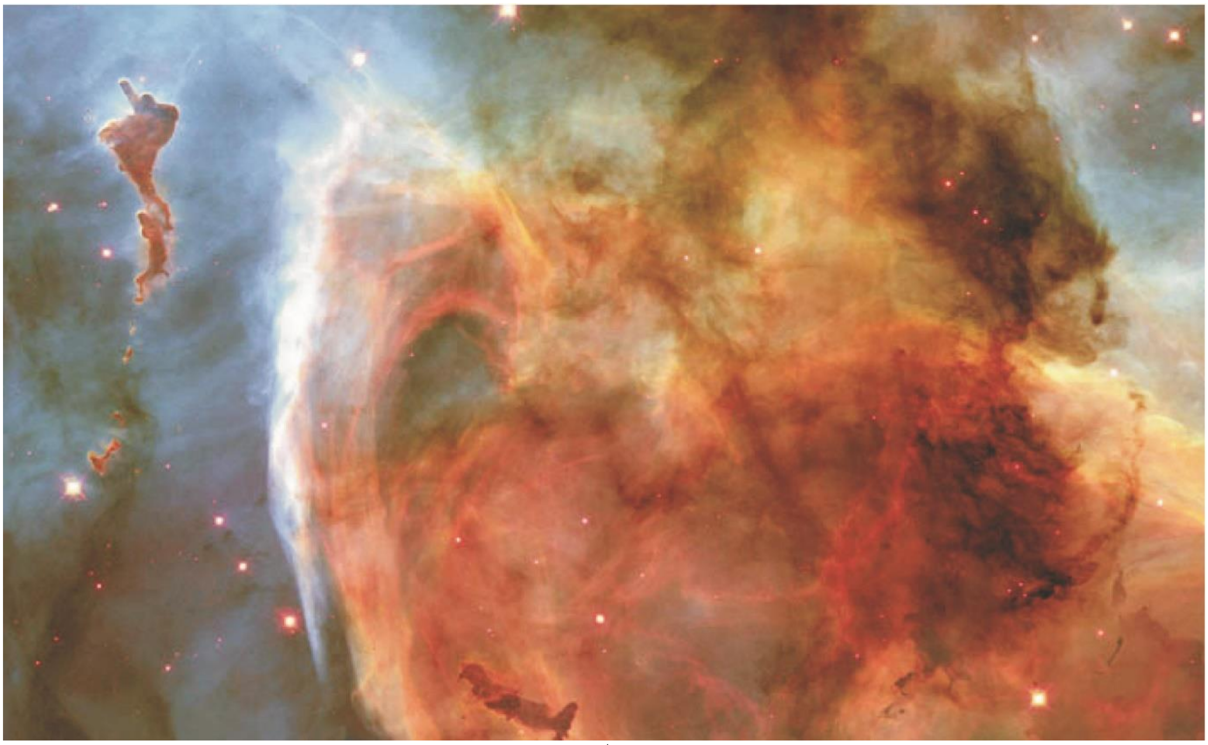
The Geology of Selati Game Reserve (2005)

Compiled by Laura Batchelor based on text, photographs and a presentation by Prof. Jan Kramer and his geology students from the University of Berne, Switzerland.



1

[1] Keyhole Nebula in Carina. Hubble space telescope. NASA

Contents

Forward

A privileged world that opens many doors on God's creation.

It is a clear starry night. Lying on our backs in the back of a truck near Mahoed, identifying constellations and counting satellites and shooting stars, the thoughts of the day run through my mind. We have climbed Sable Kop and viewed the beautiful landscape; the Drakensberg to the west, the Lillie Hills to the south and the Murchison Range to the north. The oldest tocks in the world. The children's voices break through. "How far are we from the nearest star, Dad? And, what do you mean by the oldest rocks in the world?" Lying there in wonder they have innocently opened the door on the most profound question in life – creation and beginning of time. They have also sparked a train of thoughts and actions which would eventually lead to the geology of the Selati Game Reserve being revisited and captured in this little booklet.

It has become fashionable for many reserves to provide maps of the underlying geology and soil types as these, together with weather, dictate the flora and fauna. While the beautiful topography and varied veld types of Selati would warrant such an exercise on their own, it was more the link that the geology provided with the evolution of the Earth that drove the interest which underpinned this effort.

Various conversations led me to Prof. Jan Kramers of the Institute of Geological Sciences, University of Berne, Switzerland. Jan is married to a distant relative and has lived and worked in South Africa. He shares a passion for the area and was keen to collaborate on developing a story and on using the research and mapping requirements as opportunities for his postgraduate students[2]. We are therefore most grateful to Jan and his students for their hard work on the ground and to Jan for the pictures and diagrams, and for developing the original draft manuscript. The final task of putting the story and booklet together fell to Laura Batchelor. We acknowledge and thank Laura for the fine job she has done and we thank Tony Ferrar, Jake de Villiers, Annechris Swards, Mike Peel, and Laura's husband Garth for their assistant to Laura.

Rob Snaddon

June 2005

Looking eastwards from the Cycad Reserve towards the white dumps of Phalaborwa Mine on the horizon. The koppies are underlain by Mashishimale Granite and the plain beyond by Lekkersmaak Granite

[2] This work resulted in 3 Masters theses at the University of Berne, Switzerland.

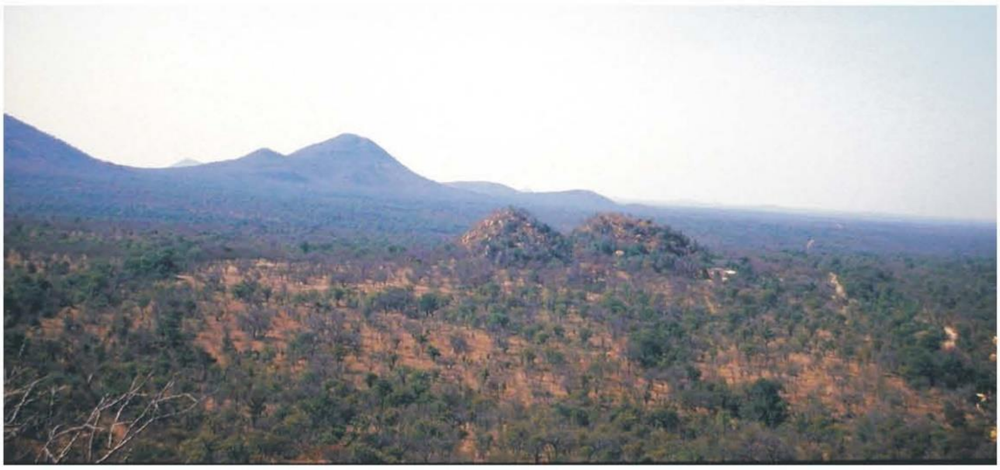
Ch. 1 Introduction

Pick up a rock in Selati and may well be holding a piece of Earth's mantle squeezed and melted into shape kilometers beneath the earth's surface some 3000 million years ago. A sequence of events that took place during the early history of our planet can be pieced together from features of old rocks and the way in which different rock types occur together.

An outcrop with interesting history. The Volcanic rock (dark) was squeezed and metamorphosed before the intrusion of the granitic magma (light) which dismembered it.

Although the rocks of Selati area are extremely old, the present surface on which we stand is considered 'young' having been exposed relatively recently – geologically speaking.

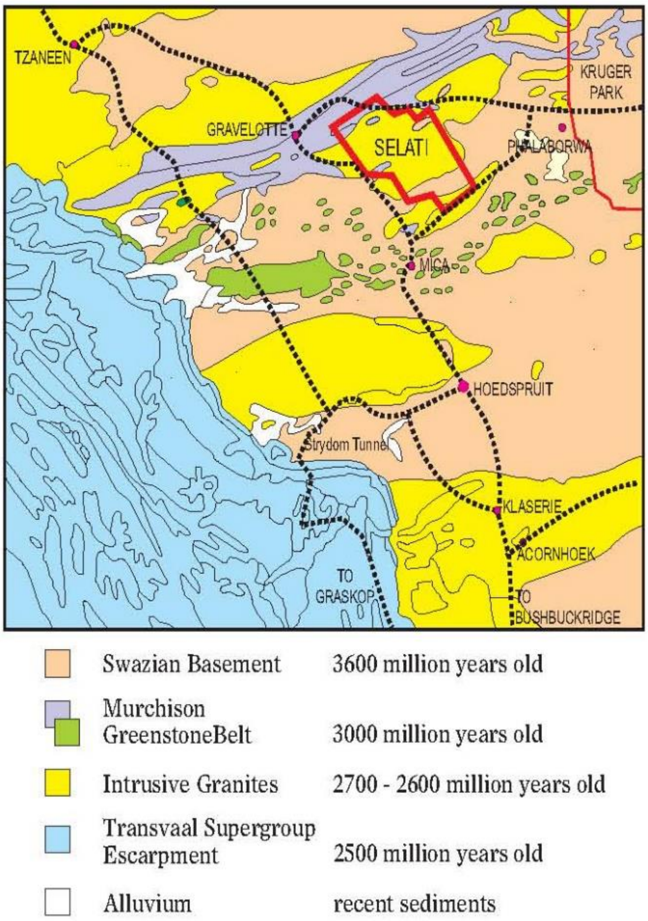
Rock types differ in their susceptibility to erosion and weathering. As erosion by wind and water removed soil the land surface is lowered. While the more resistant rock types remain to stand out as hills, the more easily weathered rock type forms low ling plains. In the northwest of Selati the hills are made of upended sediments containing quartz, which is resistant to weathering while the volcanic rocks and most of the granite types between them have been eroded to form valleys and plains.



