing these notes grew out of conversations with Bruce Lawson and Clive Thompson during a Birding Course in March 2009. For more detailed information, Field Guides are referred to two outstanding books:

- *The Story of Earth and Life: A southern African perspective on a 4.6-billion-year journey*, by Terence McCarthy and Bruce Rubidge, Struik, 2005.
- *Geological Journeys: A traveller's guide to South Africa's rocks and landforms*, by Nick Norman and Gavin Whitfield, Struik, 2006.

1. EARTH SYSTEM SCIENCE

While walking in the wilderness in an area such as the Makuleke concession we notice variations in plant and animal communities. On a local scale these ecozones are largely the result of variations in soil and topography (Figure 1), which are, in turn, the product of the underlying rocks and the geological history. On a regional scale many other factors come into play, such as latitude and precipitation.



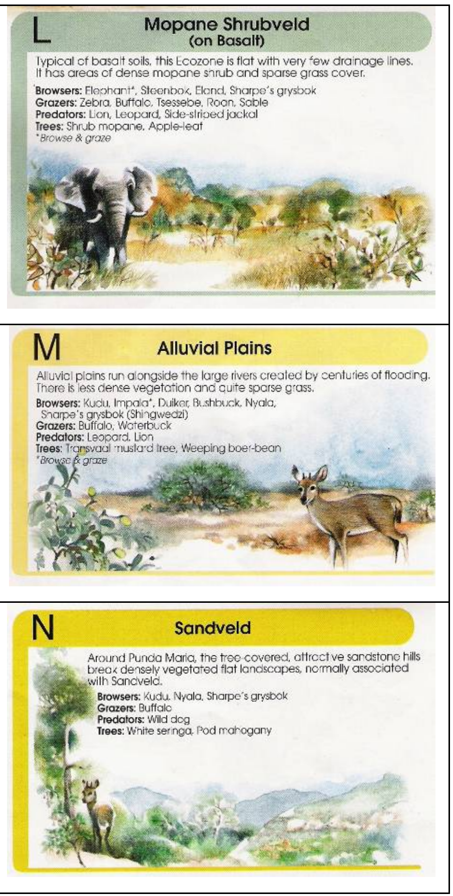
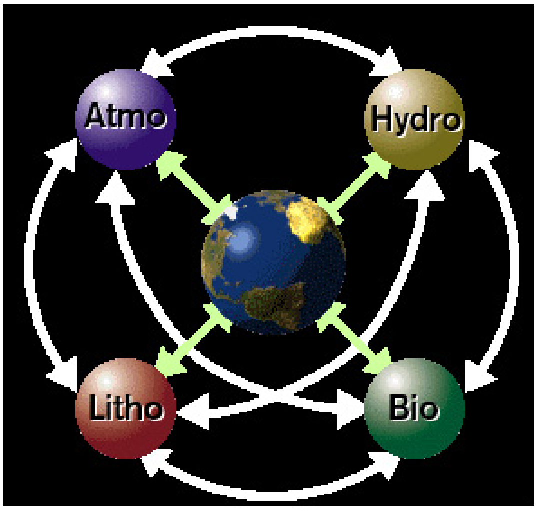


Figure 1: Ecozones of the northern KNP

[1] Compiled in 2009 by Prof Ray Durrheim, with some minor editing by Clive Thompson. See further the Geosites notes compiled by Grant Bybee and Trish Owen-Smith during a field trip arranged by Clive Thompson in April 2017. See also the notes compiled for RETURNAfrica by Johna Turner in 2017, and the KNP's own Trail Guides geology materials.

Earth system science seeks to integrate various fields of academic study to understand how the Earth works. It looks at interaction between the atmosphere, hydrosphere, lithosphere and biosphere. In these notes we focus on the lithosphere (rocky Earth), which is the subject of study of geoscientists such as geologists, geochemists and geophysicists.



2. GEOLOGICAL TERMS, CONCEPTS & TOOLS

Penguin Dictionary of Geology, 1972

Geology is a historical science. A geologist starts by describing physical entities, such as the minerals and rocks, and then goes on to deduce the processes. Here we describe terms, concepts and research techniques commonly used by geoscientists to study the Earth.

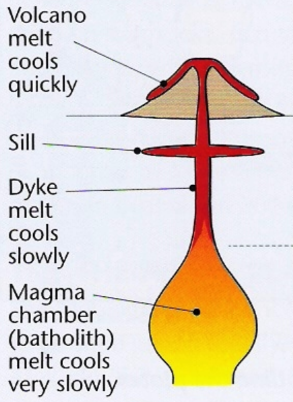
Mineral A naturally occurring chemical compound.
In hand specimens, minerals are identified on the basis of their crystal system and habit, hardness, specific gravity, luster, colour, streak, cleavage, fracture, and mode of occurrence. More detailed studies are made in the laboratory using techniques such as optical mineralogy, geochemistry, X-ray diffraction, and mass spectrometry. Minerals are divided into several groups. For example:

1. **Silica group**, e.g. quartz SiO_2 (trigonal crystal system; hexagonal pyramids/prisms, faces irregularly developed, also massive, granular; hardness 7, SG 2.65; vitreous luster; colourless, or coloured by impurities; white streak; no cleavage; conchoidal fracture; occurs in acid igneous rocks, many metamorphic and sedimentary rocks, and as a veinstone)
2. **Feldspar group**, e.g. plagioclase $Na(AlSi_3O_8)$ – $Ca(Al_2Si_2O_8)$
3. **Mica group**, platy minerals such as muscovite $KAl_2(AlSi_3O_{10})(OH,F)_2$

Rock To a geologist, any mass of mineral matter, whether consolidated or not, which forms part of the Earth's crust. Rocks are divided into three main groups:

1. **Igneous** rocks, which have crystallized from a silicate melt or magma. Igneous rocks are further subdivided into
   - Volcanic rocks, which have erupted on the surface of the Earth (e.g. basalt, comprised mostly of plagioclase and pyroxene), and
   - Plutonic rocks, which have intruded into the rocks forming the crust of the Earth (e.g. gabbro, the intrusive equivalent of basalt)

   (See Norman & Whitfield p. 14)



Colour	Light grey to pink	Medium grey	Dark grey	Dark grey to black
Minerals	quartz, alkali feldspar ±amphibole	alkali feldspar, calcium feldspar amphibole	calcium feldspar pyroxene	olivine, pyroxene
Volcanic rocks (fine-grained)	RHYOLITE (obsidian when glass)	ANDESITE	BASALT	KOMATIITE
Hypabyssal rocks (medium-grained)	microgranite	microdiorite	DOLERITE	micro-peridotite
Plutonic rocks (coarse-grained)	GRANITE	DIORITE	GABBRO	PERIDOTITE

2. **Sedimentary** rocks, which are formed from material that is derived from pre-existing rock, together with material of organic origin, by processes of **weathering**, **denudation** and **diagenesis** (i.e. the process of converting unconsolidated sediments to coherent rock). Prerequisites for the formation of sedimentary rocks are the **supply** and **accommodation** of sediments.

