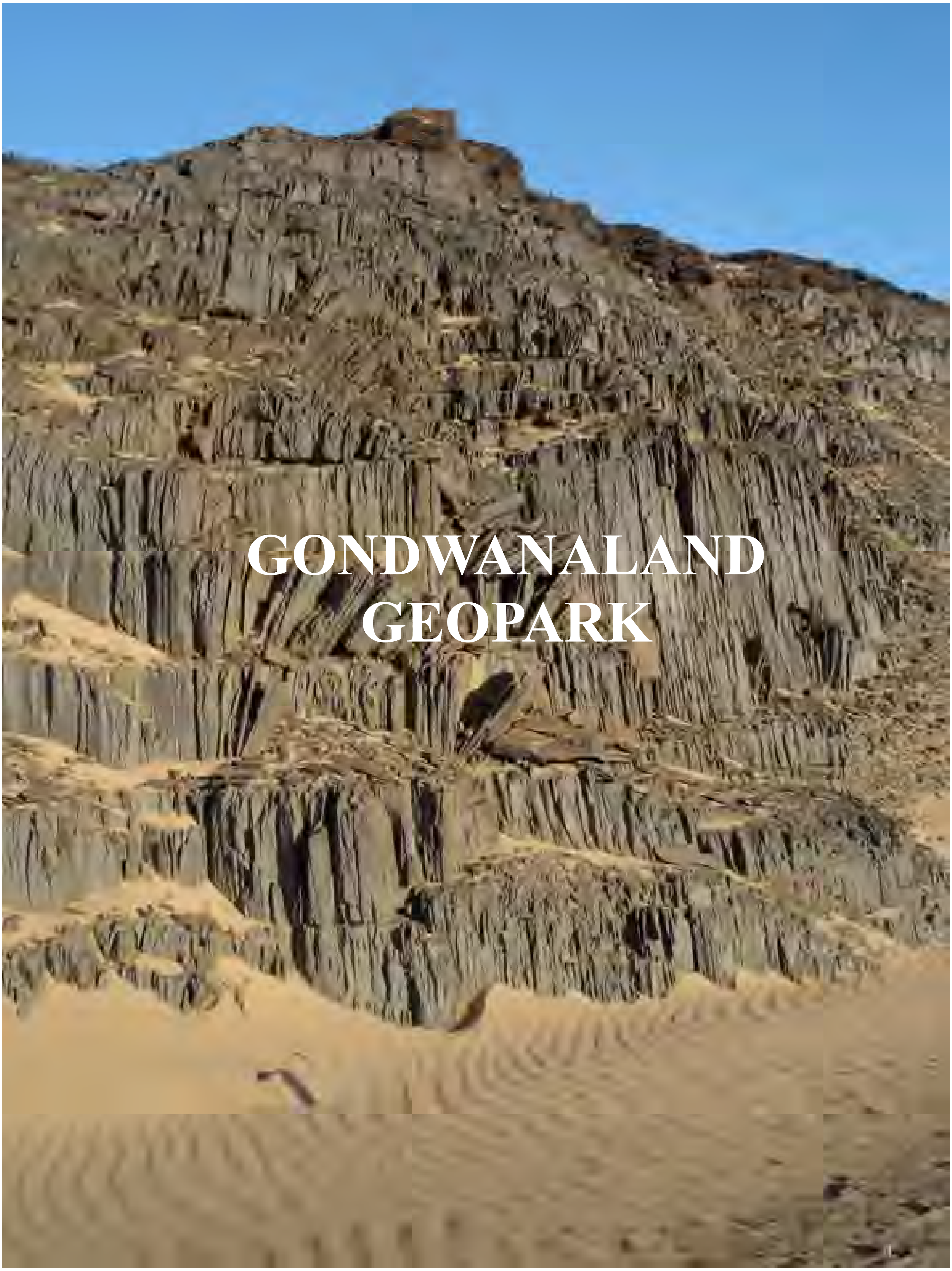
GONDWANALAND GEOPARK



Cover Photo: Chlorite-muscovite-schist of the Toscanini Formation near the mouth of the Huab River

-GONDWANALAND GEOPARK-

A proposed Geopark for Namibia

by
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EXECUTIVE SUMMARY

The United Nations Educational, Scientific and Cultural Organisation (UNESCO) has taken a decision in 2001 to support efforts of member states to promote territories or natural parks having special geological features through the inclusion in an international network of Geoparks.

Namibia's spectacular landscapes and the geological history of its rocks, minerals, fossils and landforms are of unique geological importance and constitute a significant geological heritage. This proposal for Africa's first Geopark covers an area of approximately 60 000 km² and is situated between 20º and 22º south and 13º and 16º east, in the central western part of Namibia with the Atlantic Ocean as its western boundary (see p. 10). The area boosts scenic landforms, palaeontological and archaeological sites, rare minerals and rocks, and it bears witness to geomorphological processes. These are combined with ecological biodiversity of scientific and cultural significance as well as with cultural and historical aspects.

The proposed Geopark is located in an area with an underdeveloped economy. Over the last 10 years, local communities have made tremendous efforts to develop and protect geological sites of scientific importance, forming part of Namibia's geological heritage. Local conservencies were established within the area with the aim to improve the living conditions of local communities and at the same time diversifying the rural economy. The popularization of earth sciences within the borders of a first Namibian Geopark could further strengthen the socio-economic development in a sustainable manner.

Most sites of geological interest in the proposed Geopark have no conservation status yet and are under considerable stress from unsustainable usage. They need to be protected within their rural environment. The local economy will be able to benefit from increased geo-tourism, if national and regional stakeholders can agree on management issues, and the responsibilities for the necessary conservation of geological heritage sites, including any physical maintanance. Participartory representation from all sections of the community needs to be secured, and should involve amongst others: public authorities, local organizations, private interests and research and educational bodies.

Awareness programmes for visitors to a Geopark will have to include education on environmental issues and sustainable development. Pedagogical programmes for schools need to be developed together with scientific explanations of geological features. Certain forms of geotourism have already become popular among Namibian and international tourists, and this has shown the need for sustainable heritage conservation, providing a foundation for education and scientific research and at the same time enabling the local communities to safeguard and market their own resources and earn income from them.

Proclamation of Africa's first Geopark under UNESCO patronage will ensure the appropriate recognition, preservation and utilization of Namibia's important geological and geomorphological heritage.

CONTENTS

1. Introduction

The history of planet Earth is inscribed in its landscapes, its mountains, and in the rocks beneath our feet. Only here we can trace the cycles of change and renewal that have shaped the earth in the past and that will continue to do so in the future. Too easy we forget that the geological history of the earth, its rocks, minerals, fossils and landforms are not only an integral part of our natural world, but are intrinsically linked to the evolution of life, cultural development itself and the ascent of humanity.

As a fundamental part of the natural world, geology and landscapes have had a profound influence on society, civilization, and cultural diversity, not only regarding the formation and location of mineral and energy resources, without which modern societies could not function. Our use of the land for agriculture, forestry, mining, quarrying and for building homes and cities or centers for tourism is intimately related to the underlying rocks, soils and landforms.

The record of the Earth's history is surprisingly fragile. It must be conserved so that future generations can enjoy it and further understanding of it for the benefit of humanity and the planet as a whole. The record of the geological history of the earth comprises concrete examples of features, rocks, mountainous landforms and soils and processes. We should strive to conserve this geological heritage, because it is of aesthetic, cultural and scientific significance, and because we recognize that it has nature conservation values.

The safeguarding of the Earth's geological diversity may go hand in hand with the aspects of biodiversity and of the cultural diversity generated throughout the time humankind has existed and even before (Eder, 2002a).

UNESCO offers, on request of its Member States, its assistance in establishing new entities labelled national Geoparks, territories with significant geological features, in order to promote three goals: (i) conserving a healthy geo-environment, (ii) educating in Earth Sciences at large, and (iii) fostering sustainable economic local development. According to UNESCO's guidelines, Geoparks, requesting the assistance of the Organisation, shall be designed to become a tool for a better understanding of the global geological heritage and the wise use of the Earth's surface, by sensitising the broad public to a balanced relationship between humankind and the Earth. One central principle of the UNESCO concept is that Geoparks must be capable of acting as a focus for economic activity, particularly through geotourism.

Geopark territories shall normally represent landscape elements rather than small geological outcrops of limited areal extent. Therefore, a "landscape approach" of integrating biotic and abiotic Earth heritage conservation shall be also widely adopted for the individual Geoparks. Landscape elements which share common geological and biological characteristics should be managed holistically to protect and enhance their natural characteristics. The relationship of humankind and their cultural and economic impact on landscapes shall also be recognised through such schemes. The strategy is therefore to take a holistic approach, which combines scientific, economic, cultural and social programmes to encourage sustainable development within the landscape context. A next step, the creation of a worldwide UNESCO Network of Geoparks, has provided a platform for international cooperation of different local, regional and national initiatives, and thereby enhanced the international recognition and the impact of individual Geoparks (Eder, 2002b).

In recognition of this situation, the Geological Survey of Namibia and UNESCO organized a workshop entitled "An Introduction to Geoparks", which was held on 3rd August, 2004 in Windhoek. The objective of this workshop was to disseminate the concept of Geoparks to all stakeholders and to bring them together for supporting a proposal for a Geopark in Namibia, which would be the first one of its kind in Africa.

2. Background

Many people walk across landscapes and wonder how so many varieties of rocks and shapes of mountains, hills and valleys came to be? Many have experienced a moment of exhilaration, when looking down from the top of a cliff to the sea crashing below or across the snowy ridge of a high mountain and wondered, how did these things form? Likewise, everybody who has ever picked up a rock from the floor of a quarry or from the sea shore might have wondered about that rock's long history? But are people able to find answers for their questions? Geoparks, where the aim is to explore geological heritage, can provide the answers to many of these questions.

Many people, when asked about geological heritage, think of places such as the Grand Canyon, famous volcanoes or mountain ranges such as the Himalayas. However, there is more than these special, often exceptional outcrops. Across the world there are examples of landscapes and rocks that provide key evidence of a particular moment in Earth history and they too are part of our geological heritage. Geological heritage is also a recognition, or acceptance, of Man's role to provide an economically sustainable future for the development of society as a whole, as well as our responsibility to share, but also to safeguard that heritage. In many ways the geological heritage of the world is as diverse, interesting and dynamic as the multicultural heritage of the world's different regions.

This might sound strange, as many people think that rocks, or indeed landscapes are boring or even dead. However, with the dawn of the 21st century there is a growing recognition that this mode of thinking is outdated and there is an increasing acceptance of the need not only to preserve, but also to enjoy our geological heritage. Geological heritage is also our shared history and that history can be read written in stone in the landscapes and rocks that are all around us.

More and more countries have already started to develop schemes for recognizing important geological and geomorphological sites within their national boundaries. Such Earth Heritage Sites are important for educating the general public in environmental matters. They also serve as tools for demonstrating sustainable development and for illustrating methods of site conservation as well as remembering that rocks, minerals, fossils, soils, landforms and landscapes are both the products and record of evolution of our planet Earth and, as such form an integral part of the natural world.

For a number of years, but particularly since the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992, where Agenda 21 (the Agenda of

Science for Environment and Development into the 21st Century) was adopted, the protection and enlightened management of the environment have been widely acknowledged as a top priority. UNESCO contributes to this by promoting the protection and sustainable development of geological heritage through mainly two independent programme frameworks, the World Heritage Convention and bilateral cooperation in geological heritage matters. Through the international convention adopted by UNESCO in 1972 “Concerning the Protection of the World Cultural and Natural Heritage”, the World Heritage Committee identifies and monitors properties of outstanding universal value, and decides which properties are to be included on the World Heritage List.

But what should be done with the numerous sites, which are also outstanding, of national and local value, but do not meet the strict criteria of the World Heritage List? UNESCO has received a large number of requests from all over the world during recent years, from geological institutions, and geo-scientists and non-governmental organizations, reflecting the rising need for the global promotion of geological heritage, at present recognized only nationally or not recognized at all. In response, UNESCO presented a new concept named the UNESCO “Geoparks Programme”. As a consequence, the Executive Board tasked UNESCO to support ad hoc efforts of member states to promote territories or natural parks having special geological features. UNESCO’s role is considered to be crucial in enhancing the public awareness of geological heritage matters, in achieving their fullest international recognition, and in securing their most effective political impact. UNESCO therefore continues to pursue the general objective of education in earth sciences through the promotion of geological heritage activities, providing UNESCO’s support to, and cooperation with, national initiatives on an ad hoc basis.

Few international programmes exist today, which offer the ability to identify, protect and promote sites of geological and geomorphological importance. Taking into account their common goals of pursuing activities in educating the public at large on environmental issues, promoting regional sustainable development and in supporting, training and developing scientific research in the various disciplines of Earth Sciences, UNESCO has established close ties of cooperation with the Network of European Geoparks. UNESCO, on the one hand, offers it’s sponsorship to interested member states to recognize, protect and enhance Earth heritage sites at the global level, whereas the Network of European Geoparks, on the other hand, focuses on European sites. This new potential for interaction between the socio-economic development and conservation of the natural environment adds a new dimension to the scheme of the World Heritage Convention. It recognizes as a central principle the relationship between people and geology and the ability of a site to serve as a focus for economic development, particularly through geological tourism.