Koppies of Willie Granite show resistance to weathering while the plain to the right is underlain by Lekkersmaak Granite which has proved to be more easily eroded. La Belle France hills stand out in the distance, consisting of quartz, metapsammite and metapelite.

Geologists categorise rock types into 'families'. The different families form the main building blocks of the geology in an area. In Selati the rock types can be grouped into two clear families

– those which were originally deposited in layers on the surface of the earth by volcanic activity, wind and water, and the others which originated deep inside the Earth by solidification of magma. The volcanic and sedimentary rocks have undergone metamorphosis while the granites and pegmatites have remained unchanged since they solidified.



The map shows how the rocks of Selati fit in to the regional framework. Rocks in the northwest end of Selati are metamorphosed volcanic and sedimentary rocks forming part of the Murchison Range. The rest of the area consists of granites and pegmatites except for some widespread talcactinolite schists and amphibolites south of the Selati River.

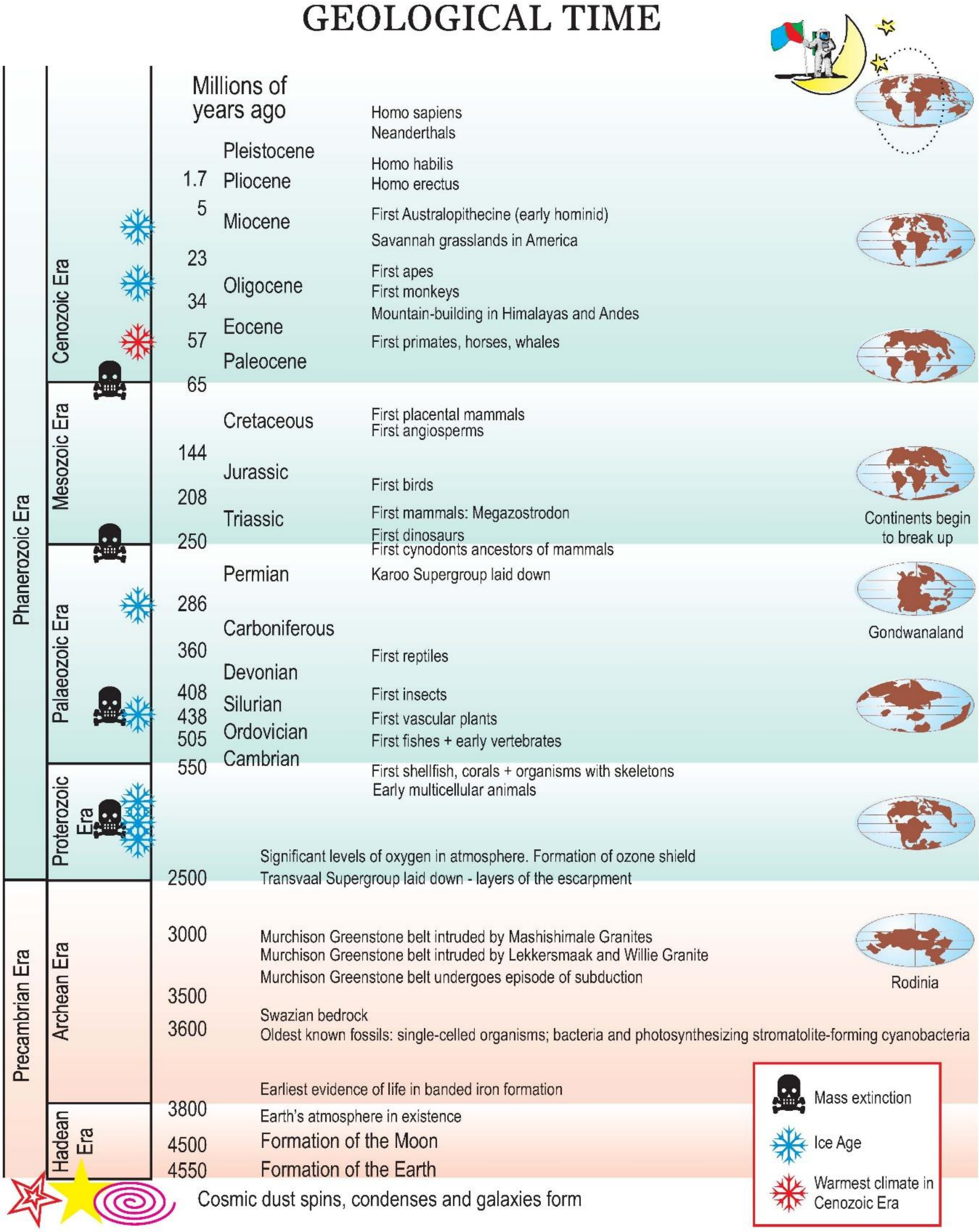
Information about the geology of an area can also be gained from satellite imagery and agricultural land-use maps. Soil types are based on the underlying geology and support different types and density of vegetation. The red colour of soils formed from rocks and volcanic origin is caused by iron and manganese oxides, which also improve soil fertility and would support a certain mix of vegetation and agriculture.

The grey-greenish colour and age of the rocks of the Murchison Range is of particular interest. Known as greenstone belts, they originate from volcanic rocks inter-layered with sedimentary rocks laid down 3500 million years ago during the Archean Era. The Barberton Greenstone Belt is the largest in South Africa, followed by the Murchison, Pietersburg and Giyani belts. Greenstone belts also occur in Australia, Tanzania, Zimbabwe and Canada. On the map the are elongate in shape, and surrounded on all sides by granites and gneisses (foliated granite-like rocks).

We know that the earth formed about 4500 million years ago and that the moon was separated from the earth 50 million years later. The first 500 million years of Earth's history is known as the Hadean Era. This was a time of great volcanic and geological activity and intense bombardment by asteroids. All this wiped out the geological record, so very little is known about this period.

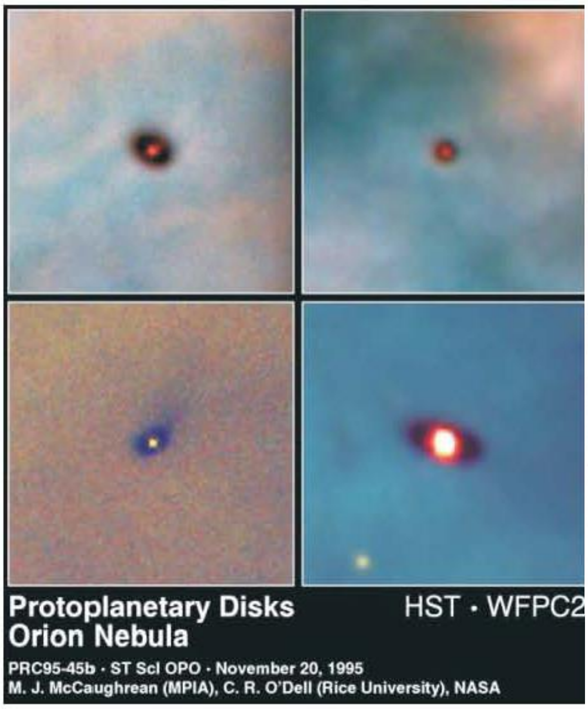
The Archean Era followed the Hadean Era. This was when the rocks of Selati were formed by differing processes and under conditions quite different from the ones we know today. For example, the atmosphere contained no free oxygen, as evidenced by the banded iron formations. All the oxygen and water has been retained by the atmosphere and not lost into space has made our planet unique amongst planets, with dynamic plate tectonics and full of life. Were this not so, the Earth would have died a death similar to Mars and the Moon.