   Sedimentary rocks may be further sub-divided into groups on the basis of the character of their material and the depositional process.
   - Clastic (e.g. sandstone, comprised of visible sand-sized grains, predominantly quartz and lesser feldspar, cemented together by silica, clay minerals or carbonate);
   - Organic
   - Chemical

   (See Norman & Whitfield p. 15)

   Sedimentary structures, formed at the time of deposition, often provide useful information about the conditions under which deposition occurred (McCarthy & Rubidge, pp. 86-87). Sedimentary structures include:
     - **Stratification features** such as varves, graded bedding and cross bedding
     - **Surface features** such as ripple marks, mud cracks, trace fossils, and raindrop impressions.

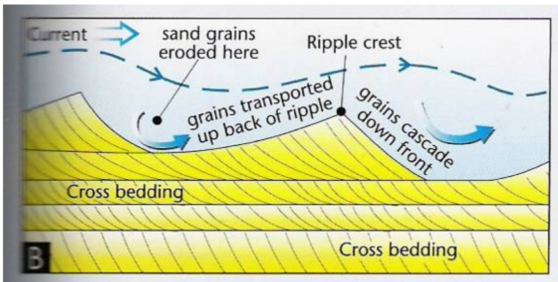
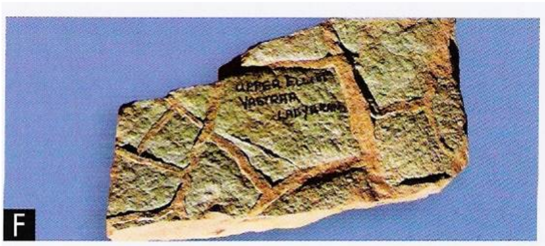


Diagram showing how cross bedding forms

Fossilised ripples in a sandstone



Fossilised mud cracks

Fossilised raindrop impressions (right) and modern-day equivalents (left)

3. **Metamorphic** rocks

   (See Norman & Whitfield p. 17)

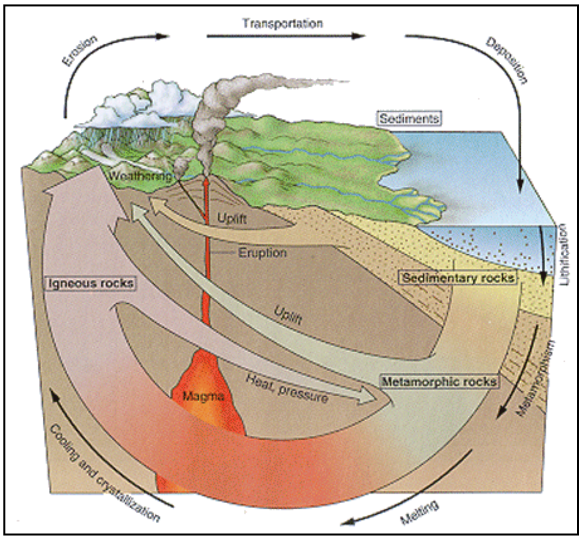
Soil To a geologist, soil is the accumulation of loose weathered material that covers much of the land surface of the Earth. A soil scientist divides the soil-subsoil-bedrock sequence into a soil profile consisting of 4 layers. Starting from the top, we have:

- Horizon A, which is strongly leached (especially of Ca, Fe, etc) and contains much organic matter;
- Horizon B, which is a zone of deposition of leached material and fine clay and silt particles;
- Horizon C, the subsoil; and
- Horizon D, the bedrock.

Craton: remnants of the oldest part of the Earth's crust, comprising the most ancient sedimentary and volcanic rocks and the granites that intruded them.

Principle of Superposition: If one series of rocks lies above another then the upper series was formed after the lower series, unless it can be shown that the beds have been inverted as the result of tectonic action

Rock cycle:

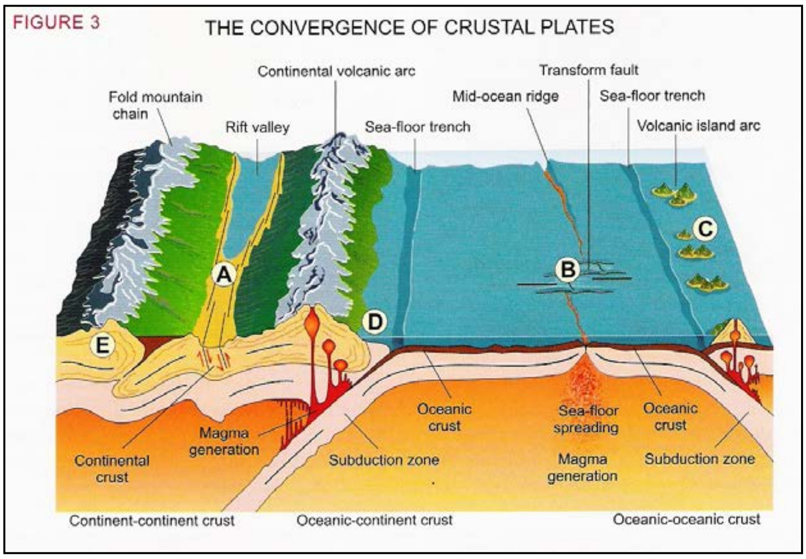


Tectonism: Deformation of the Earth's crust by means of folding, thrusting and faulting.

Terrains: Geological setting or type of geology in a general sense. May also be spelt "terrane".

Uniformitarianism:

Plate Tectonics: A theory that proposes that the outer layer of the Earth (lithosphere) consists of separate, rigid plates (in which the continents are embedded) that move relative to each other and in the process move the continents.