With respect to sustainable development, numerous areas in the World offer immediate potential for sustainable economic development, because of the presence of a diverse range of geological phenomena including, amongst others, structures, minerals and fossils. Geological heritage sites, properly managed, can generate employment and new economic activities, especially in regions in need of new or additional sources of income. Around the World, there is a growing public awareness of the necessity to conserve nature and more and more people recognize that geological features play an essential part in managing our environment in a wise way (Eder & Patzak, 2001).

Nevertheless, much remains to be done. Out of the 754 sites inscribed on the World Heritage List, 582 are cultural, 149 are natural and 23 are mixed sites. Only 19 are inscribed primarily because of their geological interest. There are 32 natural sites in Africa, which accounts for some 20% of all natural sites world wide. Off these, only one is a truly geological site, and only 4 others have a geological component. There is not a single Geopark in Africa.

During the workshop held at the Geological Survey of Namibia in August 2004, a specific area (see p. 10), suitable for a Geopark, was selected based on the following criteria:

(i) cluster of geological sites
(ii) density of cultural sites
(iii) density of proclaimed national monuments
(iv) complete geological history from the formation of Rodinia to the post-break up of Gondwanaland
(v) minerals and gemstones occurring in the area
(vi) abundance of fossils
(vii) specially adapted fauna and flora and its links to geology
(viii) existing infrastructure
(ix) low level of socio-economic development and therefore potential to increase the standard of living for the local communities through geo-tourism

The area selected comprises some 60 000 km^2 in north-western Namibia, between 20^o and 22^o south and 13^o and 16^o east, covering the northwestern parts of the Erongo Region, the southernmost part of the Kunene Region and a very small westernmost part of the Otjozondjupa Region, often also referred to as Damaraland. This area is dominated by a geological history during which Namibia was a part of the so-called Gondwanaland. In fact, the area represents a complete geological record of the period during which Namibia was deeply embedded in this ancient supercontinent Gondwanaland between 650 and 135 million years ago, covering the Late Proterozoic as well as the entire Palaeozoic and Mesozoic eras of the Earth's history. The working title "Gondwanaland Geopark" was therefore adopted.

3. Global UNESCO Network of Geoparks

Persuant to the decision of its Executive Board in June 2001 (161 EX/Decisions, 3.3.1), UNESCO has been invited "to support ad hoc efforts of Member States" to promote territories or natural parks having special geological features. To this end, the present Operational Guidelines (APPENDIX I) provide directing principles for national Geoparks requesting the assistance of UNESCO through the inclusion in a Network of national Geoparks. A Geopark seeking UNESCO's assistance is a territory with well-defined limits. It is run under the national legislation or regulations, which provide the legal framework for its managerial body, funding tools and logistical support.

National initiatives seeking UNESCO's assistance should integrate the preservation of significant examples of the geological heritage of our planet Earth in a strategy for regional socio-economic development, while safeguarding the environment, which is a concept also known as sustainable development. There should further be a balanced relationship between humankind and the Earth by heightening public awareness and respect of the Earth's value and improving understanding of the Earth's crust and the capacity to use it wisely.

In promoting the protection and sustainable development of geological heritage, Member States' initiatives shall thus contribute to the objectives of Agenda 21, the Agenda of Science for Environment and Development into the twenty-first century adopted by the United Nations Conference on Environment and Development (UNCED, Rio de Janeiro, 1992). Further, they shall add a new dimension to the 1972 Convention concerning the Protection of the World Cultural and Natural Heritage by highlighting the potential for interaction between socio-economic development and conservation of the natural environment.

Besides operating in synergy with UNESCO's World Heritage Centre and the Man and the Biosphere (MAB) World Network of Biosphere Reserves, UNESCO co-operates closely with other complementary national and international undertakings, and non-governmental organisations active in geological heritage conservation, like IUGS' Working Group on "Global Geosites", ProGEO and the "European Geoparks Network" (UNESCO, 2004).

4. General Geography

The proposed Geopark (see p.10) covers an area of approximately 60 000 km² and is situated between 20º and 22º south and 13º and 16º east, in the central western part of Namibia with the Atlantic Ocean as its western boundary. It falls within three administrative regions of Namibia, namely Kunene, Erongo and Otjozondjupa. The area comprises eight communal conservancies (app. 15 000 people) and larger settlements such as Karibib (5 000 people), Usakos (4 000 people), Omaruru (7 000 people), Uis (1 000 people) and Khorixas (7 000 people). In addition about 6000 people live on commercial free hold land. With an estimated total population of about 45 000 people, the proposed Geopark has a very low population density of less than one person per km^2, which is amongst the lowest population densities in the entire World.


Skeleton Coast

Area of the proposed Geopark

Land tenure within the proposed Geopark is divided between free-hold private farmland in the east and communal farmlands towards the west. The area along the coast up to the Ugab River is part of the West Coast Recreation Area and the coast further north belongs to the Skeleton Coast Park.

5. Landscapes

Often termed 'a geological wonderland' because of its good geological exposures, the proposed area for a Namibian Geopark is bare with little vegetation, because a harsh climate limits soil development and thereby vegetation growth. The landscape is shaped by tectonic processes forming mountain chains, glacial advances, inundations by the sea, continental break-up with its associated volcanism and erosion by wind, weather and even dissection by flowing rivers (Jacobson et al., 1995).

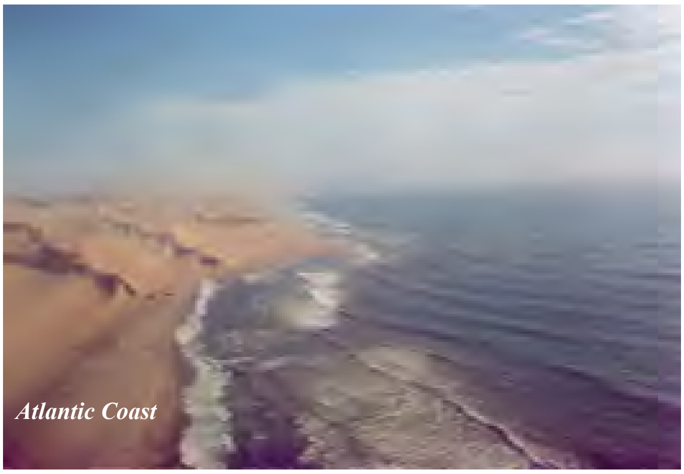
Ugab River with Brrandberg in the background

The proposed Geopark features a high plateau, from which the land falls away along the Great Western Escarpment to the Atlantic Ocean. The coastal margin between 20° and 22°south is represented by the Atlantic Ocean coast and the Namib Desert pavement. It stretches inland up to about 100 km from the coast, followed by a rise to about 800 m above sea level at the base of the Escarpment. The Namib area displays typical desert features, such as bare rock and gravel plains, rocky outcrops and gorges, sandy river beds, river canyons and saltpans, as well as an active dune system in the northern part. The high plateau features mountainous terrain underlain by old metamorphic rocks, granite and marbles. Sediments topped by the spectacular volcanic rocks of the Etendeka Plateau and prominent inselbergs such as the Brandberg add much to the geological attractiveness and appeal of the area.

Landscapes

5.1 Atlantic Coast

The coastline along the Atlantic Ocean is the western boundary of the proposed Geopark It stretches about 300 km between 20º and 22º south and lacks any population as a consequence of the desert environment. This environment along the shores of the entire coastline is dominated by sandy beaches, or mixed sand and rock. Rocky shores within the Geopark area can be found at various places, such as at Cape Cross and Torra Bay, and are separated by long stretches of sand. Large lagunal shores within the proposed area are limited to the area north of Cape Cross. Heavy wave action is common throughout the year, resulting in silting and sand-score. Namibia's coastal environ-



Atlantic Coast

ment is influenced by the cold Benguela Current System, dominated by coastal wind, induced upwhelling and strong southerly-south-westerly winds off the coast, which are responsible for the formation of the desert pavement and wind-induced shaping of rocks. The marine environment also features intertidal and subtidal regions, and spectacular sandy shores, both supporting a variety of fauna and flora.


Uniab Delta

Numerous salt pans occur within the proposed Geopark's coastal perimeter, and are used for salt mining and artificial guano platforms which have been built at Cape Cross to provide suitable nesting sites for birds. A considerable Cape Fur Seal (*Pusilis pusilis*) population lives at Cape Cross and is a popular tourist attraction.

Along the Geopark coastline, there are several coastal wetlands, consisting of extensive mud flats, and shallow marine and limited estuarine habitats that provide important feeding and breeding grounds to a large number of migratory wading and seabirds. Many of these can be regarded as important and sensitive areas such as the Cape Cross Lagoons and platforms, which support more than 20 000 birds (O'Toole, 1993). At places along the coast, ephemeral rivers, such as the Uniab and the Koigab end in pools of brackish water among the dunes. These pools of seepage water are fringed by reeds and species of sedges and attract large numbers of birds, mainly waders of various species.

5.2 The Namib Desert

Distinct desert landforms found within the proposed Geopark comprise the central Namib with its gravel plains south of the Ugab and the northern Namib with rocky outcrops and spectacular dune fields north of the Ugab River. These two Namib desert landforms reach 50-100 km inland, roughly coinciding with the 100-mm annual rainfall line (Seely, 1992). Dunes are a living and integral part of desert landforms. Created by the deposition of sand by wind, the size, shape and patterns of the dune depend on the availability and grain size of the sand in relation to the direction, speed and turbulence of the wind. A normal dune takes shape on the leeward side of an obstruction, which could be any stone or bush around which it is built. The dunes north of the Koigab river are the result of wind deposits of sand churned out onto the beaches by Atlantic Ocean waves and seized by the prevailing southerly and south-westerly winds. While longitudinal dunes stretch parallel to the prevailing wind direction, transverse dunes lie across the path of the wind, as is the case in the vicinity of Torra Bay in the northwest of the Geopark (Schoeman, 1996).


Namib Dunes


Namib Gravel plains

The hinterland of the Namib Desert is made up of gravel plains, low-lying ridges and flat-topped mountains further inland. The gravel plains are barren, bleak and desolate, but with an almost overpowering grandeur and beauty where plants are scarce – until it rains. The substrate for plant life is unconsolidated sand, coarse gravel flats, sandy gravel plains or gravel plains with scattered rocks or rock outcrops. Rain seldom falls in the Namib Desert and the main source of moisture for plants and animals is the sea fog which drifts over the dunes and plains, leaving droplets of condensation on the plants and sand.

5.3 Great Western Escarpment

A largely mountainous escarpment zone dominates the landscape inland towards the east of the Namib Desert, and is marked by a sharp rise to the western edge of the highlands with the prominent mountains of the Etendeka Plateau. The Plateau varies in altitude from a 1000 m to 1500 m above sea level and displays a diversified landscape with rugged mountains, sand-filled shallow valleys and gently undulating plains. Further south, standing out as inselbergs, are the striking mass of the Brandberg (2573 m), Namibia's highest mountain, the Spitzkuppe, and the Erongo Massiv, which all lie in an area where the edge of the Escarpment has been leveled out by erosion, and only erosion-resistant rocks remained forming these mountains.

The escarpment's landscape is a result of the continental break-up of Gondwanaland, taking place some 135 million years ago, and the subsequent continental drift and separation, which continues since then. In this process, the Atlantic Ocean formed and the margins of southern Africa were uplifted. Thereafter, weathering did set in, and slowly eroded the edges of the continent, a process that continues along the Great Escarpment to this very day and progresses in an easterly direction. In the west it leaves behind the coastal plain of the Namib Desert.

5.4 The area east of the Great Escarpment

The landscape east of the Escarpment, in the so-called central-western plains, is characterised by landforms largely formed by erosion which carved out the catchment areas of several major ephemeral rivers of which the most prominent ones in the area east of the Escarpment within the proposed Geopark are the Omaruru, the Ugab and the Huab. These rivers cut westwards through the central-western plains and are fed by various smaller tributaries which have eroded many deep valleys and caused widespread erosion. Soils within the central-western plains are typically thin, rocky and poorly developed and naturally erosive when subjected to large numbers of lifestock. Movements of wind and water over the disturbed land surface carries away large amounts of soil.

The area east of the Escarpment lies between 500 and 1000 m above sea level and is underlain by metamorphic rocks in the east. The dissected terraine consists of flat to roling ground with granite inselbergs like the Erongo Massiv breaking the surface in places. Further to the west, the landscape consists of flat-topped hills, made up of sediments and topped by volcanic rocks. The surface is covered with loose rocks in most areas of this arid landscape (Mendelsohn et al., 2002).

The central-western plains comprise a variety of grasslands and shrubland vegetation, which allows for both, commercial and communal farming activities. Thorn scrub savannah composed of a diverse mix of Acacia species is a dominant vegetation type in the catchment areas of the upper reaches of the ephemeral rivers. Mopane savannah is widespread covering large areas north of the upper Ugab.