GEOLOGICAL TIME



Ch. 2 The Birth of the Earth in the Solar System

Our solar system is thought to have originated from a supernoval explosion when an aged giant star exploded and all its matter was flung out into space as dust and gas. Heterogenies existed in this matter which was in motion. The denser regions began to spin, contract, become heavier and attract material to themselves. The rotation became faster as it condensed, as a pirouetting ballerina will spin faster as she brings her arms in towards herself. N this way a new star is formed with a dust ring held in its gravitational force. Our solar system was formed with a central star with a ring of debris in its gravitational pull.



Four examples of new (nascent) stars with dust discs around them in the Orion Nebula. (Source: Hubble space telescope, NASA)

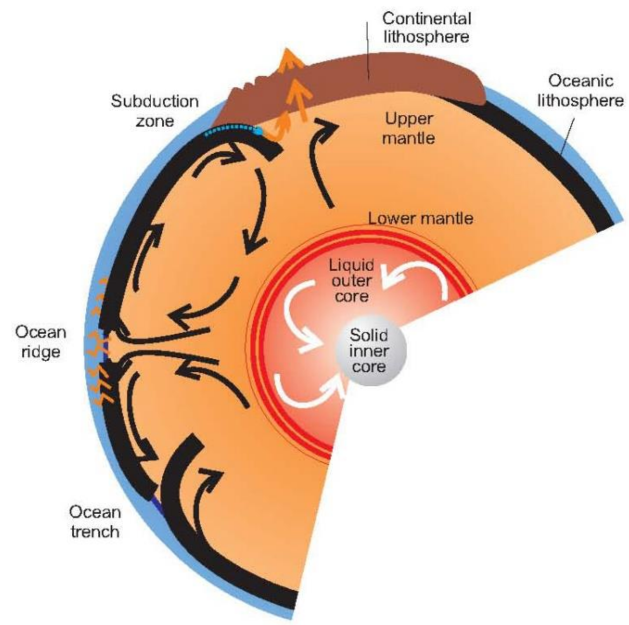
A slab of chondritic meterorite Allende; with a calcium-aluminium rich inclusion. Such inclusions are the earliest condensates in the solar system at 4570 million years old. (Source: University of Arizona)

It is estimated that our solar system began 4550 million years ago as rocky bodies or asteroids began to coalesce around our star, the Sun. The innermost rocky bodies became the terrestrial planets Mercury, Venus, Earth and Mars, with belts of asteroids. The main components of the asteroids were complex oxides of silica, magnesium, iron, calcium, aluminium and metals such as nickel. Asteroids colliding with the planets led to changes in the planets. Denser metals sank to the centre core while lighter silicas formed the mantle and the volatile elements became the atmosphere.

4500 million years ago an oblique collision with an asteroid the size of Mars caused a lump of the Earth, a quarter of the diameter of the earth in size, to be literally booted into orbit. So, Earth's Moon was formed. The collision caused most of the Earth to melt. Volcanic activity on the Moon continued until 3000 million years ago, lava filling the lunar maria. It cooled and now the Moon is a dead place. On Earth water vapour was trapped in the atmosphere and condensed to form the early oceans. The Earth slowly cooled by the process of convection beneath the surface and by radiation from the surface and surrounding atmosphere into space. The convection is the driving force behind plate tectonics as illustrated in the diagram.

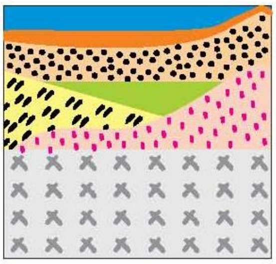
Ch.3 Selati rocks belong to the Archean Era

The Earth has a very hot, solid inner core and liquid outer core made of iron and nickel, a very dense material. This is surrounded by the mantle, some 2890 kilometers thick, which is solid with pockets of molten rock. It is not as dense as the core but is very strong. The Earth's crust is made up of oceanic and continental lithosphere. Oceanic crust is 7kilometers thick and continental crust 440 kilometers thick (in some places p to 80 kilometers).

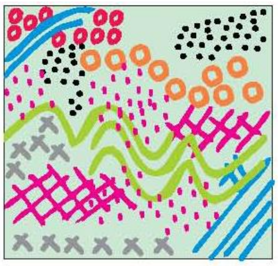


The core heats the mantle which, although solid, is plastic and acts like a fluid which conveys heat outwards to the surface. A cycle of convection is set up and so the mantle 'flows' like a liquid, and carries the continents along with it. In a subduction zone the oceanic lithosphere sinks below the continent, melting and causing volcanic activity beneath the continent.

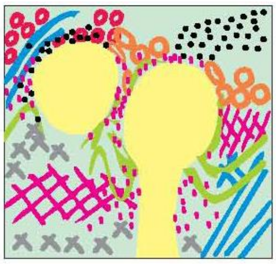
The relationships between the rock types tell us much about the sequence of evets that shaped the geology of the Selati area and make-up of the rocks gives s clues as to their origin. The sequence of events that shaped the geology time by making simple observations, using common sense, geological maps and satellite images.



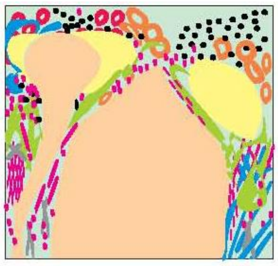
Volcanic-sedimentary layers on Swazian basement rock.



Layers metamorphosed - Murchison Greenstone Belt.



Lekkersmaak and Willie granites intrude.



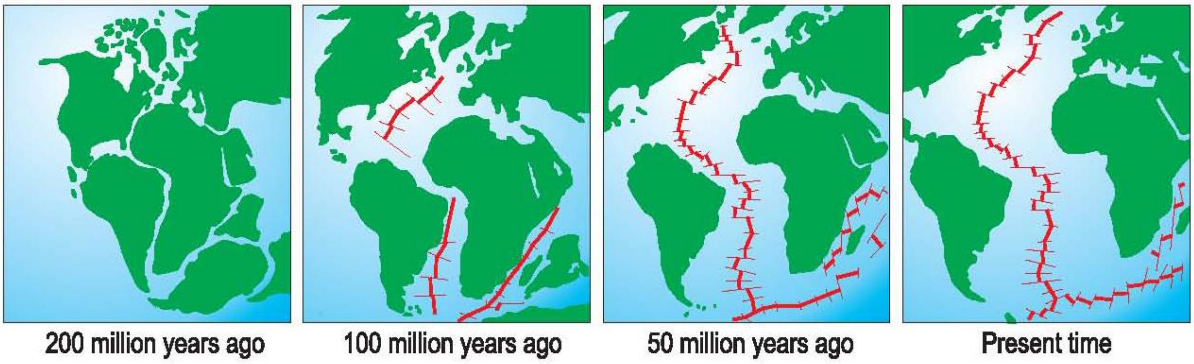
Mashishimale granites intrude.

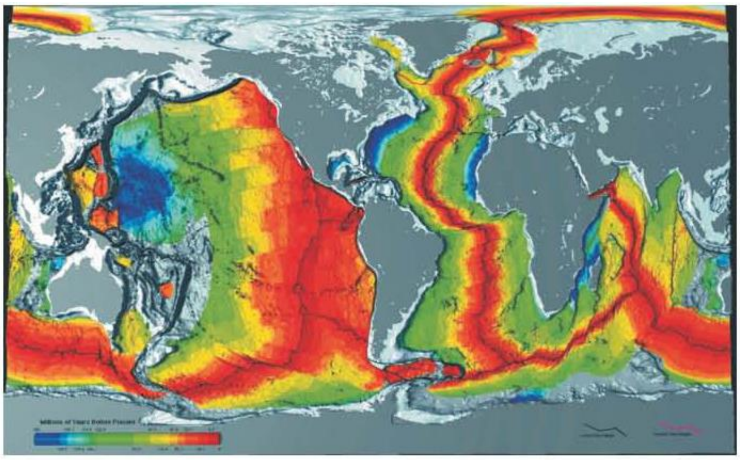
Summary of the sequence of events in Selati

- The oldest recognisable units in Selati are the volcanic-sedimentary rocks of the Murchison Greenstone Belt. The uranium-lead zircon dating determined the age of these volcanic-sedimentary rocks to be about 3000 million years old. No remnants of the Swazian basement on which they were deposited are found in Selati, but to the north of the Murchison Range, these are present although deformed, metamorphosed and partly remolten.
- The Lekkersmaak Granite is intrusive into the metamorphic sedimentary and volcanic rocks of the Murchison Greenstone Belt. This means that the volcanic-sedimentary series existed before the granites intruded. The Lekkersmaak Granite intruded between 2700 and 2800 million years ago. The Willie Granite is a special variety of Lekkersmaak Granite.
- The Mashishimale suite is clearly intrusive into, and is therefore younger than, the Lekkersmaak Granite. The age of the Mashishimale Granites has been determined by uranium-lead zircon dating to be about 2680 million years old. This is the most recent Archean event in the region.