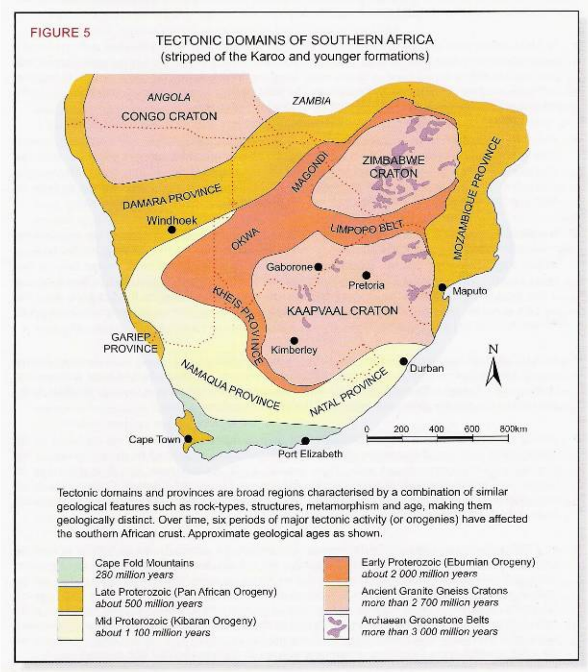


Geochronology, a suite of techniques used to determine the age of a rock (McCarthy & Rubidge, p. 68-69)

Palaeomagnetism, a suite of techniques used to determine the position of a rock relative to the Earth's magnetic pole at the time it was formed.

3. GEOLOGY OF THE MAKULEKE CONCESSION

The Makuleke Concession lies at the intersection of two geological terrains, the Limpopo Belt and the Mozambique Province. The rocks underlying the Makuleke Concession have been subjected to several enormous geological events in the course of nearly 3 billion years. We will describe the geological evolution of the region, beginning with the creation of the elements, and ending with the most recent deposits.



13,700 – 4,600 million years ago: (McCarthy & Rubidge, p. 60)

- The Big Bang!!
- Energy transformed into hydrogen and helium as the Universe expanded ($E=mc^2$).
- Clumps of gas started galaxy formation, e.g. the **Milky Way Galaxy**.
- Further clumping of gas formed stars in which heavier elements (e.g. Si, Al, O, C) are formed. These elements make up our Earth and all living creatures.

4,600 – 4,100 million years ago:

- The **Solar System** (the Sun, planets and asteroids) formed as gas and dust in the outer regions of the Milky Way Galaxy collapsed.
- The **Earth** grew by gravitational accumulation. Rocks melted and segregated into layers of different density (core, mantle, crust).
- Some scientists think that the **Moon** was formed as the result of a collision with a Mars-sized object (McCarthy & Rubidge, p. 66-67).
- The Earth cooled and crust formed on the surface, though this ancient crust was not preserved because of intense bombardment by meteorites. The mantle solidified and CO_2, N_2, and water vapour degassed to form the atmosphere. Water vapour condensed to form oceans. (McCarthy & Rubidge, p. 60).
- The oldest preserved rock (a granite in Labrador, Canada) was formed 4,100 million years ago.

3,200-3,100 million years ago:

- Island arcs started to amalgamate, forming micro-continents.
- Granites were produced by melting of the thickened crust.
- Erosion of continental rocks produced conglomerates, sandstones and mudstones.
- The core of the **Kaapvaal Craton**, a portion of the world's oldest continent, stabilised.

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2,700 million years ago:

The **Kaapvaal Craton** collided with a similar, although slightly younger, ancient continent known as the **Zimbabwe craton**. The collision, similar to that currently taking place between India and Asia, produced a Himalayan-type mountain range along their common boundary, the Limpopo Mountain Range. (McCarthy & Rubidge, Figure 4.7A). These mountains were subsequently eroded. Today we find rocks that once formed the deep roots of the Limpopo Mountain Range exposed at the surface. These rocks are known as the **Sand River Gneiss** and the **Beit Bridge Complex**, and crop out near Messina. Within the Makuleke Concession, they are almost certainly buried beneath the younger cover rocks that fill a trough on the southern (down throw) side of the Bosbokpoort Fault. The **Gumbu Formation** of the **Beit River Complex** crops out about 10 km to the west of the Makuleke Concession boundary. It is composed mainly of calc-silicate rocks and marble, which are thought to have been created by the metamorphosis of calcareous shale, limestone or dolomite. It is possible that boulders and cobbles of Gumbu Formation rock have been transported downstream by the Limpopo River and will be found in the river bed.

1,900 million years ago:

Rifts formed in the Kaapvaal Craton, parallel to the Limpopo Belt. These ruptures may have been due to a collision with the **Congo Craton** with the Kaapvaal-Zimbabwe. Sediments were deposited in the rifts underwent diagenesis, and now form the rocks of the **Soutpansberg Group**. The sedimentary rocks are stained red by iron oxide, providing the earliest evidence for the presence of significant oxygen in the Earth's atmosphere (McCarthy & Rubidge, p. 95, p. 141, Figs 4.39, 4.40 & Fig 4.41).

No Soutpansberg Group rocks crop out within the Makuleke Concession, although they are almost certainly lie sandwiched between the (older) Beit River Complex and younger cover rocks. Nevertheless, they are described here as they as they crop out 10 km or so south of the Levuvhu River. Also, many of the visitors to the Maluleke Concession may have driven on the N1 northwards from Makhado, crossing the Soutpansberg. A description of this route is given by Norman and Whitfield (p. 100-103 and Figure 14). The following rock types and formations comprise the Soutpansberg Group. The youngest formation is listed first, as it lies on top.

- Isolated 50 m thick succession of conglomerate, sandstone and shale that lies directly on rocks of the Beit Bridge Complex, exposed along the bank of the Limpopo River about 10 km west of the KNP boundary (Mabiligwe Formation)
- Sandstone (Nzhelele Formation)
- Basalt (Musekwa Formation)
- Quartzite (Wyllie's Poort Formation)
- Thick layer of basaltic lava (up to 3300 m) with minor intercalations of quartzite and tuff (Sibasa Formation).
- Thin layer (up to 20 m) of arenaceous sediments (quartzite, grit, conglomerate) (Tshifhefhe Formation).