5.5 Ephemeral Rivers and their Catchment Areas

The Geopark is traversed by five major ephemeral rivers, namely the Omaruru, the Ugab, the Huab, the Koigab and the Uniab. These westward flowing rivers are depending on catchment areas stretching far beyond the proposed Geopark boundaries in the east. Because of their ability to from limited soils and sustain an increased vegetation, the drainage systems are also referred to as 'linear oases' (Hebbard 2005). The catchment areas of the ephemeral rivers are responsible for the ongoing shaping of erosion surfaces within the Escarpment area, and landforms such as the Ugab Terraces towards the northeast of the proposed Geopark.

Ephemeral River Catchments

Ephemeral rivers flow only for short periods after heavy rains have fallen in their catchment areas. Floods re-charge aquifers and maintain dense stands of the riparian vegetation in the Geopark. Flood water stored below the surface provides essential water for settlements on or near the rivers. Floods are also the source of water and nutrients that keep the riparian forests of the ephemeral rivers alive. The forests that line the river banks are important fodder resources for livestock and wildlife in the area. Soils within the catchment areas are generally thin and poorly developed. However, limited potential for irrigation on the floodplains of the ephemeral rivers and adjacent river banks does exist (e.g. Omaruru, Usakos, Okombahe), although poor drainage, high salinisation and high evaporation pose a risk for agricultural irrigation schemes. Soil erosion and vegetation loss are the result of poor rangeland management practices observed in the area.


Ugab River

The groundwater re-charge of alluvial aquifers is important for communal and private farmers as well as for the development of tourist resorts. Small springs that flow throughout the year in all river beds are essential for the survival of people, wildlife and livestock. All ephemeral rivers are carriers of freshwater reservoirs, upon which a variety of game relies.

In terms of the biological diversity ephemeral rivers are critically important and extremely vulnerable biologically. A number of unique endemic vertebrates, invertebrates and plants are found and play an important role in marketing the area in terms of tourism.


Uniab Delta

Passing through the coastal desert area, underground water flowing towards the Atlantic Ocean tends to be brackish at times, and displays delta-like environments, such as the Uniab Delta, with waterfalls and steep gorges. Associated with the ephemeral rivers at the coast are distinct terraces formed by fluviatile sedimentation, as well as marine terraces, representing higher sea levels in geological times.

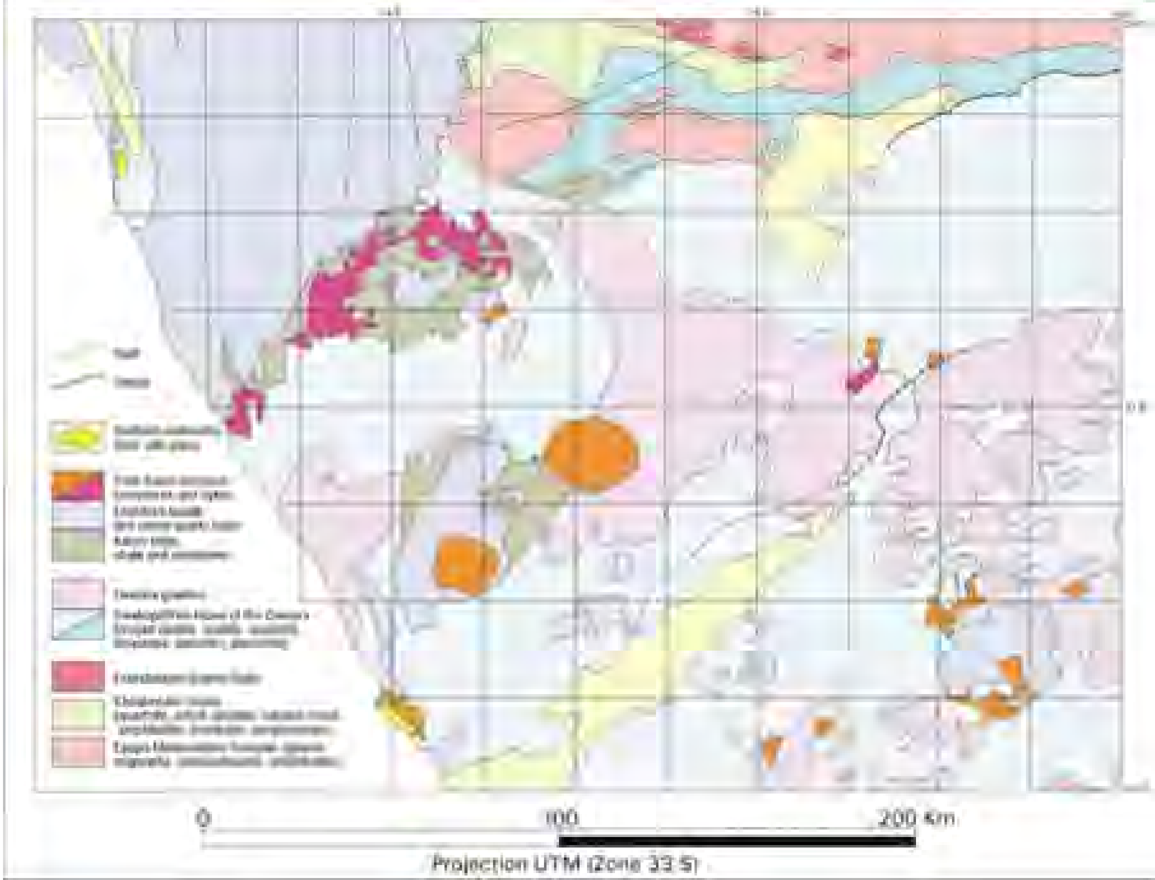
The combination of a diverse assemblage of wildlife within spectacular desert landscapes makes the ephemeral rivers a unique attraction. This heritage has great potential to generate further and increasing revenues through geo-tourism, improving the livelihood of many of the proposed Geopark's inhabitants.

6. Geology

Namibia's varied geology encompasses rocks of Archaean to Quaternary age, thus covering more than 2600 million years of Earth's history. About half of the country's surface is bedrock exposure, while the remainder is covered by surficial deposits of the Kalahari and Namib Deserts. There are five main rock-forming periods.

The oldest rocks occur within metamorphic complexes of Vaalian (> 2000 Ma) to Early Mokolian (2000 to 1800 Ma) age. These form a basement to the rocks of the next major period, which include sedimentary and volcanic successions, of Middle to Late Mokolian (1800 to 1000 Ma) age. The final events in this evolution led to the assembly of the early supercontinent Rodinia. The third main event, the formation of the Damaran mountain belt, started with intracontinental rifting and sedimentation about 900 Ma ago and culminated in continental collision during the Damara Orogeny between 650 and 450 Ma ago. This coincides with the assembly of the supercontinent Gondwanaland. Gondwanaland was a huge continent, consisting of India and all the present-day continents of the southern hemisphere. It was to remain stable for the next 350 million years, before it disintegrated to form the continents as we know them today.

Extensive erosion of the Damaran mountain belt preceded the fourth phase, the deposition of the Karoo Sequence between the Permian and the Jurassic, some 300 to 135 Ma ago. Extensive volcanism accompanied the break-up of Gondwanaland at the end of this phase. To-



Geological Map of the proposed Geopark area

day, Cretaceous to recent deposits cover many of the older rocks and constitute the fifth phase (Miller, 1992).

The proposed Geopark area covers almost all of these events. It shows a long record of Namibia's geological history starting with rocks of the old supercontinent Rodinia to the post-break up of Gondwanaland. The area is, however, dominated by rocks from the period, during which Namibia was a part of Gondwanaland. In fact, the area represents a complete geological record of the period during which Namibia was deeply embedded in this ancient supercontinent between 650 and 135 million years ago.

6.1 Vaalian to Early Mokolian rocks (> 1800 million years)

Metamorphic Complexes of Vaalian to Early Mokolian age (>1800 Ma) crop out in several major inliers in northern and central Namibia, but having undergone several cycles of metamorphism, the reconstruction of their depositional environment is quite difficult. They can, however, be interpreted as part of the developing Proterozoic Congo and Kalahari Cratons. In the proposed Geopark area, they form the basement on which the rocks of the Damara Sequence rest.

Light gneisses containing layers of quartzite, mica schist and amphibolite are the main rock types of the Huab Complex west of Fransfontein. Rocks of the Khoabendus Group occur in two separate regions in the northwestern and southwestern parts of the Kamanjab Inlier. The Group is composed largely of a volcanic lower portion and a sedimentary upper portion. The volcanics comprise acid pyroclastics, feldspar porphyry, dacite and rhyolite. The sediments include quartzite, conglomerate, limestone, dolomite, chert and banded iron formation.

In the Erongo Region, various gneisses, amphibolites and pegmatites constitute the Abbabis Complex of central Namibia.

6.2 Middle to Late Mokolian rocks (1800 to 1000 million years)

The Fransfontein Granitic Suite of Middle to Late Mokolian age (1800 to 1000 Ma) intruded rocks of the Huab Complex and the Khoabendus Group. Granodiorite and granite are dominant, small diorite bodies are also present.

6.3 Namibian to Early Cambrian rocks (1000 to 500 million years)

The Neoproterozoic Damara Orogen was formed during a complete plate tectonic cycle in successive phases of intra-continental rifting, spreading, the formation of passive continental margins, mid-ocean ridge development and subsequent subduction and continental collision involving the Congo and Kalahari Cratons, and culminating in the formation of Alpine-type mountain belts. The coastal and intracontinental arms of the Damara Orogen underlie much of northwestern and central Namibia.


Zerrissene Mountains

The basal Nosib Group was laid down marginal to, as well as inside intracontinental rifts and consists of quartzite, arkose, conglomerate, phyllite, calc-silicate and subordinate limestone. Local ignimbrites with associated subvolcanic intrusions range from 820 to 730 Ma in age.


Gemsbok River Formation

Continental break-up followed the initial rifting and the widespread clastic and carbonate deposition of the Kudis, Ugab and lower Khomas Subgroups of the Swakop Group took place in the marginal shelf regions and extended far beyond the shoulders of the early rift graben. Interbedded schists, banded iron formation and basic lavas point to quite variable depositional conditions. The Chuos Formation of the lower Khomas Subgroup forms the most important marker, since it occurs throughout the Damara Orogen. It comprises a variety of rock types ranging from mixtites deposited by glaciers and schist to conglomerate and quartzite. Similar rocks were deposited worldwide some 700 Ma ago and are regarded vestiges of several phases of global glaciation (Hoffman et al., 1998a, 1998b). To the north, a stable platform developed, where the massive carbonates of the Otavi Group were deposited.

Thereafter, a reversal of the extensional movements led to subduction of the oceanic crust under the Congo Craton and eventually to continental collision. The associated deformation created the Damara mountain belt. The intracontinental arm of the Damara Orogen developed paired metamorphic belts with a high temperature – low pressure zone in the northwest and a low temperature – high pressure zone in the southeast. Central Namibia was the location of an active continental margin with a northwestwards dipping subduction zone. In the coastal arm, another set of paired metamorphic belts developed. The intrusion of syn- to post-tectonic granites and pegmatites accompanied the mountain-building process between 650 and 460 Ma ago.

On the basis of stratigraphy, structure, grade of metamorphism, plutonic rocks and geochronology, the intracontinental branch of the Damara Orogen has been subdivided into several zones. From north to south they are the Northern Platform, the Northern Zone, the Central Zone, the Okahandja Lineament Zone, the Southern Zone, the Southern Margin Zone and the Southern Foreland, with the first three occurring in the proposed Geopark area. The Northern Platform contains the thick platform carbonates of the Otavi Group overlain by the molasse of the Mulden Group. The Northern Zone represents a transition between the platform carbonates and the shelf sediments of the Swakop Group. The Central Zone (Swakop Zone) is the high temperature – low pressure zone of the orogen, and characterised by numerous granitic plutons.

Granite Kop

6.4 Permo-Carboniferous to Jurassic rocks (300 to 135 million years)

The next rock-forming cycle took place during the Permo-Carboniferous to Jurassic (300 to 135 Ma). Following the assembly of Gondwanaland towards the end of the Damara Orogeny, stable continental conditions prevailed throughout the Palaeozoic and the early to middle Mesozoic. By the end of the Carboniferous, 200 Ma of erosion had left only remnants of the Damara mountainbelt. Most parts of present-day Namibia had become vast peneplains, separated only by those remnants. The peneplains were to become the sedimentary basins in which the rocks of the Permo-Carboniferous to Jurassic Karoo Sequence were to be deposited. Within Gondwanaland, southern Africa initially occupied a position close to the south pole, and a huge ice sheet covered the region. Basal glaciogenic rocks of the Permo-Carboniferous Dwyka Formation include moraines and fluvio-glacial as well as glacio-marine deposits.