Ch.4 Plate Tectonics

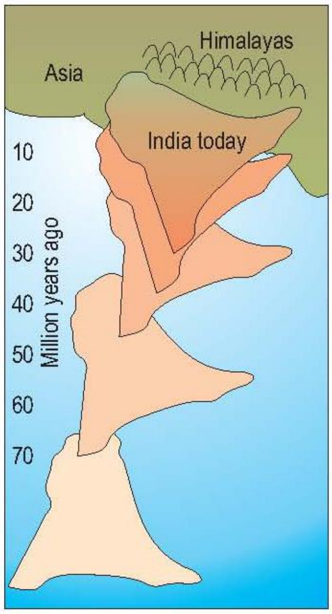
By the 1960's it was understood that the Earth's crust was divided into 7 major continental plates which moved relatively to each other across the surface of the Earth. Some of the plates contain only oceanic crust, whilst others both oceanic and continental crust. New sea floor is generated by lava flows from mid-ocean fissures, forming mid-ocean ridges. As the sea floor spreads the two plates diverge and will be bent downwards under the adjacent plate at the subduction zone. Thus, there existed a mechanism of balancing the creation of new surface area by the sinking back into the Earth's interior of oceanic crust. The presence of water lowers the melting point of rock and lubricates the process of subduction.





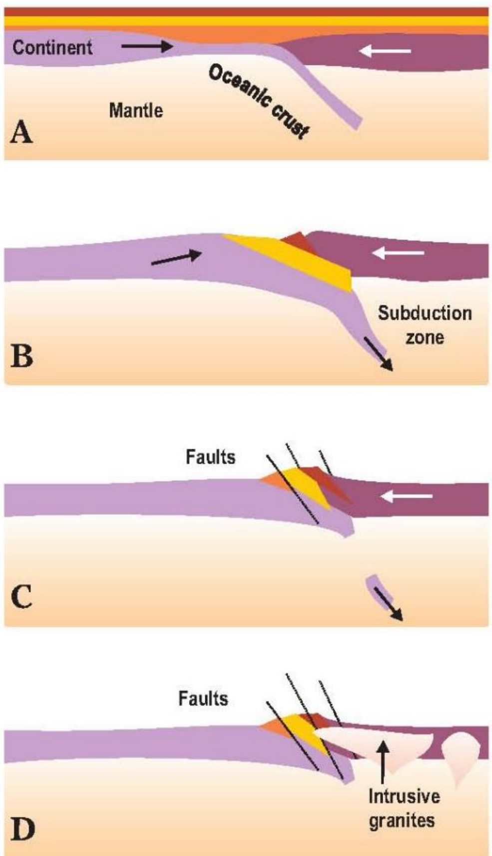
Age of the ocean floor (source: National Geophysical Data Centre, Dept. of Commerce, USA)

India moves northwards making contact with the southern margin of Asia about 55 million years ago and the Himalayas begin to form.



Ch.5 The formation of the Murchison Range and Greenstone Belt

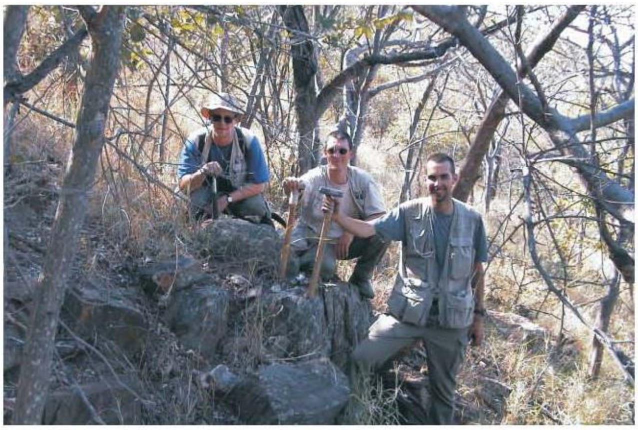
If nothing had happened to the original volcanic-sedimentary rocks of Selati since their deposition, they would still be lying horizontally; and sedimentary structures such as ripple marks, cross bedding and maybe the occasional drying cracks in muds, much still have been visible, as is the case with the Karoo Supergroup suite. Instead, the layers of these rocks have been tilted almost to the vertical. Metamorphism caused by heat and pressure has led to the formation of new minerals such as garnet. The rocks have also been variously stretched out or ‘sheared, so that any sedimentary structures that might have originally been there were obliterated. The features of tilting, shearing and metamorphism probably all happened in an episode of mountain building in the late Archean era. This is similar to what caused the Himalayas and Alps but on a much smaller scale.



In the initial subduction some of the coastal sediments and volcanic rocks were taken down to considerable depth, maybe 10-20 km, where the metamorphism occurred, this affected the area to the south the most. The minerals formed at that stage could be dated by the uranium-lead zircon method, and this allows us to fix and age for this event at about 2800 million years ago. As the subduction stopped, buoyancy forces, together with lateral stress of the collision pushed the volcanic-sedimentary rocks back up to the surface. The southernmost part of the volcanic-sedimentary unit, which is deepest, was pushed up as a separate wedge along the thrust plane and hence formed a mountain range.

Ch.6 The formation and intrusion of the Lekkersmaak, Willie and Mashishimale Granites

Subduction has other consequences apart from causing mountain building. Even though the sediments were consolidated into rocks, they still contained a lot of water in pores and in water bearing minerals such as clays. As they heated up and metamorphosed, large quantities of water 'cooked out' of them and made their way upwards. This very high temperature water vapour was 'injected' into the rocks above the subduction zone. The presence of water lowers the melting point of most rocks and therefore rocks at depth that we previously solid, underwent widespread melting without a temperature increase. This could have caused the formation of the granites that underlie most of Selati. As the granitic magmas rose from the depths they intruded the rocks above including the metamorphic sediments and volcanic rocks that has been uplifted along the thrust plane. On the geological map of Selati we see that, at the extreme western tip of Selati, near the emerald mine area, there is a definite 'packet' of layers including sediments and volcanic rocks looking like pages of a book. Just east of the emeralds mine area, a band of mainly talc-actinolite schists is turned away from this 'packet' – as if someone has opened the book. This band can be followed to the south-east, crossing the Selati River, all the way to the farm Thankerton where it connects to a set of very large blocks of talc-actinolite schists with some serpentine, amphibolite and quartzite.

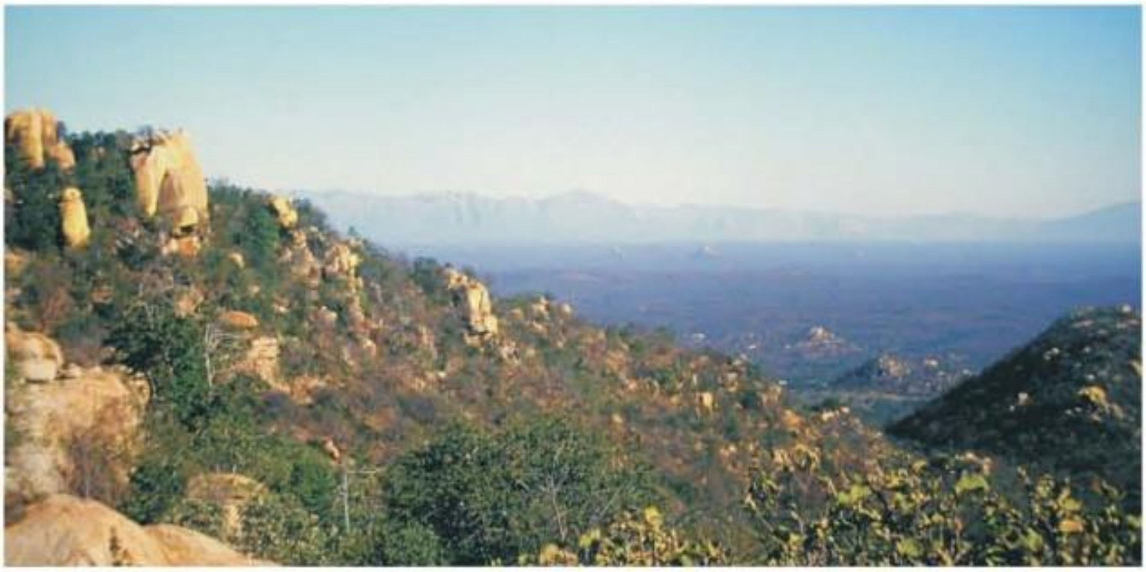


Geological hunters with a trophy: a strongly foliated 'sheared' gneiss on the eastern slope of La France Hill, locating a thrust fault.