1,900 – 300 million years ago:

The continents coalesced and dispersed several times in Earth history, the reconstructions becoming increasingly speculative the further back one goes into geological history (McCarthy & Rubidge, p. 148-149). The part of the Kaapvaal Craton on which the Maluleke Concession is situated was a passive spectator to the geological events between 1900 Ma and 300 Ma. However these events are briefly summarized here in order to give a more complete account.

- Between 3,500 and 1,500 Ma, many small cratons coalesced to form three supercontinents:
  - **Atlantica** (comprised of parts of present day West Africa and South America);
  - **Arctica** (parts of present day Canada, northern Siberia and Greenland; and
  - **Ur** (parts of present day South Africa, Madagascar, India and Australia). The Kaapvaal Craton formed the western extremity of Ur.
- Between 1,600 and 1,400 million years ago, rifting occurred between the Kaapval-Zimbabwe Craton and Congo Craton and sediments were deposited in the rift. About 1,000 Ma, Ur and Atlantica fused to form the supercontinent **Rodinia**.
- About 700 Ma, Rodinia broke up into three major fragments, which dispersed around the globe. Rifts developed in the portion that contained present-day southern Africa. Sediment accumulated in the Khomas Sea, which stretched across Namibia and Botswana. Others rifts covered part of present day Namaqualand and Mozambique.
- From 600–300 Ma, the fragments of Rondinia reassembled to form **Pangea**. This was the most recent supercontinent. Extensive mountain ranges formed where the fragments collided. These ranges have since been eroded, exposing their metamorphosed root zones, which are known s the Pan-Africa belts. The Damara Belt is one example.
- Pangea was short-lived. Rifting along what is today the southern Cape started as early as 500 Ma, and was flooded to form the Agulhas Sea. (See McCarthy & Rubidge, Fig. 7.3, p. 189.) Pangea finally broke apart around 300 Ma to form **Gondwana** and Laurasia.
- About 310 Ma, a subduction zone formed along the southern margin of Gondwana. The interior of Gondwana began to experience compression, and the sediments filling the Agulhas Sea were folded and exhumed to form the **Cape Mountains**. (See McCarthy & Rubidge, Fig. 7.8, p. 193.)
- A depression (foreland basin) formed on the northern side of the Cape Mountains and the rocks of the **Karoo Supergroup** began to accumulate. About 182 Ma a mantle plume arose beneath southern Africa, the crust ruptured and vast amounts of lava flowed out. These lavas are the youngest Karoo Supergroup rocks. The Karoo rocks cover about two-thirds of the land surface of South Africa, including the Maluleke Concession (See McCarthy & Rubidge, Fig. 7.11, p. 194), and are found as far north as the DRC. They are described in more detail below.
- Gondwana split, and South America, Australia, India and East Antarctica moved away from the African core, and the Atlantic, Antarctic and Indian Oceans formed.

310 -180 million years ago:

Most of the rocks that crop out in the Maluleke Concession belong to the **Karoo Supergroup**, where the basaltic lavas of the **Letaba Formation** and the aeolian sandstones of the **Clarens Formation** form prominent topographic features.

The lower eight formations of the Karoo Supergroup are essentially sedimentary, with an aggregate thickness of about 1000 m in the Tshipise area. The upper two formations are volcanic, with a combined thickness of about 2000 m. The detailed descriptions given below are based on the booklet *The Geology of the Messina Area: explanation of sheet 2230* by G. Brandl (Department of Mineral and Energy Affairs, 1981) obtainable from the Council for Geoscience

At the very base we find the **Tshidzi Formation**, which rests on the upper formations of the Soutpansberg Group. It is a diamicitite composed of angular and rounded clasts (up to 2 m in diameter) embedded in a sandy or bluish grey, muddy matric. It is probably fluvioglacial in origin, and may be correlated with the Dwyka Formation of the main Karoo basin

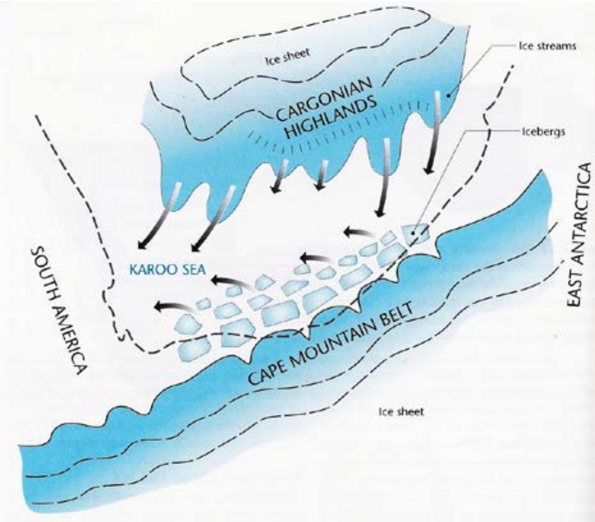
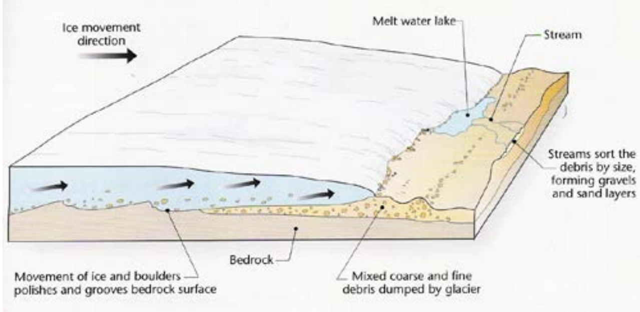
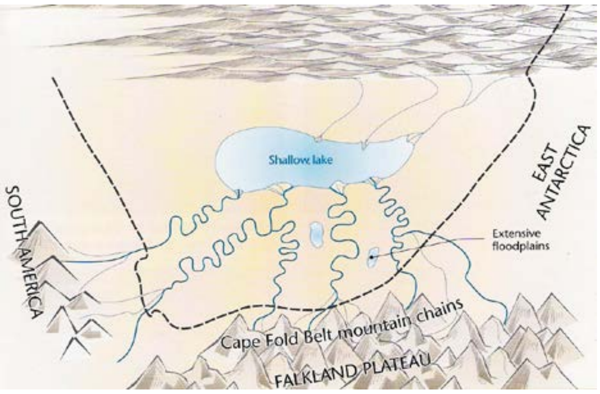
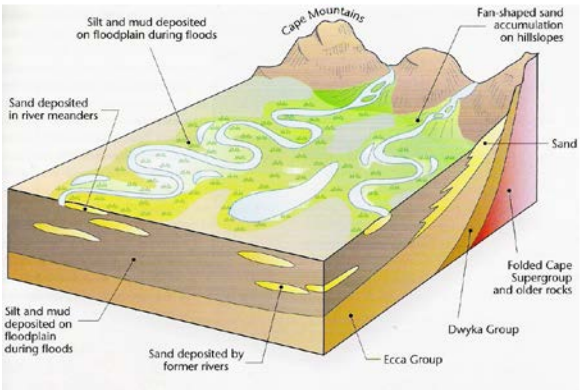
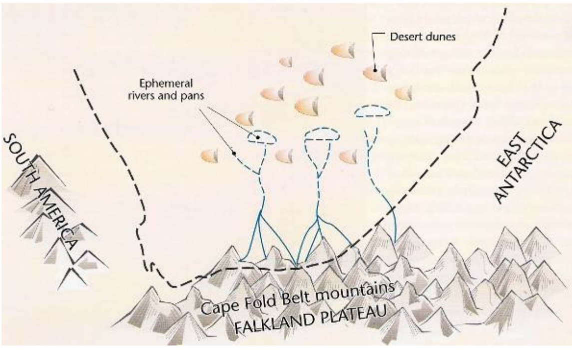