Dwyka Glaciation

The Dwyka glaciation ended approximately 280 Ma ago, when plate tectonic movements brought southern Africa to a more moderate climatic realm. The melting ice sheet provided ample water to create an environment with huge lakes and rivers, in which lacustrine grey-to green-weathering shales, mudstones, limestones, sandstones and coal-bearing shales and fluviatile sandstones were deposited. A number of smaller sedimentary basins developed in Namibia, of which the Huab Basin is of relevance for the proposed Geopark area. In this basin, the Dwyka Formation is overlain by grey to green shales, mudstones, limestones, sandstones and coal-bearing shales of the Verbrandeberg Formation, deposited by widespread meandering fluvial systems, on flood planes and in lakes.

The Verbrandeberg Formation in turn is overlain by the fluvio-deltaic to shallow marine sandstone deposits of the Tsarabis Formation. These are followed by the marine carbonate-clastic deposits of the Huab Formation, comprising laminated calcareous mudstones. These sediments were deposited in a marine basin that deepened to the west, and developed as an intracontinental rift valley, similar to the East African Rift Valley of today, and was therefore the result of extensional tectonics that would eventually lead to the break-up of Gondwanaland more than 110 million years later.


Gai-as Formation

Overlying the Huab Formation is the Gai-As Formation, which was deposited in a huge lake and by the rivers that flowed into this lake, some 260 to 250 million years ago. Lake Gai-As had an extent of more than 1.5 million km^2, and was elongate in a northwest-southeast direction. It therefore was an enormous inland water body. Fine-grained mudstones are overlain by more coarse-grained gravels, sandstones and mudstones. Sedimentary structures reveal that there was appreciable wave action along the shores of the lake, and that braided rivers dewatered into the lake forming deltas. Lake Gai-As straddled a latitude of approximately 40^{o} south, and the climate was therefore warm to temperate, sub-humid and seasonal. The palaeogeographic position suggests that during the winter months strong storms occurred occasionally, and this is also obvious in the rock record through the presence of so-called tempestites. These are storm deposits, showing evidence of violent disturbance of pre-existing sedimentary structures, followed by re-depositon in shallow waters (Schneider & Marais, 2004).


Etendeka Volcanics

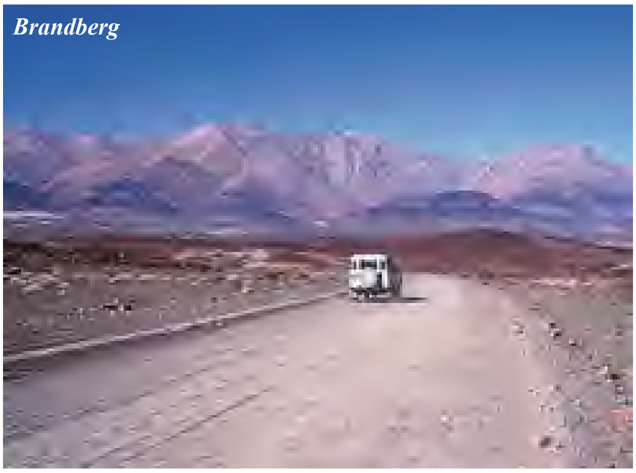
6.5 Cretaceous to Cenozoic rocks (< 135 million years)

Extensive volcanism between 180 and 130 million years ago heralded the break-up of Gondwanaland towards the end of the Jurassic and into the Cretaceous period. This volcanism was an expression of tension in the Earth’s crust, which eventually led to the break-up of Gondwanaland in the course of plate-tectonic movements. Australia, India and Madagascar separated from Africa slightly earlier than did South America, almost like a zip that opened slowly from east to west around the southern part of Africa, which explains why the volcanic rocks in Namibia decrease in age from south to north. In the proposed Geopark area the volcanic activity is represented by the extensive series of lavas of the Etendeka Plateau, as well as numerous dolerite intrusions (Schneider & Marais, 2004).

Meanwhile, severe changes of the environmental conditions during the Jurassic led to the establishment of an extremely arid climate. During the Early Cretaceous, some 133 to 132 million years ago, a major aeolian sand sea system was active across much of southern Gondwana, immediately before and during the early phases of the Etendeka volcanic activity. In Namibia, sediments deposited during this period are preserved in the Huab Basin, where they rest unconformably on Carboniferous-Permian to Triassic rocks of the Karoo Sequence. The succession starts with the fluvial conglomerates of the so-called Krone Member overlain by fluvial and aeolian sandstones, and these are, in turn, overlain by a main aeolian unit. Fossilised transverse dunes of up to 100 metres high are present and were exceptionally well preserved by the low-viscosity lava flows in the form of baked aeolian sandstones. The sedimentary structures of the dunes indicate wind transport from sources to the west of the Huab area. The topmost crests of the large dunes were not always entirely buried by the initial lava flows, and they could thus be reworked by smaller barchan dune systems to form the uppermost aeolian unit that is interbedded with the Etendeka lavas in places. However, as more and more lava covered the old dunes, the supply of sand diminished, and aeolian deposition eventually ceased completely. Today, the lava erodes more rapidly than the hard-baked sandstone, and the old dunes are once again exposed (Jerram et al., 2000).


Twyfelfontein Sandstone

Complex intrusions, such as the Brandberg for example, with ages of 137 to 130 Ma occur in a zone extending from the coast north of Swakopmund in a northeasterly direction. Some of them are extremely complex layered intrusions and contain rhyolite, granophyre, granite, syenite, foyaite, gabbro, dunite, pyroxenite and carbonatite. They are not related to any orogeny and interpretated as a result of a hot mantle plume.


Brandberg

During the Cretaceous and Tertiary, southern Africa completed its separation from the neighbouring parts of Gondwanaland. As a result of isostatic movements, the subcontinent underwent various stages of uplift and the present interior was subjected to erosion. Such isostatic uplift is most prominently visible along the edges of a continent, where erosion is most intense. Consequently, the entire southern Africa is surrounded by the Great Escarpment, and a sedimentary basin, the Kalahari Basin, has formed in the center of the subcontinent. The main sediment transport has occurred towards the Atlantic Ocean in the west. The Pleistocene glaciation in the northern hemisphere, and the associated melting of the arctic ice sheet at the end of the glaciation also resulted in climatic variations and sea level changes in the southern hemisphere. The strong long-shore drift transported much of the sediment deposited in the Atlantic Ocean northwards to form gravel- and sandy beaches at various sea levels. The sand of these beaches has been picked up by the wind and blown inland to form the sand sea and dune belts of the Namib Desert. Most of the large westerly flowing rivers have a Tertiary to recent fill consisting of fluviatile sediments as well as thick, calcrete-cemented sand and conglomerate (Schneider, 2004).

7. Geological sites in the proposed Geopark area

The area of the proposed Geopark hosts a wide variety of different geological attractions, ranging from spectacular mountains, volcanic features and sedimentary structures, to semi-precious stone occurrences and palaeontological sites. For the mineral collector, it is an area worth visiting, and it has a rich mining history. Noteworthy, geological features are readily visible , because of the sparse vegetation in the arid environment, and present themselves like a story book of the earth's history.

Geological Places of Interest

7.1 Brandberg

The Brandberg is one of the Cretaceous anorogenic complexes of northwestern Namibia, and from a spacecraft, it is one of the most eye-catching circular features visible on Earth. The isolated massif of granite, with approximate dimensions of 26 by 21 km, rises more than 2000 m above the surrounding peneplain of the Namib Desert. The edges of the roughly cupola-shaped plutonic body are dissected by numerous gorges, which penetrate the central part of the complex to form a radial drainage system. The summit, named Königstein, at 2573 m above sea level is the highest elevation in Namibia. The reddish colour of the weathered granite surfaces led to its German name "burning mountain" as well as its original Damara name "Daureb" meaning a pile of ash. The Brandberg is a National Monument, and the main access is via the road from Uis leading to the "White Lady" rock painting in the Tsisab Gorge.

The dominant plutonic rock type of the Brandberg is a medium grained biotite-hornblende granite showing little textural variation. Fine-grained enclaves near the contact are interpreted as a chilled margin facies. Segregations of a chemically evolved biotite-leucogranite locally form apophyses within the main granite. Numerous leucocratic dykes cut the granite massif and the adjacent country rocks. These dykes range in size from a few centimeters to about 3 m in width. Another plutonic variety is a coarse-grained pyroxene-bearing monzonite which is exposed in the western interior of the massif. Contact relations suggest that the monzonite is older than the biotite-hornblende granite. Quartz-hornblende porphyries occur in the central south-eastern part of the mountain. The youngest intrusive phase is a small arfvedsonite granite sill, which crops out in the Amis Valley at the southwestern edge of Brandberg. This granite carries the amphibole arfvedsonite as the main dark mineral and is highly variable in mode and texture. An indurated hematised variety forms the prominent cliffs in the inner part of the Amis Valley. Related aplitic to pegmatitic dykes intruded the biotite-hornblende granite and the marginal Karoo volcanics in an area up to 1 km distance from the contact zone.

The dominantly medium-grained granite of the main intrusion is reddish on weathered surfaces but appears gray-greenish when fresh. Fine-grained rounded enclaves of similar composition range in size from a few cm to about 50 cm and are common in the marginal facies of the granite. Miarolitic vugs filled with coarse K-feldspar or quartz are occasionally present. In hand specimen, one can observe tabular plagioclase which are often rimmed by whitish K-feldspar. Biotite and hornblende are the most abundant dark minerals. Opaque minerals are titano-magnetite and ilmenite and accessory minerals include apatite, zircon, titanite, monazite and the rare titanite variety cheffkinite. The textures and compositions of the minerals indicate that the Brandberg granite crystallized from a relatively hot and dry magma. Differentiation of the magma produced late-stage leucogranites. These contain biotite as the almost only mafic mineral, although tourmaline is also occasionally present. Macroscopically visible granophyric intergrowth of quartz and orthoclase are common in the leucogranitic dykes, which indicates crystal growth during rapid cooling.

Radiometric dating of the main Brandberg granite has yielded an age of about 130 million years. This immediately post-dates the peak volcanic activity in the Etendeka flood-basalt province, and the surrounding Goboboseb Mountains, as well as the intrusion of the Messum Complex to the southwest. Field evidence clearly indicates that the Brandberg post-dates at least the lowermost units of the Etendeka lavas.

A series of dark coloured trachydacitic ring-dykes is present to the north and northeast of the massif in the Gomatserab area. These dykes are sub-parallel to the rim of the intrusion and dip about 30° to 50° towards the center. In the uppermost reaches of the massif, few rafts of dark volcanic hornblende and quartz porphyries are preserved. These and the trachydacite ring-dykes can be related to the early volcanic phase of the Brandberg.

The surrounding country rocks of the Brandberg intrusion consist of Damaran granites and metasediments and overlying Karoo Sequence sediments and volcanics. The sediments comprise siltstones, altered to black hornfels in the contact aureole of the Brandberg, which are overlain by white, quartz-rich coarse conglomerates. They are in turn overlain by basalts capped by quartz latites. Remnants of the Karoo rocks are preserved in a collar along the western and southern margin of the massif and are down-faulted towards the contact. The angle of dip increases as the contact is approached and is near vertical at the contact, where clasts of country rocks occur within the granite forming a magmatic breccia.

A likely scenario for the genesis of the Brandberg is that heating and subsequent partial melting within the crust was triggered by emplacement of mantle-derived basaltic magma. Assimilation of crust-derived partial melts by the cooling and crystallizing basic magmas led to the formation of a hot and anhydrous hybrid granitic magma, which was capable of rising up to near-surface level.

On the way to the parking lot at the eastern edge of Brandberg, the trachydacite dykes can be seen to the north of the road, forming smooth dark hills weathered out of the older Damaran granites. Small roadside outcrops are present near the contact of the Brandberg massif. The trachydacite is a gray porphyritic rock with plagioclase phenocrysts up to 3 cm in length. The mafic mineral assemblage comprises pyroxene and hornblende, set in a fine-grained matrix of intergrown K-feldspar and quartz. Dolerite dyke swarms which cut the Damaran granites are also present close to the road. The dark, highly altered holocrystalline dolerites have a fibrous texture of plagioclase and contain relics of decomposed olivine phenocrysts. Similar dolerite dykes cutting the Brandberg granite have been described from the interior of the massif in the Tsisab Gorge and Bushman Valley (Diehl, 1990).

Tsisab Gorge

The interior of the Tsisab Gorge is filled with debris, which carries huge granite boulders up to 3 m in diameter. The higher flanks of the gorge display well exposed surfaces of granite polished by erosion. At the lower flanks, multiple stages of onion-skin weathering typical for granites can be observed.

Along the southern margin of the Brandberg along the road to the defunct Brandberg West Mine, one can find highly altered pyrophyllite bearing Karoo siltstones within the Brandberg metamorphic aureole, which are locally quarried and manufactured into ornaments.

White Lady

The archaeology of the Brandberg has been the subject of seroius research for more than 80 years. Detailed surveys of the rock art have recorded more than 1000 sites, some with a hundred or more individual paintings. Although the most famous site, the Maack or “White Lady” Shelter, has given rise to several fanciful interpretations, systematic excavations in other parts of the mountain show that the area was inhabited by hunter-gatherer communities until the first appearance of nomadic livestock farming about 1000 years ago. Small bands of hunters evidently lived in the upper parts of the mountain during the dry season, when little water or food could be obtained in the surrounding desert. The structural geology of the mountain, with its well-developed sheet-joints, provides many small aquifers, and where these emerge, rock painting sites are never far away (Axel Schmitt, Rolf Emmermann & John Kinahan *In*: Schneider, 2004).