The impression from the map is that a wedge has been driven into a previously coherent packet of sedimentary and volcanic rocks. This impression is correct, and the wedge is the intrusion by part of the Lekkersmaak and the entire Willie Granite. The talk-actinolite schists of Thankerton are chemically quite similar to those of the La France and La Belle France regions, and really belong to the volcanic-sedimentary sequence. This idea of a granite intrusion acting as a wedge may see strange, as one would expect the granites intruded in the molten state and would therefore not have the required mechanical strength to force though solid rock. The fact is, however, that granitic magmas ca be extremely viscous, particularly when they are close to their 'freezing' temperature, so that the concept of the 'wedge' is possible.

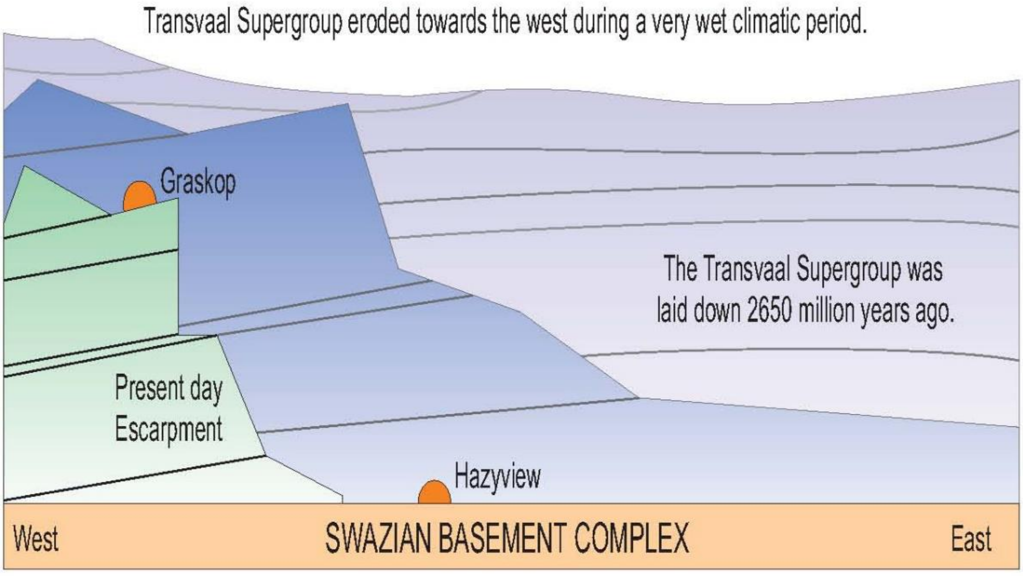
Ch.7 Selati's post Archean Era history

After the intrusion of the granites the Archean edifice of the crust in the Selati areas was completed. This episode may have been followed by a period of weathering and erosion removing some of the uppermost part of the crust. The rocks which form the escarpment to the west once covered the whole area of the Murchison Range, Selati, and most of the Lowveld. These are sediments belonging to the Transvaal Super group which were deposited between 26550 and 2100 million years ago. In the area where these still occur they are several thousand meters thick.

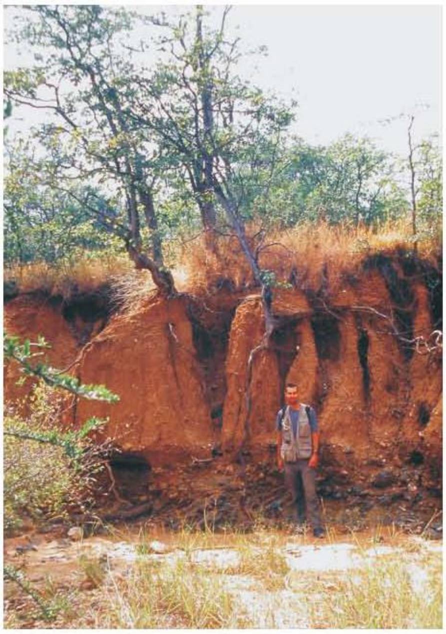


View from the Cycad Reserve towards the Transvaal Supergroup escarpment in the south

Above the Transvaal Supergroup sediments existed the sediments and lava flows of the Karoo Supergroup which were laid down between 300 and 1150 million years ago. The dolerite dykes in Selati are evidence of these lava flows. They occur throughout the Lowveld to the Limpopo River and beyond. These dykes represent fissures through which basaltic magma rose to the surface of the Earth's crust 150 million years ago. The present land surface of Selati would been thousands of meters inside the Earth's crust then.



During the deposition of the volcanic-sediments of the Karoo Supergroup, Africa was connected to India, Antarctica, and South America. The Atlantic Ocean started to open 180 million years ago, and the southern Indian Ocean 150 million years ago. After India, Madagascar, Antarctica, and South America had separated from Africa, southern and eastern Africa began to rise, lifting the Karoo sediments up to 2000 meters above the sea where they were originally deposited. This happened without any continental collision or mountain building: the layers remaining almost level. Initially there was a high coastline. This was eroded so that the edge of the escarpment is effectively moving further inland. As the rapidly eroding escarpment moved westwards the Archean rocks of the Lowveld were exposed once again. Erosion has since slowed as there are indications that the inland erosion by the rivers which exposed the Lowveld, happened in a much wetter climate. Firstly, the water flow needed to remove the completed mass of rock, several kilometers thick, from above the present Lowveld surface even in 100 million years is much greater than what we see I the rives at present. Secondly, the evidence of extensive weathering can be observed in the Mulati River course, where it runs through (originally) chlorite schists at the north end of Selati. Here weathering has produced red soils (laterites) which can be 20 meters or more in depth. Such deep lateritic soils are a characteristic of tropical weathering for which high temperatures and high rainfall are necessary. Today we have the high temperatures, but not the high rainfall and there must have been a long period of very high rainfall in the geological past.

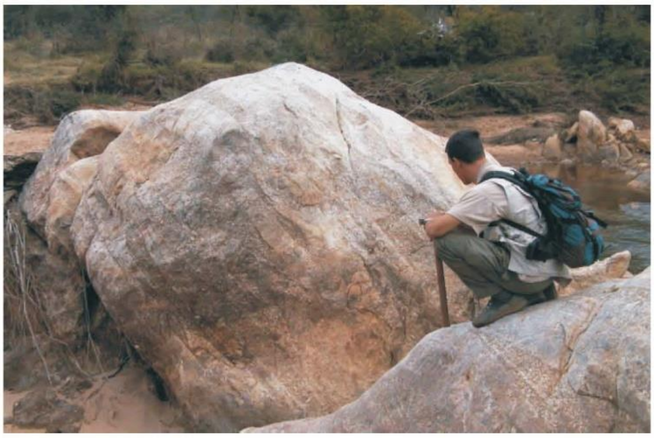


Thick laterite development by weathering of chlorite schist and talc-actinolite schist (visible at the bottom) Mulati River S 23 54 45, E 30 43 15

A further indication of climate change from very wet to dry is evident by the intense development of calcite over the granite. This can be found on the banks of the Selati River where the floods of 2000 have exposed them. Deep weathering of the granites leached calcium out of them which then formed calcrete in the soils above. So, the indications are that the present land surface of Selati was exposed in a tropical high rainfall climate, which caused deep weathering and rapid removal of the overburden, leaving the present escarpment. However, conditions under the present, much dyer, climate are much more static and tranquil. Remnants of the tropical rain forest of many thousands or even millions of years ago only survive in isolated steel valleys of the escarpment, such as those near Magoebaskloof.

Ch.8 Geological Mapping

Knowledge of the rock types and their arrangement helped us to understand the landscape and its history. A geological map is an inventory of rock types to be found on or near the surface. Each rock type is assigned a colour on the map.



Pegmatite intruding finer grained granite in parallel bands

Rock outcrops are relatively rare and to map only outcrops would not give a complete picture of the geology on the ground. If there are granite outcrops, then it is assumed that the soil-covered area in between is also underlain by granite. Soil produced by the weathering of granite is sandy, containing quartz and feldspar, while the soil covering volcanic rock is normally dark red, coloured by iron oxide, the iron originating from the magnesium and iron silicates in the volcanic rock.

View from Cycad Reserve north showing plains underlain by Lekkersmaak Granite and the Murchison Greenstone Belt

Another clue to the underlying geology is the species composition of the vegetation. Plants have specific soil and nutrient requirements often closely reflecting the basic or acid constituents in the soil.