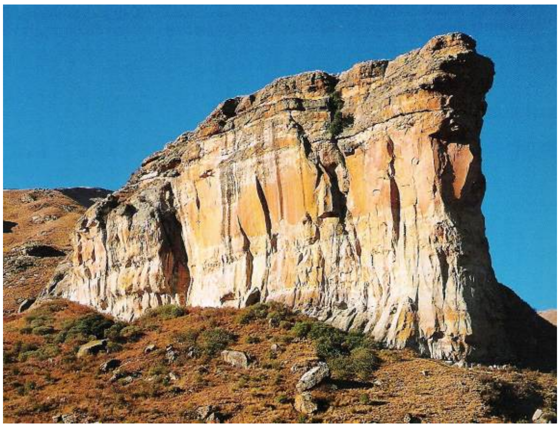
Figure 7.20 *Sedimentary deposits formed by melting icebergs consist of fine rock flour with occasional boulders, or dropstones.*











Karoo Supergroup formations found in or near to the Maluleke Concession

Age Ma	Formation	Lithology	Max. thickness
	Jozini	Pink to reddish rhyolite. The nearest outcrops are along the Mozambique border, about 30 km south of the Makuleke Concession	70 m
183	**Letaba**	Almost entirely comprised of basaltic lava with subordinate rhyolite flows and tuffs. Typically the basalt is a massive, fine-grained, dark-grey or greenish black shiny rock. Amygdales of zeolite, quartz, calcite, chalcedony or chert are abundant. The Letaba Formation is estimated to reach a thickness of 2000 m along the eastern fence of the KNP. Outcrops are generally poor. Black-turf soil usually obscures the rocks in the uniformly flat terrain. In the northeastern corner of the area (i.e. Maluleke Concession) up to 250 m of dark- to purplish grey amygdaloidal limburgite is developed at the base of the Letaba Formation. Lavas of the Letaba Formation probably covered parts of the Soutpansberg as this area was a peneplain during Karoo times and the Soutpansberg contributed very little material to the Karoo sediments.	2000 m
	Clarens	The Clarens Formation is divided into two members, with a gradational contact between them: The **Tshipise Sandstone Member** is at the top. It is a massive, whitish or cream-coloured, fine-grained equigranular rock, which locally exhibits large-scale cross-bedding. Near the base the sandstone is sometimes pink or green. It usually forms prominent south-facing ridges characterized by caves and vertical rock faces. It reaches a maximum thickness of about 150 m. The **Red Rocks Sandstone Member** is at the base. It consists generally of very fine to fine, pink or red argillaceous sandstone. It attains a maximum thickness of 35 m in the KNP, but is not mapped in the Maluleke Concession. Both members are characterized by the ubiquitous presence of calcareous concretions. Deposition seems to have occurred mainly in an aeolian environment.	150 m 35 m

180 - 65 million years ago:

(McCarthy & Rubidge, p. 244, 249)

Gondwana broke up and dispersed. In contrast to the Karoo, where sedimentation on land provides a complete record of terrestrial life for almost 120 million years during the Permian, Triassic and early Jurassic periods, there is only a fragmentary record of the later Jurassic and Cretaceous Periods. It seems that southern Africa was elevated and the interior was experiencing erosion. The sediments were mostly being deposited in the developing Indian and Atlantic Oceans. One exception was the northern KwaZulu-Natal coastal plain, extending into Mozambique and the eastern edge of the KNP (McCarthy & Rubidge, Fig 9.2, p. 248). The rivers entering the sea along the ancient coastline gave rise to a variety of settings for sedimentation, including estuaries, beaches and shallow marine conditions. The warm shallow seas were host to life forms similar to those found on a modern reef today, although the species (such as ammonites, up to a metre in size, McCarthy & Rubidge, Fig 9.5, p. 252) were different.

In the Maluleke Concession, these Cretaceous-age deposits are known as the **Malvernia Formation**, and reach a maximum thickness of about 80 m along the eastern fence of the KNP, between 5 and 20 km south of the Levuvu River. The Malvernia Formation consists of whitish, coarse-grained and gritty sandstone and conglomerate with limestone and marl intercalations. The pebbles of the conglomerate are rounded to subrounded, have a maximum diameter of 500 mm, and are derived partly from the Soutpansberg Group and partly from granitic terrain. The matrix of the arenaceous sediments is usually calcareous (Brandl p. 24).

65 - 5 million years ago: THE AFRICAN LAND SURFACE

(McCarthy & Rubidge, p. 263-267; Norman & Whitfield, Fig 4 p. 23)

After the break-up of Gondwana (ca. 120 Ma) the drainage of the interior of southern Africa was dominated by three major river systems, the most extensive being the Limpopo. These river systems were responsible for removing Karoo Supergroup strata over a vast region, exposing the pre-Karoo land surface (i.e. pre 310 Ma). Mountain ranges such as the Soutpansberg were originally shaped by glaciers at the start of Karoo times, and have only been slightly modified by erosion since then. This surface is termed the **African Erosion Surface**. Soils on this surface are deep and tropical in character, showing extreme leaching.