7.2 Messum Crater

The Messum Complex of northwestern Namibia is one of a series of Cretaceous anorogenic igneous complexes and lies just to the southwest of Brandberg. Messum distinguishes itself from the other Mesozoic complexes by its highly diverse assemblage of intrusive and extrusive rocks, which in turn appear to have intruded volcanic rocks of the Goboboseb Mountains. It has a diameter of 18 km and is a multi-stage gabbro-granite-rhyolite-syenite subvolcanic ring structure. The outline of the complex in satellite photographs is roughly circular, however, on the ground, the outer contact with the Goboboseb lavas is often obscured by Cenozoic sediments. Dating of the various rock units of the Messum Complex has established an age for their emplacement of between 132 and 135 Ma (Korn & Martin, 1954; Milner et al., 1995).

The rocks of the Messum Complex can be divided into an outer series of gabbro and granite, and an inner core of syenites and rhyolitic breccia some 6 km in diameter. Two distinct ridges of basalt occur within the outer eastern and southern parts of the complex and represent the earliest subsidence phase of the intrusion. The basalts are extensively intruded by dykes and veins of granite, which contain basaltic xenoliths.

Volcanic breccias and rhyolite lava domes form the central hills of the Messum Complex. The breccias and lavas have undergone contact-metamorphism and are intruded by syenite, dolerite and granite. They are also interbedded with large quartzite bodies, interpreted as recrystallised Etjo sandstone of the Karoo Sequence, which underlies the Goboboseb volcanics. The volcanic lithologies of the central Messum Complex are interpreted as the earliest uplifted sequence in the history of the complex.

The oldest intrusions in Messum are best exposed in the eastern and southern parts of the complex and consist mainly of granite with abundant mafic inclusions and syenite. These are followed by two gabbroic intrusions, namely the eastern gabbro, which is the older of the two, and the western gabbro. The last major intrusion in Messum is formed by syenite intruding the inner core region of the complex.

The relationship between the different intrusive phases is complicated and provides evidence of extensive magma mixing, which in turn led to the development of the large number of different subordinate magmatic hybrid rocks, such as theralites, basanites and phonolites (Ewart et al., 1998). In summary, the basalts are the oldest phase and represent the subsidence stage of the intrusion. The rhyolites are fragments of a subaerial volcanic superstructure built during an early phase in the evolution of a Messum volcano. The rhyolites appear to have collapsed along a caldera margin and have been partially engulfed in the rising syenite magma. The Messum gabbros predate the alkaline rocks of the core. They were intruded by syenites, and this event was accompanied by collapse of a large fragment of the superstructure of the Messum volcano. Then followed the last stage of the intrusion represented by the syenites of the core (Harris et al., 1999).

The relationship of the Messum Complex with the surrounding Goboboseb volcanics is of particular interest. The Goboboseb Mountains are a southern remnant of the Etendeka Formation volcanics consisting of a 600 m thick sequence of quartz latites and basalts, which almost completely enclose the Messum Complex, and gently dip towards it. Field evidence and the close relationship between some of the Messum intrusives and the Goboboseb quartz latites, suggests that the Messum volcano may have been the source for some of the quartz latites. Messum might have played a prominent role as magma source during the formation of the Etendeka continental flood basalt, which is one of the largest continental flood basalt bodies in the world, covering some 78 000 km². Like the Etendeka volcanics, the Messum Complex rocks have been dated at 132 Ma (Milner & Ewart, 1989; Schneider, 2004).

7.3 Doros Crater

The Doros Crater is a differentiated igneous intrusion, situated to the northwest of the Brandberg. It can be regarded as one of the finest and best-exposed examples of a differentiated complex in Southern Africa. All the individual layers, except for the marginal phase, can be recognized from aerial photography, and it is therefore a textbook example of a layered igneous body. The Crater has the same height as the surrounding hills, but it stands out because of the dark colour of its rocks.


Doros Crator

The Doros Complex has intruded sediments of the Karoo Sequence, from which it is separated by a sharp contact. The grade of contact metamorphism associated with the intrusion is low. The complex is pear-shaped, and its longer axis measures 7 km. The outer contact of the complex dips towards the centre of the body at angles between 39° and 51°. The extreme southern extension of the complex lies practically concordant with the near horizontal Karoo beds.

All the layers of the Doros Complex are gabbroic. On the basis of mineralogical differences, seven layers can be distinguished, and have been identified as gabbro aplite, chrysotile tilaite, intrusive chrysotile tilaite, hyalosiderite gabbro, foliated hyalosiderite gabbro, foliated melagabbro and hyalosiderite melagabbro.

Two age determinations on rocks of the complex have been published, citing an age of 125 and 128 million years respectively (Hodgson, 1972).

7.4 Organ Pipes

The organ pipes, 6 km east of Twyfelfontein, are located on a short detour en route to Burnt Mountain. About 3 km after the Twyfelfontein turn-off on road 3254, and some 7 km before Burnt Mountain is reached, a small road turns off towards the east and leads to the Organ


Organ pipes

Pipes. At this locality, a dolerite sill, related to the break-up of Gondwanaland in the Early Cretaceous, has intruded Damaran metasediments and Karoo sediments. As the dolerite cooled, it developed a system of intersecting, contractional fractures termed "columnar jointing", which upon weathering, give the appearance of organ pipes, from which the locality gets its name.

Columnar jointing consists of a close-packed series of hexagonal, sometimes pentagonal or heptagonal, prisms lying perpendicular to the upper and lower surfaces of a lava flow or sill. The joints are formed during the cooling of the lava by contraction and by the resultant tensional forces acting towards a number of centers within one layer. These forces tend to pull open a series of joints, which ideally assume a hexagonal pattern, and, as cooling proceeds towards the central part of the mass, the joints develop at depth (Whitten & Brooks, 1981; Schneider, 2004).

7.5 Petrified Forest

Although the occurrence of petrified wood in rocks of the lower Karoo Sequence is not uncommon, the "Petrified Forest" 45 km west of Khorixas is the biggest accumulation of large petrified logs in southern Africa. The logs are in an excellent state of preservation and the Petrified Forest is a declared National Monument, and no samples may be taken. The logs occur at the 280 Ma old base of the Permian Ecca Group of the Karoo Sequence and have been deposited in an ancient river channel. The matrix carrying the logs is a brownish, cross-bedded sandstone.


Petrified forest

Recent erosion has exposed many of the logs and also several smaller pieces. The larger logs are up to 1.2 m in diameter and at least two trees are exposed with a full length of 45 m. Although the trunks are broken into sections 2 m and shorter, the individual segments are still in place. The trunks are straight and taper gradually. Several hundred different logs are partly or completely exposed, appearing as if they had drifted into their present position in the old river sediments. Such a drift, for example during a heavy flood event, and the associated rapid deposition and burial, provides a good explanation for the concentration of large amounts and good state of preservation of the fossilized wood.

The petrified wood pieces belong to seven different species of the collective type *Dadoxylon arberi Seward* (Kräusel, 1928; 1956). The wood has been silicified and agatized except for some parts, which are filled with calcite. The colour varies from brown with white streaks to red with light coloured streaks, and some pieces are also white. Presence of annual growth rings of varying thicknesses indicates that the trees grew in a seasonal climate with pronounced rainfall variation. Cell structures are well preserved.

Dadoxylon arberi Seward was a conifer belonging to the now extinct order *Cordaitales* of the *Gymnospermopsida* class. The woody plant formed a highly branched tree with simple, needle-like leaves. The simple pollen cones were not more than a few centimeters in length. The root system is believed to have been shallow and extending laterally for several meters (Stewart & Rothwell, 1983; Schneider, 2004).

7.6 Spitzkuppe

The Grosse and Kleine Spitzkuppe are Cretaceous anorogenic complexes, located in central western Namibia, some 40 km northwest of Usakos and north of the road to Henties Bay. Part of Grosse Spitzkuppe, also known as the Matterhorn of Africa, is a declared National Monument. It has a height of 1728 m above sea level. The complex has a diameter of some 6 km and towers more than 670 meters above the Namib plain, providing a challenge to many a rock climber. The Pontok Mountains to the immediate east also belong to the complex and attain a height of 1628 m above sea level.


Grosse Spitzkuppe

The neighbouring Kleine Spitzkuppe, situated some 15 km west of the Grosse Spitzkuppe, has a diameter of slightly more than 6 km and reaches a height of 640 meters above the surrounding peneplane, with a total height of 1584 m above sea level. However, most of the granite of Kleine Spitzkuppe occurs as low-lying micro-granite outcrops.

The Spitzkuppe granites have interesting erosional formations, sculpted by the persistent westerly winds and extreme differences between night and day temperatures. During the cooling of the granite magma, numerous joints formed due to the decrease in volume during the transition from the liquid to the solid phase. Between these joints, the granite is arranged in concentric layers according to the progressive cooling from the inside to the outside. Erosion later removed layer by layer, leaving the typical rounded granite boulders. This type of weathering is termed “onion-skin weathering” and typical of granitic rocks in subtropical regions.

The emplacement of the Spitzkuppe granites in metamorphic rocks of the Damara Sequence was part of the widespread magmatic activity in Namibia which occurred with the opening of the South Atlantic Ocean during Gondwana break-up some 130 Ma ago. Erosion of overlying country rocks led to the exposure of the Grosse and Kleine Spitzkuppe granite complexes, with the roof pendant now completely eroded away. Locally the country rocks comprise basement rocks of Damaran granite and metasediments of the Damara Orogen. The Spitzkuppe granites were preceded by a period of basaltic-rhyolitic magmatism, evident as mainly north-northeast trending dyke swarms. The emplacement of the Spitzkuppe granites into the high crust is probably due to cauldron subsidence.

The Grosse Spitzkuppe is a zoned granite complex comprising of three texturally distinct granite phases, a marginal, medium-grained biotite granite, a coarse-grained biotite granite and a central porphyritic granite. Late stage aplite and porphyry dykes, as well as lamprophyre dykes cut the granite phases of the complex. Syn-plutonic mafic dykes and mafic to intermediate magmatic enclaves within the granites demonstrate the bimodal character of magmatism. The outer contacts of the complex and the upper margins of aplite dykes are marked by banded pegmatite-aplites and fan-shaped alkali feldspar growth, which resulted from under-cooling of the magma. The presence of miarolitic cavities and pegmatite pockets are common, especially in the outer parts of the medium-grained biotite granite, in the porphyritic granite and in aplite dykes, indicative of fluid saturation during the final stages of crystallization.

The granite phases contain quartz (31-38%), alkali feldspar (30-42%) and sodic plagioclase (16-25%). Biotite typically represents less than 6% of the rock volume. Magmatic topaz is an ubiquitous minor constituent occurring as subhedral grains. Other common accessory minerals include tourmaline, beryl, fluorite, columbite, monazite, thorite, magnetite, and niobian rutile.

The Kleine Spitzkuppe complex consists of two main granite types, an equigranular medium-grained granite that forms the Kleine Spitzkuppe Mountain, and numerous low-lying outcrops of equigranular to porphyritic microgranite containing abundant miarolitic cavities and pegmatite pockets. Both granite phases are composed of quartz, alkali feldspar and sodic plagioclase, with biotite and topaz occurring as minor constituents, and columbite and beryl as accessory minerals. Minor intrusive phases include a number of flow-banded rhyolitic dykes that cut into the country rock and a few, approximately 1 m wide lamprophyre dykes occurring within the complex. The contact with the Damaran country rocks is often marked by layered marginal pegmatite from which local inhabitants mine gem quality topaz and aquamarine crystals. The “African Granite” company operates a quarry for dimension stone south of the Kleine Spitzkuppe.


Kleine Spitzkuppe

Geochemically, the granites of the Grosse and Kleine Spitzkuppe are very similar, with little compositional variation between the granite phases of each complex. According to Streckeisen’s classification of plutonic rocks, the Spitzkuppe granites can be classified as monzogranites. These granites are high in silica, subalkaline and marginally peraluminous, and are characterized by higher Si, Fe/Mg, F, Zn, Ga, Rb, Zr, Hf, Th, U, and REE (except Eu), and by lower Ca, Mg, Al, P, B, and Sr when compared to average granitic rocks. The granites of the Grosse and Kleine Spitzkuppe are interpreted to have formed by crustal remelting related to mafic underplating in a continental rift environment (Frindt & Kandara, 2004).

7.7 Burnt Mountain

At Burnt Mountain in southwestern Damaraland, a sheet of dolerite, associated with the Etendeka volcanism, intruded mudstones of the Verbrandeberg Formation, Karoo Sequence. The succession at Burnt Mountain starts with the Verbrandeberg Formation, consisting of mudstones with coal horizons and sandstone channels. The Verbrandeberg Formation is overlain by coarse fluvial sandstone of the Tsarabis Formation, followed by calcareous mudstone of the Huab Formation. Lacustrine red mudstones of the Gai-As Formation rest on the Huab Formation, and the sucession is capped by the aeolian Twyfelfontein Sandstone.