- The geological map places the rock types into spatial components and is an essential tool for:
- Civil engineers when designing and surveying roads, dams and bridges.
- Mining and prospecting operations.
- Understanding the vegetation, and making decisions about what to plant in different places.

- Understanding the geological history of the region. Rocks originate from layered sediments and lavas or solidified magmas at depth. Rocks ae also broken down by erosion and weathering. Including:
  - Interpreting the geological forces which tilted, folded and re-melted the rocks.
  - Understanding of the sequence of events that led to the rocks being emplaced
  - Interpreting the sequence of events that lead to the landforms as we see them in their present form, the geomorphology of the rocks.

Ch.9 Rock Types of Selati Game Reserve

The rocks of Selati comprise of three basic types:

1. Metamorphosed Volcanic Rocks,
2. Metamorphosed Sedimentary Sands, and
3. Solidification of Magma.

Metamorphosed Volcanic Rocks

Talc-Actinolite Schist

A schist is a metamorphosed rock with a strong foliation. Talc and actinolite ae light green minerals, both are magnesium-rich silicates containing water. Talc (as in talcum powder) can be 'split' by hand like the pages of a book. The talc rubs off easily. This rock was originally volcanic, a very magnesium-rich (20% MgO) basalt, called Basaltic komatiite. These original minerals were changed to talc and actinolite during burial in the crust. Such a process is known as metamorphism, and rocks that owe their specific mineral composition to it are called metamorphic rocks. In the present day landscape these schists form in low-lying areas except where they occur interlayered with other, harder rock types which protect them from the elements of weathering and erosion.

Serpentinite

This is a dark green mineral. More magnesium-rich than talc and actinolite (32% MgO). Metamorphosed from basaltic komatiite – magnesium-rich volcanic rock. Such komatiitic lavas are rarely exposed today. The Great Dyke in Zimbabwe is serpentine and pyroxenite and from hills. In the bushveld complex only pyroxenite forms hills. Serpentinite is favoured by sculptors for its uniformity and easy malleability.

Quartz-chlorite Schist

The blue-green mineral chlorite is a magnesium- and ion-rich mineral, with less magnesium and more iron than take and actinolite, that forms when basalt undergoes metamorphism at medium temperatures in the crust – between 200°C and 500°C. These chlorite-rich schists are thus metamorphosed basaltic lavas. These basalts in the Archean Era were similar in composition to the basalts of today. The chlorite-rich schists are normally deeply weathered and soft; they probably underlie most of the very flat areas in the north-west extreme of Selati.

Chlorite schists (bottom) weathered to dark red lateritic soil (above). Tributary of the Mulati River

Folded amphibolite, Thankerton section, S 24 1 25.99, E 30 46 6.03

Amphibolite

Hornblende, a common dark green silicate mineral of the "amphibole" group is a main constituent mineral. Like chlorite, hornblende is rich in iron and magnesium, but it forms b metamorphism at higher temperatures than chlorite – 550°C to 700°C. The rocks from which amphibolite was formed were thus basalts, similar to the precursors of the chlorite schists, they were buried deeper in the crust and therefore subjected to higher temperatures. Note that the chlorite schists are mainly found in the north-west extreme of Selati and the amphibolites south-east of them. Amphibolites are hard, resistant rocks that form hills.

Metamorphosed Sedimentary Sands

Quartzite

SiO_2, silicon oxide. Quartzite's originate from quartz sands that consolidate to sandstones, the term quartzite is only used for a rock in which the quartz has been recrystallized, thus, a metamorphic rock of sedimentary origin. Today pure quartz sands are found on beaches and in river deltas. In Archean sedimentary sequences quartzite layers ae common and may indicate very intense chemical weathering in the source area of material, in which all minerals except the highly resistant quartz were destroyed. In the present landscape, quartzite's are hard, weathering-resistant rocks that form marked ridges such as the hills of La France and La Belle France. A special feature of the quartzite's in the area is that they are mostly bright green. This is caused by tiny amounts of fuchsite, a chrome-bearing mica.

Quartzitic Conglomerate

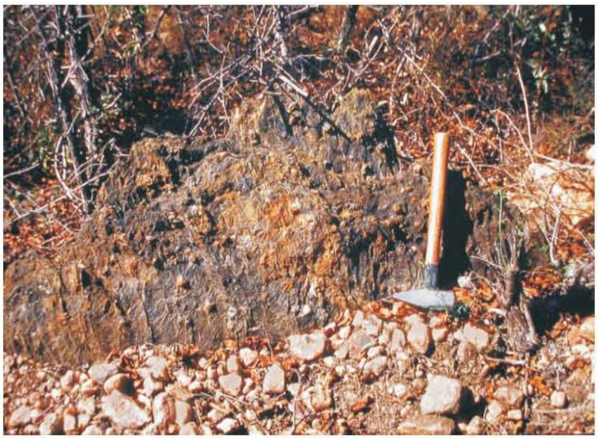
A conglomerate is a sedimentary rock containing pebbles, such as would form if a present day riverbed were consolidated. "Quartzitic" means that the groundmass in which the pebbles are embedded is a quartzite. In this case the pebbles are also mad of quartz. Like quartzite, the conglomerate is a weather resistant rock that stands out in the landscape.

The term 'metapsammite'

"Psammite" is a name given to a sandstone of medium grain size, regardless of what minerals are in it. "Meta" means that it has undergone metamorphism: there has been re-crystallization and new minerals have formed in it.

The term 'metapelite'

"Pelite" is a very fine-grained sediment, and because the fine fraction of silt in rivers are usually clay, pelites are rocks formed by the consolidation of clay deposits. Because clay minerals are very fine-grained, the clay minerals typically become unstable at increased temperatures. Metapelites are particularly useful indicators of the heat and pressure under which the metamorphism has taken place. In the metamorphism of a pelite, aluminium silicates such as kyanite and sillimanite, and iron-bearing silicates such as garnet and staurolite, are formed. These form nodules in the metapelites on the southern slopes of La France and La Belle France. Garnet can be dated using radioactive isotopes.



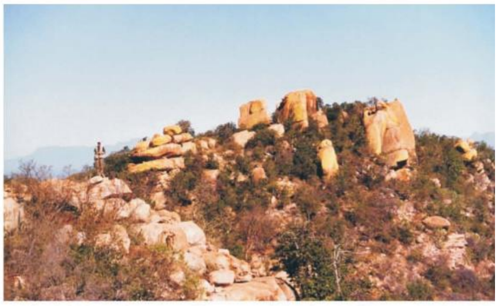
Metapelite with foliation, folded on a small scale. Nodules are crystals of minerals staurolite (Al-Fe-Mg silicate) and andalusite (Al-silicate) which have grown as a result of reheating in the crust. Outcrop along track running NS to east of La Belle France Hill. S 23 56 44.6, E 30 41 7.40

Carbonate Schist

Contains carbonate, i.e. calcite, $CaCO_3$, and dolomite, $CaMg(CO_3)_2$. These minerals are commonly found as the main components of limestone and dolomite as marine sedimentary rocks. In this case however, hot fluids carrying carbonates in solution permeated rocks in the area forming carbonate schists which, are the end products of rocks associated with the movements and the heating that took place preciously. Carbonate schist weathers easily and is only found in river cuttings.

Banded Iron Formation (BIF's)

These are chemically deposited rocks that formed when the Earth had no oxygen in its atmosphere. BIF's consist of multiple thin (<4mm) layers of iron oxides, separated by thin layers of silicates, mainly quartz. There is one small outcrop 2 km due north of La Franc Hill (S23 55 19.26, E 30 42 54.36).



Granite koppie, summit of Cycad Reserve. View to the west with the escarpment in the background

Lekkersmaak Granite. Selati riverbed, Hall's camp

Solidification of Magma

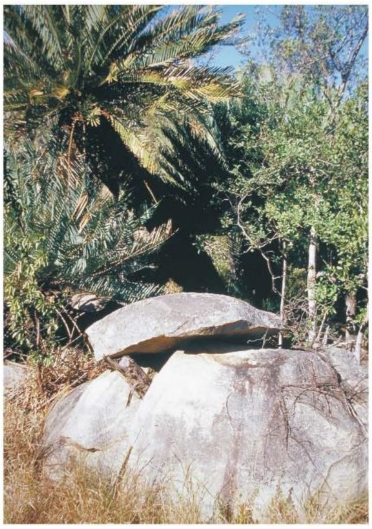
Granite

This consists of the minerals quartz, feldspar (aluminium silicate with potassium, sodium, and/or calcium) and dark mica (biotite), occasionally containing translucent mica (muscovite) and/or amphibole. Granites are course-grained so that individual minerals can be clearly seen with the naked eye. Granites are intrusive rocks that formed by the solidification of aluminium-rich magma deep in the crust. The cooling of the magma happened very slowly, taking tens of thousands of years, so that large crystals had time to form. Volcanic rocks in contrast usually have small grain sizes (<1mm) as their magmas solidified rapidly near the surface.