The marginal **Escarpmen**t (the step in the landscape from the elevated interior down to newly formed coastal plains) formed as a result of the uplift and rifting (Fig 9.14B, D).

The Limpopo River developed along a rift that formed at the time of opening of the Mozambique Channel, but which failed to develop further (McCarthy & Rubidge, Fig. 9.1A). Its catchment stretched as far as Angola (McCarthy & Rubidge, Fig 9.15A). The sediments carried by the Limpopo River built a large delta on the Mozambique coast, which today forms the arc-shaped coastline between Maputo and Beira (Fig 9.1 B, C).

About 60 Ma, gentle arches began to from in the interior of the African continent. The Kalahari-Zimbabwe axis cut off the headwaters of the Limpopo (Fig 9.15B).

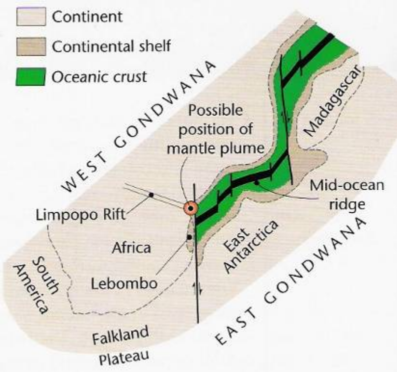


Fig. 9.1A

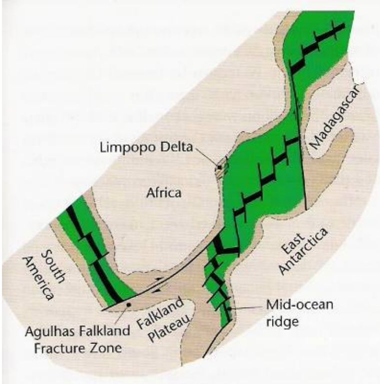


Fig. 9.1B

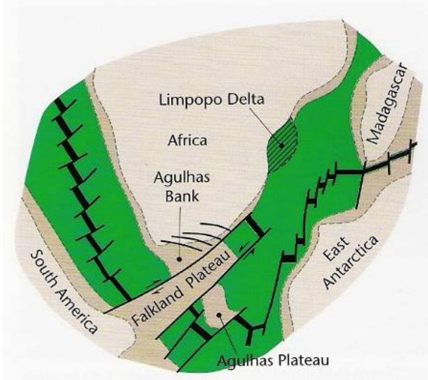


Fig. 9.1C

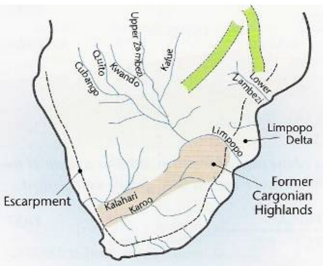


Fig. 9.15A

Fig. 9.1B

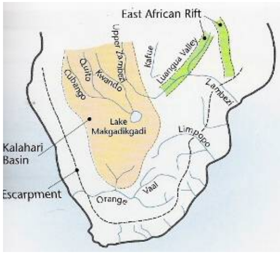


Fig. 9.1C

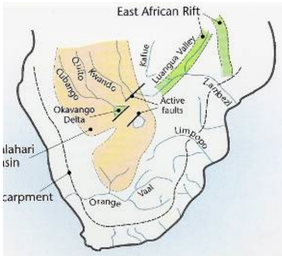
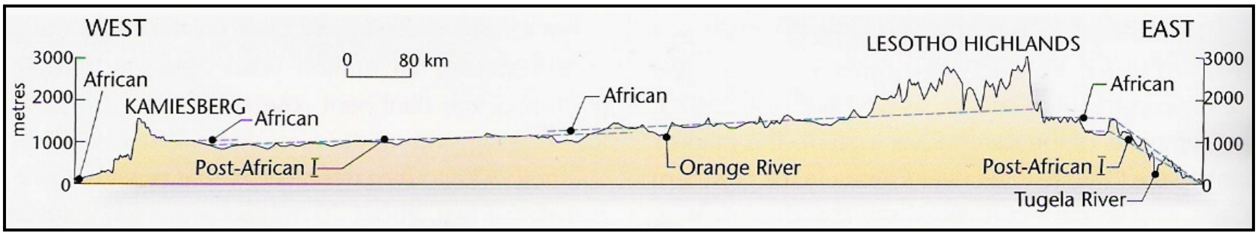


Fig. 9.1D

The interior of southern Africa began to rise. One view is that there were two major periods of uplift, each accentuating the escarpment and tilting of the interior land surface to the west, giving rise to renewed erosion in the interior (forming the Post-African I and II Surfaces) and incising deep valleys and gorges across the coastal plain (McCarthy & Rubidge, Figs. 9.14D, 9.17 and 9.18). Would Lanner Gorge be an example??

- The first episode, about 20 million years ago, caused a maximum rise of about 250 m in the east, removed much of the old soil cover that had formed on the African Surface, and formed the **Post-African I Surface**.
- The second episode, only 5 million years ago, caused a maximum rise of about 900 m in the east and formed the **Post-African II Surface**.

The cause of the massive uplift is unusual and not fully understood. The topographic anomaly, called the **African Superswell**, has become the focus of research.



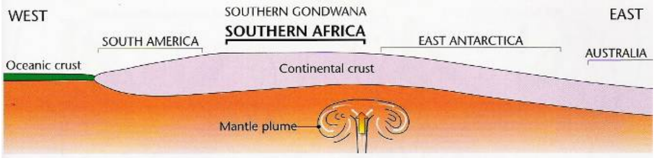


Figure 9.14A *Schematic diagram showing the bulging of the crust of southern Africa as a result of the rise of a mantle plume about 180 million years ago. The vertical scale has been greatly exaggerated*

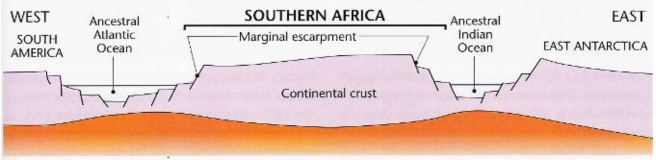


Figure 9.14B *By 120 million years ago, rifting along the east and west coasts of southern Africa had thinned the continental crust, opening the proto-Indian and Atlantic Oceans. The interior of southern Africa became separated from the coastal plain by an escarpment. The interior remained higher in the east.*