Burnt Mountain

The mudstones were originally deposited in a lacustrine environment, and therefore contained carbonaceous material derived from remnants of organisms. During contact metamorphism caused by the intrusion of the hot dolerite magma, the organic material evaporated from the sediments, leaving behind a black, clinker-like rock, mainly composed of fritted clay minerals. A secondary coating of manganese minerals adds a purple luster to the black rocks. In contrast, the sediments show all shades of white, yellow and red, and this dramatic combination of colours, coupled with the lack of vegetation, has resulted in the name “Burnt Mountain” (Jerram & Schneider, 2004).

7.8 Etendeka Plateau

The Etendeka Plateau of volcanic rocks occurs in northwestern Namibia covering a region of some 78 000 km², with the main outcrop located between Cape Cross and the area south of Sesfontein, and outliers at Gobobosebberge, Albin, Huab, Khumib and Sarusas. The volcanics of the Etendeka Group have an age of 132 Ma. They reach a maximum preserved thickness of 880 m at Tafelberg in the southeast, while the original maximum stratigraphic thickness is believed to be in excess of 2 km (Reuning & Martin, 1957). The landscape is characterised by high, table-topped mountains, which gave the area the Himba name "Etendeka", meaning place of flat-topped mountains. Rocks of the Etendeka Plateau can be correlated with the volcanics of the Paraná Basin of Brazil, together with which they formed a major igneous province in western Gondwanaland just before continental break-up. This province had an estimated original volume of up to 2 million cubic kilometers of volcanic rocks, and is one of the largest continental flood volcanic provinces in the World.


Etendeka Volcanics

Volcanics of the Etendeka Group consist of a bimodal association of mafic to intermediate

(51-59% SiO_2) tholeiitic lavas interbedded with more felsic (66-69% SiO_2) quartz latite rheoignimbrites. The basalt flows and the massive quartz latite units at higher stratigraphic levels overlie the aeolian sandstones of the Etjo Formation of the Karoo Sequence, and frequently also overstep the Karoo Sequence to rest on older, Damaran basement. The basal basalt flows are typically up to 40 m thick and are frequently intercalated with lenticular Etjo sandstone lenses, which then form conspicuous yellow bodies within the grey to reddish lavas. Quartz latites represent a significant portion of the succession, and constitute about 20% of the rock outcrop. They form widespread units between 40 and 300 m thick. Dolerite dykes and sills associated with the Etendeka Formation often intrude basement rocks, but rarely Karoo strata and the overlying volcanics.


Etendeka Volcanics

Five basaltic lava types can be geochemically distinguished, namely the Tafelberg, Albin, Khumib, Huab and Tafelkop Basalts. The Tafelberg Basalts are by far the most abundant basalt type in the main Etendeka lava field. They are interbedded with the Khumib Basalts north of Terrace Bay and become progressively rarer further north. The Huab Basalts are a very fine-grained variety. The Tafelkop Basalts occur at the base of the succession in the northern part of this volcanic province and are the only olivine-bearing basalts in the sequence.

The quartz latite units appear to represent individual flows and have features common to both lavas and ash-flow tuffs. They can be divided into basal, main and upper zones. The main zone usually constitutes over 70% of the unit and is fairly featureless. The basal and upper zones of the flow are up to 6 and 10 m thick respectively, and are characterised by flow banding, pitchstone lenses and breccias with pyroclastic textures. These characteristics enable the discrimination of individual flows. Several of the units are affected by zones of alteration resulting from hydrothermal activity and degassing within the flow shortly after deposition. These flow-top breccias are commonly mineralised by quartz, agate, zeolite and calcite.


Etendeka Volcanics

There are three main quartz latite horizons named the Goboboseb, Springbok and Tafelberg Quartz Latites. The Goboboseb Quartz Latite is the oldest, consists of three flow units and crops out along the southern margin of the lava field. The Sprinbok Quartz Latite is best developed just north of the Huab River. Its upper part is truncated by erosion and is transgressively overlain by Tafelberg Basalts (Milner et al., 1988). The Springbok Quartz Latite is composed of upper and lower members which are separated by approximately 90 m of basaltic lavas. The base of the lower member is situated approximately 150 m above the base of the Etendeka Formation, and the contact with the underlying basalt is transgressive. The upper Springbok Member has a maximum thickness of 270 m and thins out rapidly towards the north. Outcrops of the more massive upper Springbok quartz latites are characterised by large, rounded, boulder-strewn hills, which are in contrast to the typical trap-basalt outcrops of the Tafelberg volcanics. Upper and lower quartz latites of the Tafelberg succession are up to 100 m thick and are separated by some 320 m of basaltic material. The volcanics of the Tafelberg succession exhibit a classic trap morphology and individual flows with a constant thickness can be traced for many kilometres. The Tafelberg Quartz Latite forms the thick uppermost layer of the flat-topped mountains of the eastern Etendeka Plateau south of Palmwag (Milner, 1986; Schneider, 2004).

7.9 Erongo

The Erongo Complex with a diameter of approximately 35 km is one of the largest Cretaceous anorogenic complexes in northwestern Namibia. It represents the eroded core of a caldera structure with peripheral and central granitic intrusions (Emmermann, 1979; Pirajno, 1990). Surrounding the outer granitic intrusions of the Erongo Complex is a ring dyke of olivine dolerite, which locally reaches some 200 m in thickness and has a radius of 32 km. The ring dyke weathers easily and is therefore highly eroded. However, it can be easily identified on aeromagnetic data and satellite images. The best exposure is where the road from Omaruru to Uis cuts the ring dyke, about 12 km west of Omaruru. Here, one finds large, rounded blocks of the dark green or brown olivine dolerite. Compositionally similar NE striking basaltic dykes are also abundant in the vicinity of this locality. Erongo is also the locality where well-known German geologist Hans Cloos undertook his fundamental studies on granite published in his book "Gespräch mit der Erde" (Cloos, 1951).


Erongo

The central part of the Erongo complex consists of a layered sequence of volcanic rocks, which form prominent cliffs rising several hundred meters above the surrounding basement. The interior of the complex is deeply eroded, giving access to the roots of the structure. The basement rocks consist of mica schists and meta-greywackes of the Kuiseb Formation and various intrusions of granites. In the southeast, the rocks of the Erongo Complex overlie the Triassic Lions Head Formation, which consists of conglomerates, gritstone, arkose with interbedded siltstone and mudstone, and quartz arenite.

The base of the Erongo Complex consists of a series of flat-lying basaltic lava flows and interbedded pyroclastic rocks. These basal volcanics are exposed throughout the entire complex and may originally have had an even wider distribution. With some 300 m thickness, the thickest layers of the basal volcanics are located in the southeastern part of the complex. The rock compositions range from tholeiitic, fine-grained basalt and basaltic andesite to andesite. Most basalts are considerably altered and commonly amygdaloidal, with vesicles filled with calcite and chalcedony. The alteration also caused local growth of quartz, actinolite, epidote and chalcopyrite. Plagioclase is sericitised and saussuritised, and clinopyroxene is replaced partially or fully by chlorite and epidote.

The basal volcanics are followed by a sequence of felsic volcanic units, which have been subdivided by Pirajno (1990) into four phases. The first phase is characterized by minor eruptions of mafic-intermediate lavas and major ash-flow tuffs of intermediate to felsic composition. These so-called Erongorus ash-flow tuffs occur mainly in the north, the northwest and the west of the complex, but the units are absent in the east. They are generally altered and characterized by a devitrified groundmass with phenocrysts of quartz and altered K-feldspar.

The Erongorus tuffs are overlain by the Ombu ash-flow tuff sequence, which is volumetrically the main rock type of the complex and forms the most prominent cliffs. The Ombu tuffs are generally more quartz-rich than the Erongorus tuff units, but the most striking difference is that the Ombu tuffs frequently contain abundant sizable (cm- to dm) fragments of basement rocks. Compositionally, the Ombu tuff units are of rhyodacitic and rhyolitic composition.


Erongo

The next volcanic phase was an explosive eruption and intrusion of rhyolitic magmas. Rhyolites occur as erosional remnants of rheomorphic tuff at the top of the volcanic sequence, and rhyolite dykes are especially common in the northeastern part of the complex.

The final volcanic to sub-volcanic phase involved the intrusion of subvolcanic plug-like bodies of basanites, tephrites and phonolites, which intrude Erongorus tuffs at the northern edge of the complex. All rocks are under-saturated in silica having less than 5% normative nepheline. A good, and possibly the thickest exposure of the basal basalts occurs on Farm Niewoudt on the south-eastern edge of the complex. On the way to the farmhouse one passes exposures of Ombu tuff and can also see the contact between the basalts and the conglomerates of the Lions Head Formation, Karoo Sequence, and the contact between the Erongo basalt and the Ombu ash-flow tuff.

Intrusive into the basal volcanics is the Ombu granodiorite. This granodiorite body is mineralogically and geochemically very similar to the Ombu ash-flow tuff rocks and contains the same distinctive assemblage of basement xenolith fragments. The contact between the two units is gradational. Based on these observations, Emmermann (1979) concluded that the Ombu ash-flow tuff units are the erupted equivalents of the granodiorite. The Erongo granite is volumetrically the most important intrusive phase of the Erongo Complex, and is found as isolated stocks, dykes and sills around the complex. The granite is a massive, coarse-grained, equigranular leucocratic biotite granite with an average modal composition of 36% quartz, 33% perthitic orthoclase, 25% albite, 4.5% biotite and 1.5% accessory minerals (Emmermann, 1979). Finer-grained facies, aplitic dykes and rare pegmatitic pods and lenses also occur. Accessory minerals include tourmaline, beryl, zircon, monazite, fluorite, apatite and topaz. An exceptional and distinctive feature of the Erongo granite is the presence of quartz-tourmaline "nests", up to 30 cm in diameter, which occur in all facies of the granite. The "nests" consist of tourmaline, quartz, K-feldspar, plagioclase, biotite, fluorite, apatite, topaz and cassiterite. On the farms Ameib and Omandumba one can find all forms of Erongo granite. An interesting formation of Erongo granite is the group of huge boulders known as "Bull's Party" at Ameib. Rock paintings are common in the Erongo granites, and the Phillips Cave on farm Ameib is a National Monument.

Geochemical variation diagrams show that the felsic volcanic and intrusive units of the Erongo Complex can be derived from a common magma source. Emmermann (1979) suggested that the Ombu tuffs and granodiorite were derived from crustal rocks similar to those in the local basement because of their peraluminous composition, the fact that they contain cordierite, and the abundance of crustal xenoliths. New evidence in support of crustal origin comes from a radiogenic isotope study of the Ombu granodiorite and the Erongo granite (Trumbull et al., 2001). Both units cover a narrow range of values, which overlaps completely with data from Damaran metasediments and granites. However, the basaltic rocks at the base of the Erongo are geochemically distinct from the felsic units, they must therefore have a different source, and by analogy with the chemically similar Etendeka flood basalts elsewhere in Namibia, their source is thought to be the upper mantle (Wigand & Emmermann, 2004).

7.10 Vingerklip and the Ugab Terraces

Vingerklip is a prominent, 30 m-high erosional remnant on the farm Bertram 80 in the Ugab River Valley southwest of Outjo. The Ugab River, from its source east of the proposed Geopark, follows an almost direct west-southwest course to the sea and has incised a broad valley into the Early Cenozoic landsurface. The Ugab has a steep gradient and during periodical floods incises itself into older terraces. Three terrace levels are present in the valley, with the main terrace at 160 m above the present river. It rests on an Eocene surface and contains more than 100 m of sand and sandy, calcrete-cemented conglomerate, capped by calcareous sandstone. Late Cenozoic uplift resulted in a mainly erosional Lower to Middle Pleistocene terrace 30 m above the present river, followed by an Upper Pleistocene wet phase, which caused erosion below the present floodplain. Subsequently deposited sandy alluvium containing Middle Stone Age tools is at present undergoing dissection into a lowermost terrace.


Ugab Terraces

Vingerklip is a remnant of the main terrace, which is best preserved on the northern side of the valley. It consists of calcrete-cemented conglomerate and calcareous sandstone of the main terrace. Boulders in the conglomerate have been derived from Damaran schists, marbles and quartzites and pre-Damaran gneisses in the Ugab River catchment area. The intercalations of conglomerate and sandstone give an indication of the changing sedimentologial conditions in the river during the last 40 Ma. The hardness of the conglomerate and its capping, which facilitated the survival of this erosional remnant, is due to the proximity of the neighbouring dolomite ridges in the N, which yielded the carbonate matrix of the terrace capping. The less indurated valley fill on the southern side of the Ugab River has succumbed more easily to erosion. From the site of Vingerklip one has a magnificent view of the main terrace of the Ugab River (Schneider, 2004).