There are three varieties of granite in the reserve:

Lekkersmaak Granite: this is the granite type that underlies the larger portion of Selati and is well exposed in the Selati riverbed. It is medium-grained (<1cm grain size) and quite light coloured. It weathers to a sandy soil. The feldspars decompose so that the grains are predominantly quartz.

Willie Granite: occurs north of the Selati River on Willie Farm. It is "porphyritic", in that one mineral (feldspar) is courser grained than the others. Feldspars in the Willie Granite can be up to 4 cm in size. As this granite is more resistant to weathering it forms koppies (small hills).



Mashishimale Granite: contains green hornblende (amphibole), and occurs as a separate intrusion into the Lekkersmaak Granite in the extreme southeast end of Selati. Also more resistant to weathering than the Lekkersmaak Granite it characteristically forms the very beautiful koppies in the southeastern area.

Mashishimale Granite in the Cycad Reserve, showing typical blocky weathering and absence of foliation

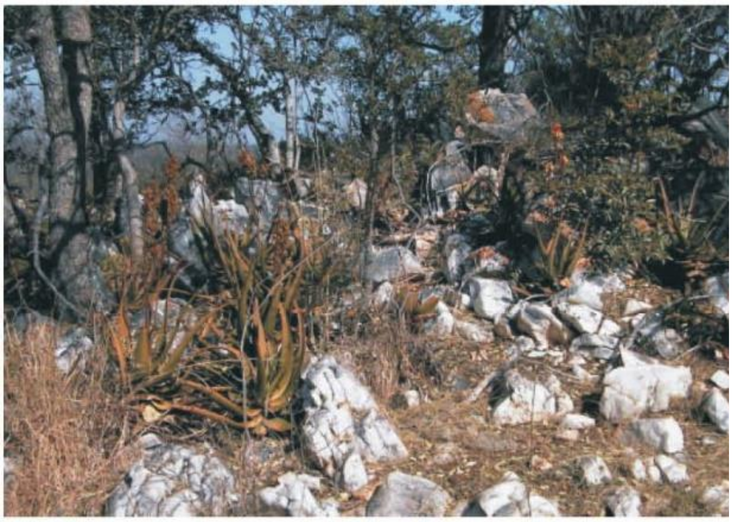
Pegmatite

This is an extremely course-grained granite: mineral grains larger than a meter have been observed, although the pegmatites of Selati usually have grain sizes less than 10 cm. Pegmatite is the rock mined for mica at Mica. It occurs as small intrusions or veins, less than 100 m in extent. Pegmatite formed from magma containing water and cooled under low pressure and temperature which promoted the formation of large crystals. This magma when enriched in rare elements such as beryllium and boron, forms tourmaline and beryl. Emerald, a variety of beryl, is green as it contains traces of chromium, which forms when pegmatitic fluids come into contact with talc-actinolite schists and sepentinites which contain chromium.

Quartz Veins

These are formed from the residual fluids of predominantly quartzose/silica material coming from magma. The quartz veins can be related to pegmatites as they represent a progression from siliceous melt to hydrous solution. The quartz veins often contain tourmaline, and may locally have caused emerald mineralization in the same way as pegmatites did. The quartz veins and stockworks are resistant to erosion and weathering, and the soil on them is poor and colonized mainly by hardy succulents. In many areas, but not in Selati, gold mineralization is associated with quartz veins.

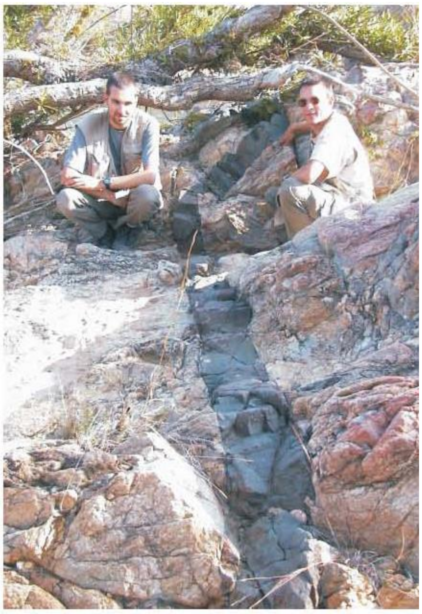
The term 'stockworks' describes how the liquid quartz that crystallised flowed between the pieces of rock which appears to have shattered into cubes. Thus the resulting stockworks look like an interlaced matrix of quartz around rectangular blocks of rock.



Typical outcrop of massive white quartz stockwork intruding granite found on Thankerton. S 23 59 54.62, E 30 41 11.09

Dolerite Dykes

Basaltic in composition, but unlike true basalt which is formed by the solidification of lava extruded at the surface, dolerite is crystallised from magma up fissures or "dykes". Dolerite dykes crystallised slowly. The Karoo dolerite dykes are about 150 million years old. Being much younger than the other rocks in the area, they are completely unmetamorphosed. They confront s with the three-dimensional aspect of landscape development. The dykes were cracks in the crust though which basaltic magma pushed up to the surface.



Dolerite Dyke seen to intrude coarse grained Willie Granite, Selati riverbed. S 23 59 46.46, E 30 40 56.06

Notes on the concept of metamorphism

In the above descriptions we have encountered metamorphic volcanic and metamorphic sedimentary rocks, and seen that what sets them apart from non-metamorphic rock is the formation of new minerals due to **high temperatures** during episodes of burial in the crust. **Pressure** is also a factor in metamorphism.

Experimental work by generations of scientists 'cooking up' rocks in the laboratory under various temperatures and pressures has provided insight and understanding into metamorphic processes. We can now deduce the range of temperatures (and occasionally pressure) of the metamorphism from the mineral assemblage present in rock.

The suites of rocks resulting from such processes are known as 'facies'; a facies defines the range of temperature of metamorphism. Two facies are distinguished on the geological map in the metamorphic rock: 'lower greenschist facies'(300°C-400°C) and 'amphibolite facies' (550°C-700°C)

Ch.10 Places and routes to experience the geological history of Selati

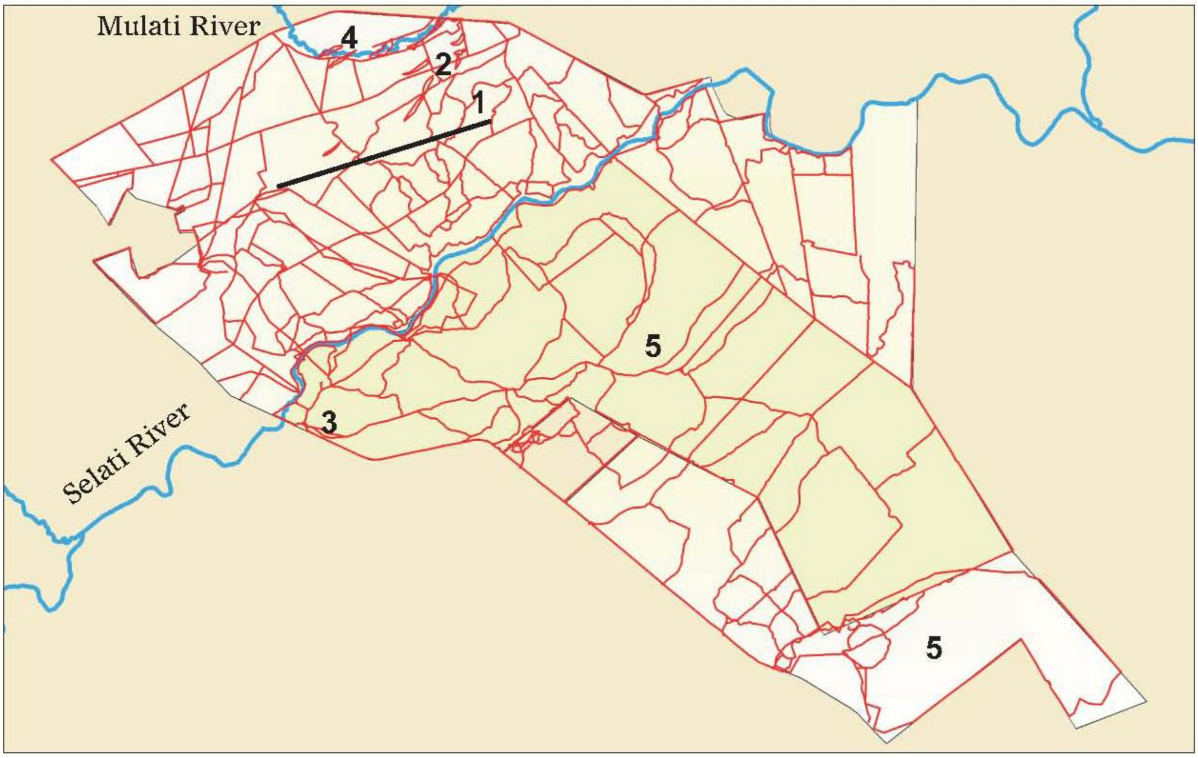
Many rock types in a small area (1)

One of the most instructive tours to see many rock types, and appreciate the geological contrasts of history of the area would be to traverse the La France hill from north to south. This has to be done on foot, as the roads run through the lowlands and miss most of the outcrops.