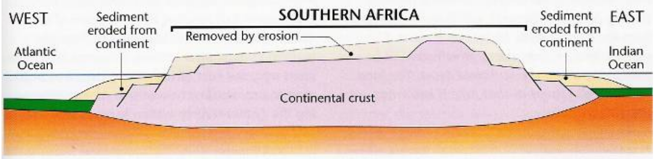


Figure 9.14C *By 65 million years ago, oceanic crust floored the growing Atlantic and Indian Oceans. The interior of southern Africa had experienced considerable erosion, and the eroded material had been deposited on the continental shelf. The marginal escarpment had been cut back during this process. The Lesotho Highlands remained as a small remnant of elevated ground on the east of the subcontinent.*

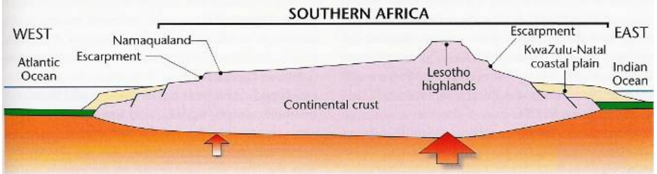


Figure 9.14D *At 20 million and five million years ago, southern Africa experienced episodes of uplift and tilting towards the west, which created renewed erosion in the interior, but the major features of the ancient landscape remained.*

The last 2 million years (the Quaternary Period, divided into the Pleistocene and Holocene Epochs)

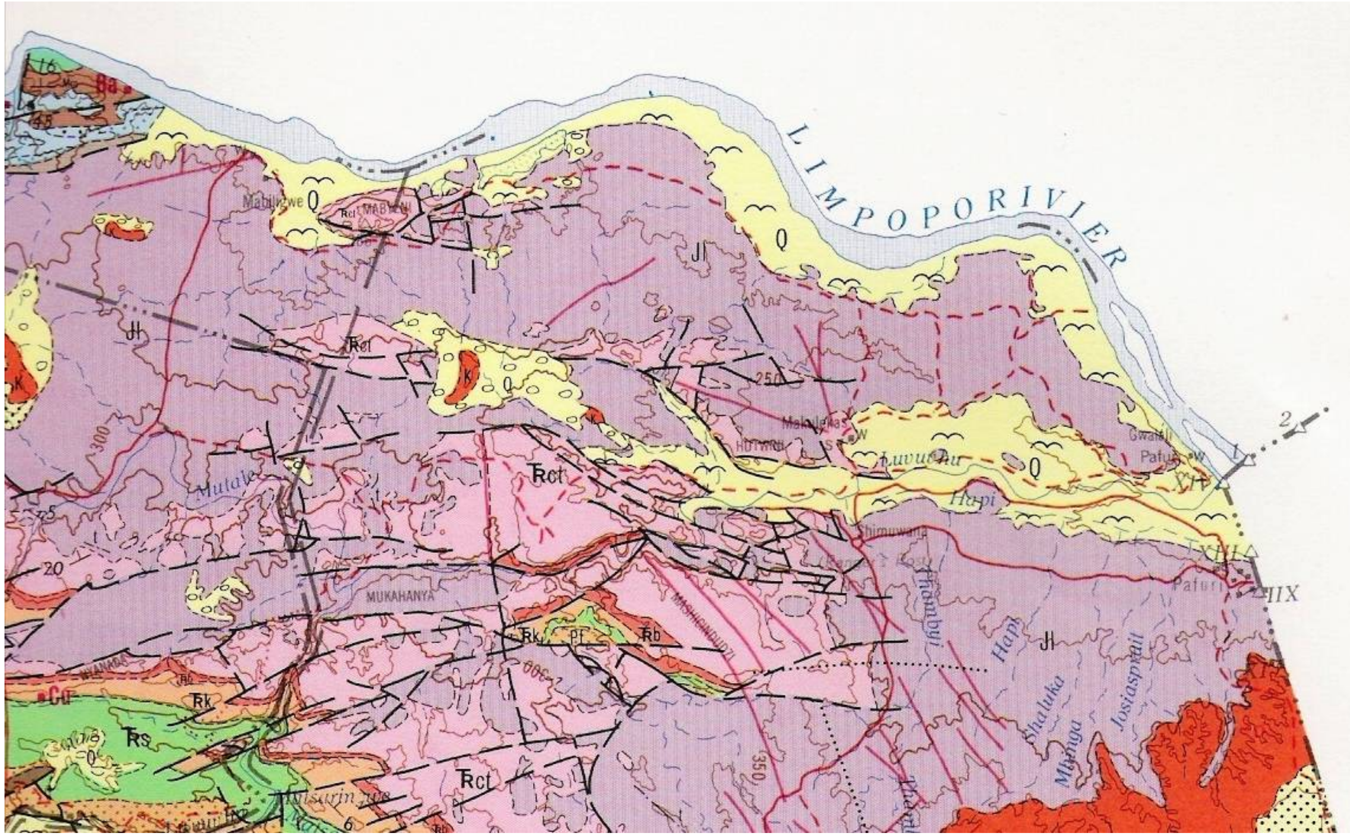
During the **Pleistocene Epoch** (2 Ma – 10,000 a) there were many changes in climate due to a succession of ice ages:

- Sea level dropped by as much as 130 m as water was locked in ice caps,
- Rivers incised the continental shelf, especially where the bedrock was comprised of soft Cretaceous sediments,
- Rainfall dropped and a vast sand desert formed in the interior of southern Africa. The Kalahari is a small remnant of the desert.

Today we are in a period with a relatively mild climate, known as the **Holocene Epoch**. The dramatic changes in climate in the last few million years have had a profound influence on the environment and on mammalian evolution and distribution, including the emergence of *Homo sapiens* about 800,000 years ago.

Deposits of Quaternary age in the Makuleke Concession consist of alluvium, sand, scree, gravel, calcrete and ferricrete. A high-level gravel lying at an elevation of up to 60 m above the present river beds is found surrounding the outcrop of Malvernia Formation. The well-rounded cobbles and boulders are up to 600 mm in diameter and have been derived from the Wyllies Poort Quartzite Formation.