8. Minerals and Gemstones

The area of the proposed Geopark is the heartland of Namibia's semi-precious stone production, both by small miners, as well as through formal mining operations. In addition, a variety of mineral specimen of sought-after quality are recovered by small miners and offered at many places along the roads. If in possession of a non-exclusive prospecting lincese of the Ministry of Mines and Energy, mineral collector can also endeavour to hunt for minerals themselves.

8.1 Tourmaline

Tourmaline is one of the most valuable semi-precious stones found in Namibia, and occurs mainly in Late Pan African pegmatites. The first important gem tourmaline deposit was found before the outbreak of World War I in the mountains 3 km east of Usakos, where the Deutsche Kolonialgesellschaft was mining cassiterite from a Damaran pegmatitic rock (Bürg, 1942). It is said that a druse as big as a room was struck at a time when cassiterite operations were about to cease. The cavity was encrusted with fine, high quality, magnificently coloured tourmalines and quartz crystals. The tourmaline and quartz crystals were carefully removed from the druse and stored in several old cementbarrels, which stood for quite some time at Usakos, nobody realising their actual value. Several years elapsed before they were shipped to Hamburg in Germany, where a gem cutter form Idar Oberstein was lucky enough to discover the precious cargo and bought it very cheaply.

Tourmaline

Late Pan African tin-, lithium, beryllium- and gemstone-bearing rare metal pegmatites occur along four liner, northeast-trending belts, namely the Brandberg West-Goantagab tin belt, the Cape Cross-Uis pegmatite belt, the Nainais-Kohero pegmatite belt, the Sandamap-Erongo pegmatite belt and in the Karibib pegmatite district. Tourmalines of gem quality are often found in association with cassiterite pegmatites of the Sandamap-Erongo pegmatite belt, which stretches from the abandoned tin mine at Arandis northeast to the farm Omapjiu Süd 77 to the Otjimbojo Tin Mine in the Karibib District.

The Usakos tourmaline deposit occurs in a pegmatite swarm within the Sandamap – Erongo pegmatite belt, striking northeast to north-northeast in mica schist. The rock is studded with numerous black to bluish black tourmaline crystals, with green and bluish-green varieties confined to kaolinised cavities found within a lepidolite-rich zone. Miarolic schlieren, 0.4 to 2 m wide, located in a feldspar-quartz zone, are exceptionally rich in green to blue tourmaline. Clear, partly zoned light red to red tourmaline has been rather scarce. Numerous trenches and pits have been sunk to varying depths, ranging from less than a meter to approximately 10 m. The bulk of the current Namibian tourmaline production comes from this deposit.


Tourmaline

In the northeastern portion of the farm Sandamap 64, approximately 3 kg of green and blue tourmaline have been recovered from a pegmatite about 800 m north of the old tin workings. Dark bottle green tourmaline has been found in the northwestern corner of the farm Goabeb 63 in cassiterite bearing portions of a pegmatite. Limited quantities of transparent green and blue tourmaline of gemstone quality have been obtained from the cassiterite-bearing pegmatites on the farm Davib Ost 61 in the Karibib District, and a dark blue variety from the southwestern slope of the Erongo Mountains at Pietershill. Within the same pegmatite belt, green and bluish green crystals of tourmaline were found on the farm Ameib 60 in the Karibib District, and a blue variety on the western boundary of the farm Onguati 52. On the farm Okawayo 46, 6 kg of green, blue and rose red varieties of gem quality were extracted from pegmatites.

A tourmaline deposit is located on the farm Neu Schwaben 73 in the Karibib District. It has been worked intermittendly since its discovery in 1923. The tourmaline occurs in a prominent pegmatite which attains a maximum width of more than 200 m and forms a low ridge striking northeast for about 1 km. The pockets and cavities containing gem-quality green and blue tourmaline are found exclusively in kaolinised and greisenised streaks and replacement bodies along the core of the pegmatite. Considerable quantities of tourmaline were recovered from the alluvial overburden along the southeastern slope of the ridge. Today, the deposit is utilised by small scale miners, who have dug numerous trenches into the overburden and the pegmatite itself.


Tourmaline

Tourmalines of excellent quality have been recovered from a pegmatite in the northwestern portion of the farm Otjakatjongo some 4 km due east of the Goldkuppe in the Karibib District. The quartz core of the pegmatite, forming the crest of a hill, is commonly associated with rose red, green and blue tourmalines. Tourmaline displaying various shades of green was mined about 3 km south of the Goldkuppe. Blue and red varieties have been extracted from a prominent tourmaline pegmatite swarm on the southern portions of the farms Omapjiu Süd 77 and Omapjiu Süd II 76. Stones of gem quality have also been found within the scree alongside the pegmatite. Gem tourmaline is known to occur in the extreme northeastern part of the farm Otjimbojo Ost 48 at the Otjimbojo Tin Mine.

Rose red coloured tourmalines have been recovered from pegmatites in the immediate vicinity of the Henderson Mine southwest of Usakos. A rich tourmaline pocket was struck in a pegmatite on the farm Nudis 96 in the Karibib District, where approximately 500 kg of the mineral yielded 4 kg of gem quality. The crystals are mainly green to blue, generally small, and often badly flawed. In the northern portion of the farm Otjimbingwe 104 in the Karibib District, olive green and pink to red tourmaline has been recovered intermittently. The tourmaline is associated with smoky quartz and citrine in a pegmatite hosted by mica schist and amphibolite, which strikes for about 300 m in a northwesterly direction. Many of the crystals are large, well formed and frequently exhibit zoning of green and pink. However, much of the material is flawed and has a cloudy appearance.

The pegmatites of the Brandberg West - Goantagab tin belt, the Cape Cross – Uis pegmatite belt and the Nainais – Kohero pegmatite belt are relatively poor in precious tourmaline, although the dormant mines of Armoedsvlakte and Messum have produced tourmaline in the past. At Paukuab in the vicinity of Okombahe in Damaraland, dark green and rose coloured tourmaline are found in association with cassiterite.

Mainly green varieties occur as small crystals to the southwest of the Brandberg Complex in southern Damaraland, approximately 500 m south of where the Brandberg West road crosses the Orawab Rivier. A zoned, rare metal pegmatite is intruded along the contact of a syntectonic granite with a biotite schist of the Amis River Formation. Adjacent to the quartz core, an albitized zone and a coarse grained cleavelandite-quartz-lepidolite zone occur. Green to dark indigo tourmaline is found associated with coarse lepidolite crystals up to 3.5 cm in diameter. The tourmalines are up to 3 cm long. They have accumulated in nearby alluvial deposits, from where they are occasionally mined.

At Klein Spitzkuppe in southern Damaraland, rose, light green, green, blue green and blue tourmalines are present in a pegmatite (Schneider & Seeger,1992).

8.2 Aquamarine-Heliodore-Morganite

Aquamarine has been discovered in numerous drusy pegmatites in the Mesozoic granite of the Klein Spitzkuppe group of inselbergs. In addition to aquamarine, the drusy cavities are often lined with beautiful crystals of orthoclase, smokey quartz, topaz, beryl, phenacite, bertrandite and fluorite. Most of the aquamarine has been found embedded in a reddish to greyish clay, derived from the weathering of feldspar, and many bluish-green, well-shaped, transparent, prismatic crystals have been collected from the surface. Several shallow shafts have been sunk along the pegmatitic zones which, however, seldom exceed a thickness of a few metres.

A small amount (some 2 kg) of pale blue aquamarine has been found on the farm Neu Schwaben 73, in the Karibib District, in a pegmatite also containing rose quartz. On the farm Kawab 117, in the Omaruru District, excellent crystals of aquamarine have been obtained from quartz-rich greisen bodies in a pegmatite (Bürg, 1942).

Other occurrences of aquamarine have been reported from the farm Anibib 136, from the Brabant pegmatite in the southern portion of the Erongo Mountains, from the northwestern slope of the Kranzberg in the Omaruru District (Bürg, 1942), and from beryl bearing pegmatites on the farm Sorris Sorris 186, Damaraland.

More recently, superb mineral specimen and gemstone quality aquamarine has been recovered in the southwestern part of the Erongo Mountain. They occur in pockets the Erongo Granite and are associated with black tourmaline, albite, columbite-tantalite and fluorite. Crystals with a length of a couple of cm are not rare. The specimen are so impressive, that the occurrence has been colloquially called "The blue wonder of the Erongo"

Heliodore from the Klein Spitzkuppe has been found in closely spaced pegmatitic druses within Mesozoic granite (Bürg, 1942). The heliodore frequently occurs together with a light yellow fluorite and is mainly confined to the smaller druses, where it is associated with fine mica. It is also found intergrown with orthoclase. The largest heliodore crystals are up to 12 cm with diametres up to 5 cm. The colour varies from a deep golden yellow and light yellow through yellow green, to tints approaching aquamarine.

Huge morganite crystals, 3 m long and 1.5 m in diameter, have been found in the Etiro Pegmatite on the farm Etiro 50 in the Karibib District. The colour was good but unfortunately all of the crystals were intensely fractured and were therefore mined as common beryl (Schneider & Seeger, 1992).

8.3 Dumortierite

Bright, speckled, deep blue dumortierite is known to occur on the farm Etemba 135, to the north of the Erongo Mountains, in the western Omaruru District. It has been found only in small quantities concentrated as a streaks parallel to the selvage of a pegmatite dyke. Approximately 7 t were recovered during 1957 alone.

A bowl and an obelisk carved from Etemba dumortierite were displayed in the former museum of the Prussian Geological Survey in Berlin prior to World War II (Schneider & Seeger, 1992).

8.4 Garnet

Dark red, transparent to translucent almandine occurs in mica schist of the Kuiseb Formation in the Karibib and Swakopmund Districts. It has also been reported from pegmatites and pegmatitic granites at the Paukuap Tin Mine and from the farm Kohero West 113 in the Omaruru District and from near Usakos, on the farm Ukuib West 116.

Green garnet occurs in an area located to the immediate northwest of the Erongo Mountain on farm Tumib 20 and environs. Beautiful green demantoid has been recovered from altered impure marbles of the Otjongeama Member of the Karibib Formation, where these have undergone sufficient calc-silicate replacement. Garnet crystals are often related to brecciation zones that have opened cavities in the altered marbles.

Grossularite-Andradite has been found in small quantities together with beryl and bismuth minerals in pegmatites on the farms Davib West 62, Davib Ost 61 and Tsawisis 16 in the Karibib District. It has been used as gem material (Schneider & Seeger, 1992).

8.5 Pyrophyllite

A rock containing pyrophyllite in the Amis Schlucht on the western slopes of the Brandberg Complex is occasionally quarried. The pyrophyllite is associated with low-grade metamorphosed and acid metasomatised Karoo pelites adjacent to the peralkaline granites of the Amis Layered Complex. Pyrophyllite probably formed metasomatically during low-temperature rock-fluid interaction processes. The alteration produced a mosaic of light-coloured, angular zones within the deep reddish-brown pelites. The altered sediment consists of quartz and fine-grained, fibrous crystals of pyrophyllite, hematite and accessory tourmaline and zircon. The lighter and darker areas reflect different pyrophyllite hematite ratios and indicate a remobilisation of iron from the lighter parts. The attractive rock (“Brandberg Pyrophyllite”) is used as a carving stone. Production is very irregular (Schneider & Seeger, 1992).

8.6 Rock crystal

Rock crystal is widespread in the pegmatite areas of the Karibib, Omaruru and Swakopmund Districts, where it is generally found in miarolic cavities or pockets within pegmatites and as a constituent of quartz veins. At Klein Spitzkuppe well formed crystals have been recovered together with other gem minerals from impersistant miarolic pegmatites associated with post-Karoo granites Schneider & Seeger, 1992).

8.7 Amethyst

Bürg (1942) already mentioned a deposit of deep violet amethyst of gem quality from the Brandberg Complex. Today, extensive small scale mining operations are carried out in the Goboboseb Mountains northwest of the Brandberg, where beautiful amethyst mineral specimen, as well as facetting quality amethyst are recovered from cavities in the Etendeka volcanics. The crystals often display a multi-phase growth, with amethyst overgrown on rock crystal or smoky quartz and vice versa. Zepter quartzes are common. The crystals are particularly sought after, because they frequently contain fluid inclusions visible with the naked eye.

Several amethyst bearing quartz veins occur in Salem Granite on the farm Otjipetekera Süd 97 in the Omaruru District. Striking north, the largest vein persists for several hundred metres and varies in width from 0.3 to 1 m. The main trench has been worked for 40 m along strike to a depth of 8 m. Mostly translucent amethyst of a rather pale tint occurs as thin, impersistent bands, up to 3 cm wide, which alternate with white quartz. Towards the west on the same farm, similar but smaller amethyst-quartz veins have also been worked. Also in the Omaruru District, light violet, well-shaped crystals have been found in quartz veinlets on farm Ombuinja 11.

8.8 Smoky quartz

Smoky quartz has been found in numerous vuggy pegmatite segregations in the Mesozoic granite of Klein Spitzkuppe, where beautiful mineral specimen of smoky quartz together with amazonite occur. Smoky quartz also occurs in the Goboboseb Mountains (see 8.7).