Starting on the east-west running road north of the hill a walk south traverse's serpentine and talc-actinolite schist, and then metapsammite which forms the norther slope of La France. Passing over the ridge just west of the summit, green quartzite's are encountered, which are folded in a giant fold too large to be sein in the outcrop but noticeable on the map. All these rocks are steeply dipping in geological terminology.

The upper part of the south slope of La France is made up of metapelites, which have nodules of over a centimeter of kyanite – an aluminium silicate. The south slope is rather steep and halfway down, or at the base (depending on exactly where you descend), you encounter intrusive contact of granite.

This walk is fascinating from various points of view. Firstly, it shows a lot of rock types in a relatively small space, ad illustrates how the rock types determine the landscape topography. Secondly, one can appreciate the spatial relationships between the different rock types, the tectonics, the metamorphism, and the intrusive contact of the granite, and what they all mean. Finally, this walk provides beautiful views. The vegetation changes as the underlying rock types change, and there is plenty of room for further study!



Banded Iron Formation (2)

The banded iron formation can be observed along the road that traverses Selati east-west just north of the hills La France and La Belle Franc; good outcrops are found where the road crosses a stream bed north of La Belle France (S 23 55 19.26, E 30 42 34.36)

Willie Granite (3)

Of the geological sights to be seen in the Selati River, one of the most beautiful is the contact between the Willie Granite and the talc-actinolite schists of the band that was wedged apart from the main Murchison Belt. This is close to the Ermelo Range manager's house and provides one of the few outcrops of an intrusive contact.

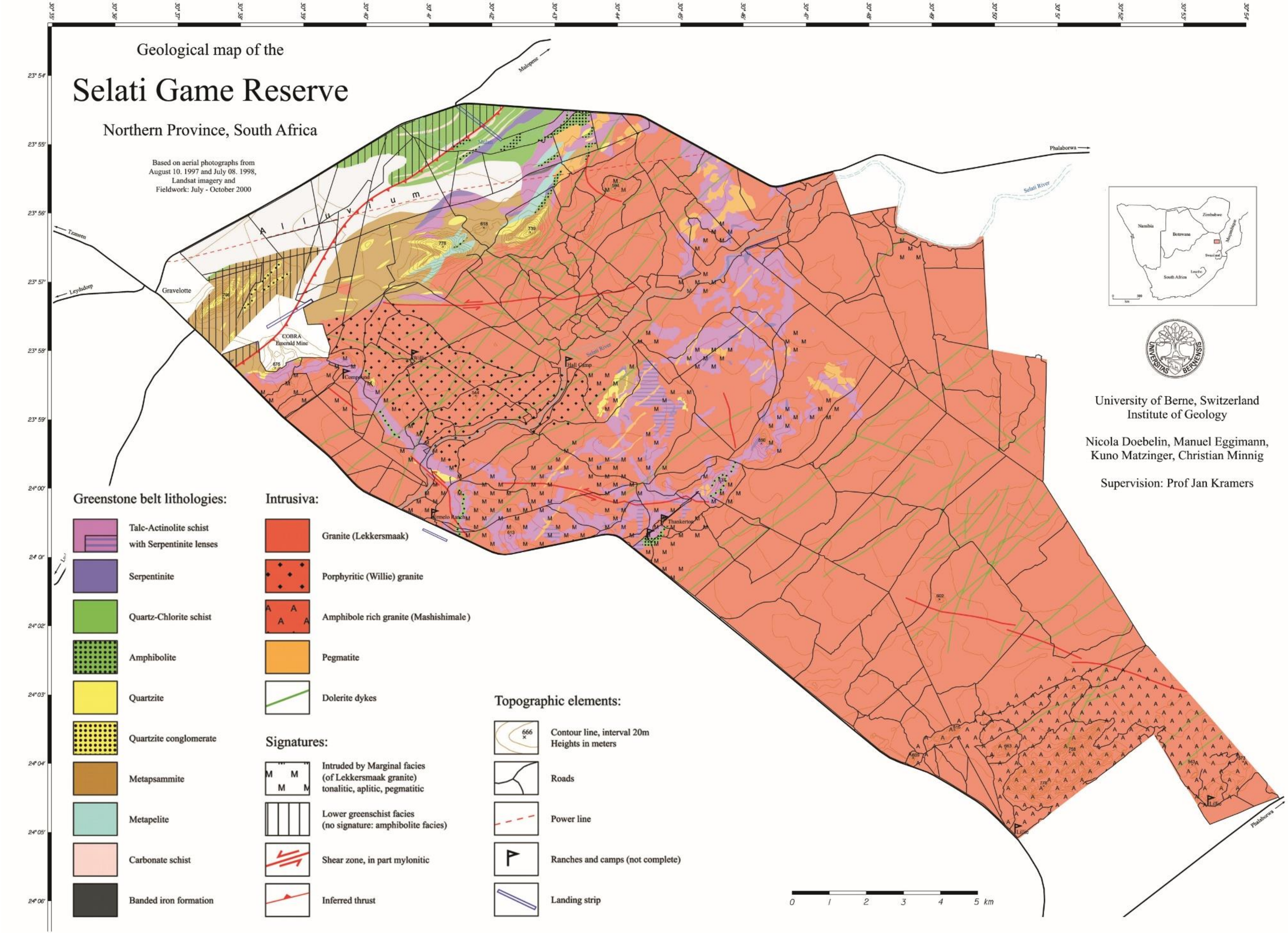
Effects of Weathering (4)

Deep weathering can be seen in many places in the Mulati riverbed, where it is also possible to see the transformation of rocks into red laterite soil, with remnants of rock still in place within the laterite.

Subsoil Activity (5)

A feeling for the gradual lowering of the landscape can be achieved particularly when standing on any of the koppies in the southeast of Selati. Subsoil activity, transforming rock into soil, is patchily distributed and inhomogenies accentuate themselves with time. Once a piece of bare rock stands out above the level of the soil, the rainwater runs off it, very few trees and other plants manage to grow on it, and there is no subsoil chemical and biological activity anymore to turn into soil.

Only the very sparse activity of rainwater and lichen, combined with the thermal expansion stress of temperature differences between night and day, manage to gnaw a little bit at those boulders and domes once they are exposed, while the surface of the soil covered areas around them descends much faster. This produces the 'balancing rocks' landscapes. No matter how it happened precisely, Selati is rock exposed where it formed 5km inside the Earth's crust 3000 million years ago.


Geological map of the
Selati Game Reserve
Northern Province, South Africa
Based on aerial photographs from
August 10. 1997 and July 08. 1998,
Landsat imagery and
Fieldwork: July - October 2000
Alluvium
Gravelotte
COBRA
Emerald Mine
Phalaborwa
Selati River
University of Berne, Switzerland
Institute of Geology
Nicola Doebelin, Manuel Eggimann,
Kuno Matzinger, Christian Minnig
Supervision: Prof Jan Kramers
Greenstone belt lithologies:
Talc-Actinolite schist
with Serpentinite lenses
Serpentinite
Quartz-Chlorite schist
Amphibolite
Quartzite
Quartzite conglomerate
Metapsammite
Metapelite
Carbonate schist
Banded iron formation
Intrusiva:
Granite (Lekkersmaak)
Porphyritic (Willie) granite
Amphibole rich granite (Mashishimale)
Pegmatite
Dolerite dykes
Signatures:
Intruded by Marginal facies
(of Lekkersmaak granite)
tonalitic, aplitic, pegmatitic
Lower greenschist facies
(no signature: amphibolite facies)
Shear zone, in part mylonitic
Inferred thrust
Topographic elements:
Contour line, interval 20m
Heights in meters
Roads
Power line
Ranches and camps (not complete)
Landing strip
0 1 2 3 4 5 km