Dolerite sills and anorthositic rocks are usually covered by whitish or brownish calcrete.
[Calcrete is a term given to superficial gravels cemented by $CaCO_3$ deposited from solution.]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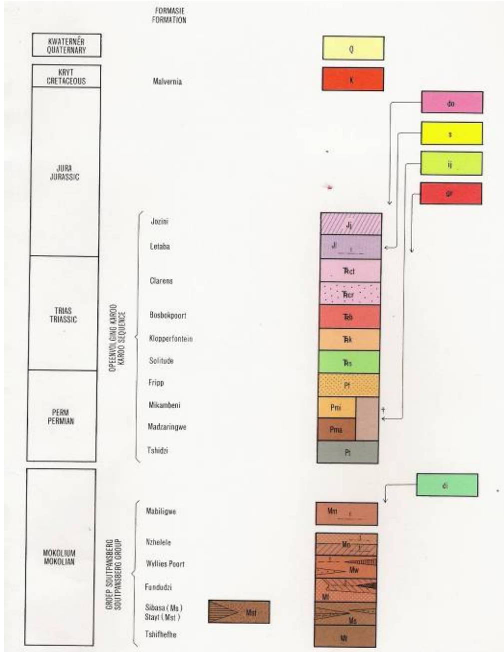
FORMASIE
FORMATION
KWATERNÊR
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PERMIAN
MOKOLIUM
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OPEENVOLGING KAROO
KAROO SEQUENCE
GROEP SOUTPANSBERG
SOUTPANSBERG GROUP
Jozini
Letaba
Clarens
Bosbokpoort
Klopperfontein
Solitude
Fripp
Mikambeni
Madzaringwe
Tshidzi
Mabiligwe
Nzhelele
Wyllies Poort
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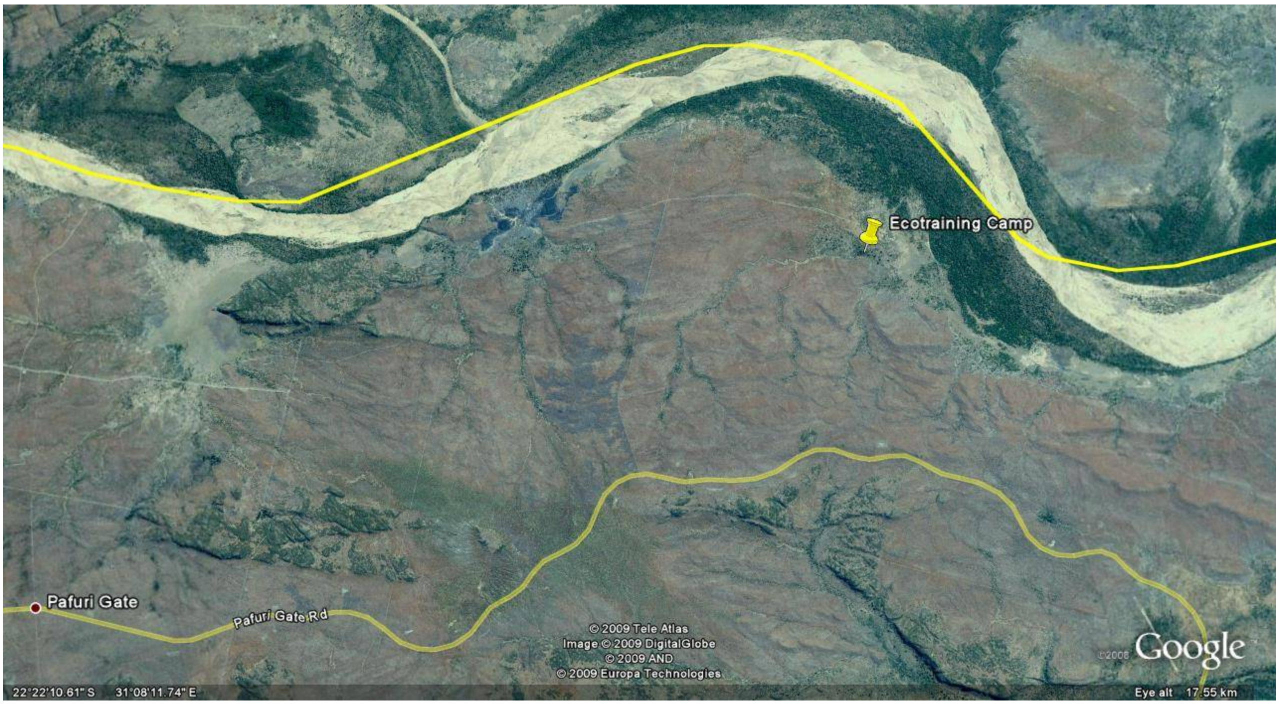
4. GEOSITES

1. Limpopo River

This should be a good site to discuss erosion of rock and the transportation and deposition of sediments. We should be able to find examples of sedimentary processes (e.g. the sorting of particles of different sizes) and structures (e.g. ripple marks, mud cracks).

The Limpopo is a broad, meandering river. The Makuleke concession is about 300 km from the coast, and only 300 m above sea-level. The surrounding topography is gentle. This indicates that it is a mature river that is approaching its base level of erosion.



2. Flood plain of the Limpopo River

Here we should be able to find examples of natural levees [raised river banks], oxbow lakes, mud cracks, animal tracks.

3. Calcrete deposits

Here we should be able to talk about the movement of ground water, the solution and precipitation of $CaCO_3$.

4. Basalt ridges

Here we should be able to find examples of onion skin weathering, soil formation, amygdales. We should be able to discuss the massive outpouring of lava during the rifting of Gondwana in the context of plate tectonics.

5. Springs

Here we can discuss the basic principles of geohydrology. Porosity, permeability, acquifer, water table, recharge, etc.

6. Lanner Gorge

Here we should be able to find examples of sedimentary structures (e.g. stratification, cross-bedding, mud cracks, ripple marks, graded bedding) which can be used to deduce the depositional environment. There should also be examples of concretions [during diagenesis certain constituents of sediments tend to concentrate in certain parts of the rock, often around a nucleus]. This will provide an opportunity to discuss the deposition of the Karoo Supergroup (300 Ma – 180 Ma), from the formation of the Cape Fold Belt to the fragmentation of Gondwana. The dramatic topography will be an ideal site to discuss the evolution of the African Landscape from the break-up of Gondwana (120 Ma) to the present day.