8.9 Rose quartz

South of Uis and east of Cape Cross in the Swakopmund District, several east-striking pegmatites contain rose quartz. The dyke-like bodies are intrusive into syn- to post-tectonic Pan African muscovite-biotite granite or into metasediments of the contact zone surrounding these granites. They are composed of graphically intergrown K-feldspar and quartz, muscovite, tourmaline and accessory garnet. Rose quartz is found in pods and lenses up to several cubic metres in volume. Some 15 t of highly translucent material have been produced.

A smaller deposit is located 40 km south of the Brandberg. A dark variety of rose quartz, displaying a purple tinge in places, occurs as scattered alluvial pebbles in an area underlain by marble of the Karibib Formation southwest of Okombahe (Bürg, 1942). The rose quartz originally derives from schists of the Karibib Formation, where it forms up to 10 cm wide bodies.

Rose quartz of pale to medium colour is found on the farm Neu Schwaben 73 and Tsaobismund 85 in the Karibib District. The material from the latter farm has an attractive, slightly waxy lustre (Schneider & Seeger, 1992).

8.10 Agate

Agates pebbles associated with marine gravel beds are found at several localities along the coast from the Orange River to the Kunene River and also inland associated with Mesozoic volcanics.

North of the Ugab Rivier, agates derived from decomposed Etendeka Basalt, occur along the coast as well as inland in marine and fluvial gravel beds and in residual soil. The agates are usually small flattened and elliptical in shape, but may also be irregular and occasionally spherical. They are commonly white, grey, bluish grey, brown, reddish and yellowish brown (Schneider & Seeger, 1992).

8.11 Topaz

The first recorded topaz found in Namibia, at Klein Spitzkuppe and on the farm Ameib 60 in the Karibib District, dates back to the late 1880s, when the two localities were referred to as Keins Berge and Hauneib, respectively.


Topaz

At Klein Spitzkuppe, brilliant, colourless and transparent topaz crystals have been discovered in appreciable quantities in miarolic pegmatites within Mesozoic granite. According to Bürg (1942) bags full of loose crystals were gathered at that locality and some of them were of beautiful pale blue to bluish green colour or yellow to yellowish green. A few rare crystals of exceptional size, measuring 15 by 12 by 8 cm have been recovered, and many fine crystals from this locality have found their way to museums overseas.

Grading into pegmatite on its eastern side, a quartz blow 250 to 300 m long is reported to have contained clear, colourless topaz crystals within cavities in its central portion, as well as a yellow variety associated with the pegmatite in its eastern portion. The crystals have been described as being commonly prismatic with faces showing only very slight, if any, vertical striation. The size of the crystals recovered averaged only a few millimetres, although exceptions have been found and one crystal, embedded in quartz, measured over 5 cm.

Topaz also occurs at Gross Spitzkuppe and near the Brandberg Complex. A pale blue variety has been reported from the farm Etemba 135 and Anibib 136 in the Omaruru District. Recent topaz production has only been on an informal basis and no figures are available (Schneider & Seeger,1992).

8.12 Jeremejevite

The extremely rare aluminium borate Jeremejevite was found near Cape Cross in 1973, more than 100 years after it had first been described from the only other known occurrence so far, the Kola Peninsula, Russia. The blue, translucent crystals form elongate hexagonal crystals, and are often of gem quality. They are associated with the Cape Cross pegmatite, where they occur in pockets. More recently, spectacular Jeremejevite has also been found in the Erongo Mountain.

8.13 Zeolites

In places, the quartz latites of the Etendeka volcanics carry vugs and cavities that are rich in beautiful zeolite specimen. Many of the small miners in the area sell these mineral specimen, which show crystals up to some cm in size. While stilbite is the most common mineral, skolezite, heulandite, chabasite, prhenite and analcim do also occur.


Stilbite

9. Historical Mining

The area of the proposed Geopark is also the heartland of Namibia's tin mining, and the World's largest hard-rock tin mine in terms of reserves, albeit closed, is situated here. From the early days of the 20th century, numerous occurrences were mined for tin, together with semi-precious stones, tungsten, lithium and beryllium. Namibia's first and only "gold-rush" also took place in the proposed Geopark area. Diamonds, dimension stone and copper are other commodities that have been produced.

Dormant Mines

9.1 Tin

In Namibia, cassiterite mineralisation is mainly associated with rare metal pegmatites of various ages and composition. It is also, to a lesser extent, found associated with vein-type and replacement-type deposits. In the early days tin was worked in alluvial occurrences, althoug subsequently pegmatite mining became the more important producer, and up to 1990, Uis, the largest hard rock tin mine in the world, was still operative. The tin deposits of Namibia occur mainly in central portion of the Damara Orogen, aligned along distinct north-east-trending tin-belts. Hydrothermal vein systems and replacement units are genetically related to late Precambrian, calc-alkaline granites, or Mesozoic, intracratonic anorogenic, alkaline granites.

9.1.1 Brandberg West - Goantagab tin belt

The Brandberg West - Goantagab tin belt represents a northeast-trending zone located to the northwest of the Brandberg Complex. This zone is about 60 km long and some 25 km wide. Cassiterite occurs in both Pan African rare metal pegmatites and within vein-type/ replacement-type stockwork mineralisation. To date, the Brandberg West tin-tungsten deposit remains the only deposit to have been mined on a large scale.

The Brandberg West deposit is located in the lower Ugab River area, about 45 km west-northwest of the Brandberg Complex. Tin-tungsten mineralised quartz veins occur in north-east-trending, foliated, turbiditic metasedimentary rocks of the Zebrapütz and Brak River Formations, Lower Ugab Group, of the Damara Sequence. The country rocks consist mainly of greenschist to amphibolite facies metagreywacke, metapelite and intercalated marble bands. Tin-tungsten mineralised quartz-veins occur at the intersection of circular structures and a north-northwest trending fracture.

The mineralisation, covering an area of about 900 by 300 m, is associated with a sheeted vein system, that occurs mainly in quartz-biotite schist of the Zebrapütz Formation. There are five sets of quartz-veins of which the earliest is barren, whereas the four later vein systems contain tin-tungsten mineralisation. A sequence of alteration processes has been recognised, occasionally superimposed, but generally starting with a greisen stage, followed by quartz-sericite alteration and finally a hematite alteration stage.

The mineralised quartz veins were formed by at least 3 pulses of hydrothermal fluids, and these are reflected in different wall rock alterations. Mineralogically, the quartz veins consist of 70 to 95% quartz, with K-feldspar, tourmaline, fluorite, graphite, beryl, apatite and sulphides including pyrite, chalcopyrite, sphalerite, stannite, pyrrhotite, galena and marcasite. The oxide ore assemblage includes cassiterite, wolframite, scheelite, hematite and goethite.

It has been suggested that the Brandberg West quartz vein system is genetically related to deep-seated granitic intrusions of possibly Mesozoic age which are responsible for the greisen-type alteration and the deposition of tin-tungsten mineralisation in hydrothermal veins. Prospecting and drilling of the ore bearing veins commenced in 1945 and from 1946 to 1980 the tin and tungsten-bearing vein deposit was mined in an opencast operation. During this period 14 374 t of concentrate grading 32 to 56% tin oxide and 14.5 to 19% tungsten oxide were produced.

The Frans prospect – Gamigab – Goantagab deposits occur at the northern end of the Brandberg West-Goantagab tin belt and comprise a number of tin-tungsten and tin mineralised quartz veins and Fe-rich replacement units.The occurrence of the Kukukabis cassiterite-bearing quartz vein in biotite schist of the Amis River Formation situated about 1 mile south of the Ugab River and 5 km northwest of the Brandberg Complex has also been described. The hydrothermal vein is reported to be 60 cm wide and contains sporadic massive cassiterite crystals, up to 15 cm long.

North of the Brandberg Complex a number of stanniferous pegmatites of the De Rust pegmatite swarm have intruded into turbiditic metasediments of the Amis River Formation, Lower Ugab Group of the Southern Kaoko Zone. The De Rust pegmatite, which is the largest of the swarm, is situated 6 km west of the boundary of the farm De Rust 532 and some 2.5 km north of the Ugab River. The perfectly zoned pegmatite belongs to the group of complex, Li-rich rare metal pegmatites and is mined on a small scale for cassiterite and tantalite.

9.1.2 Cape Cross - Uis pegmatite belt

The Cape Cross - Uis pegmatite belt forms a 120 km long and up to 24 km wide, northeast-trending zone, stretching from Cape Cross towards Uis. The belt is characterised by foliated metasedimentary rocks of the Amis River Formation, Swakop Group of the Southern Kaoko zone, which host mineralised rare metal pegmatites. Pegmatites crosscutting the metasedimentary fabric are known to contain very low concentrations of tin, niobium, tantalum, and lithium. Complex pegmatites occur in three distinct swarms, namely the Uis pegmatite swarm, the Karlowa pegmatite swarm, and the Strathmore pegmatite swarm.


Uis Mine

Unzoned, coarse-grained pegmatites carrying disseminated cassiterite mineralisation belong to the important rare-metal bearing pegmatite type and have been the major source of tin in Namibia. The Uis deposit, located at the northern extremity of the Cape Cross - Uis pegmatite belt, about 28 km east of the Brandberg Complex, represents the most extensive and constantly mineralised pegmatite swarm in the belt.

Since the discovery of the deposit in 1911, both alluvial and hard rock mining of cassiterite has occurred. In 1989 the IMCOR Tin (ISCOR) opencast mine produced about 140 000 kg tin concentrate (67.5% metallic tin) per month from 85 000 tons of ore mined from eight large pegmatite bodies. ISCOR was mining a low-grade deposit, with average tin-concentrations of 1 000 to 1 500 ppm and proven reserves of 72 Million tons to a depth of 75 m. Mining was actually subeconomic, but possible, because in the light of the international embargo against South Africa at the time, Uis was almost the only source of tin for this country. However, due to the low tin price and the very low tin concentration in the deposit, the mine closed down in September 1990.

The Uis pegmatite swarm consists of a central pegmatite field of approximately 120 pegmatites, each with a northeastern to eastern strike direction, dipping 30-70º northwest. The central pegmatite swarm is accompanied by a peripheral pegmatite field of approximately 25 pegmatites, with a dominantly north-northeasterly strike and northwesterly dip. The maximum width of the pegmatites in the peripheral field is 4 m. In the central field some of the pegmatites in the vicinity of the Uis Tin Mine are exceedingly large, up to 1 km in length and some 50 m wide.

Rare metal pegmatites of the Uis type are coarse-grained, mica-bearing, quartzo-feldspathic bodies without noticeable internal zoning but with disseminated, low-grade cassiterite mineralisation. The emplacement of the pegmatites is structurally controlled by the presence of “tension gashes” in knotted schist and biotite schist of the Amis River Formation. These “tension gashes” have been identified as sinistral Riedel shears, arranged as S-shaped, en echelon fractures. They are associated with dominantly north-northeast to south-southwest striking faults and shear directions in the tensional environment of a half-graben.

Mineralogically, the Uis pegmatites consist mainly of quartz, microcline to microclino-perthite, albite and muscovite. The accessory mineral assemblage includes a variety of ore minerals such as cassiterite, minerals of the columbite-tantalite series and zircon. Li-minerals, such as petalite and amblygonite, occasionally occur in saccharoidal albite-rich, irregular replacement zones. Sporadic small amounts of subhedral spodumen, often altered, have been found in coarse-grained, red microcline-quartz rich portions of the pegmatite.

In addition to niobium/tantalum and tin oxides, the accessory mineral assemblage consists of garnet, tourmaline, beryl, galena, pyrite, amblygonite, petalite, apatite, monazite, zircon, malachite, azurite, calcite, varlamoffite, stannite and kesterite. Interpretations of the alteration and replacement processes in the Uis pegmatites conclude that cassiterite is closely related to albite and muscovite-rich replacement zones which tend to occur along late fractures in coarse-grained pegmatite. The highest concentrations of cassiterite are reported from irregular greisenised zones which dominantly consist of micaceous aggregates of green, Li-rich muscovite, quartz, albite and coarse-grained specks of black cassiterite (up to 5 cm). Secondary, fine to medium-grained, layered, greisen-type alteration is found sporadically along irregular schlieren-like bands cross-cutting and successively replacing coarse-grained quartz-microcline-albite-muscovite pegmatite.

In the K5 pegmatite, the largest body of the swarm, cassiterite not only occurs disseminated, but also as massive secondary veins in blocky microcline-perthite-quartz rich portions of the pegmatite. These veins may be to 0.5 cm thick. In thin section, the cassiterite shows intense pleochroism from light brownish-green through brown to deep reddish-brown and colour zoning is often developed. Microprobe analyses show that the dark zones are enriched in niobium/tantalum, whereas light-brown zones are composed of almost pure SnO_2. The most characteristic feature of the cassiterite from the Uis-type pegmatites, however, is the abundance of dark to opaque inclusions of various niobium/tantalum/tinoxide solid solutions which have been identified microchemically as tapiolite, ixiolite, Ta-rich columbite and wodginite. The analyses indicate that both the total composition of niobium/tantalum-pentoxide in cassiterite and also the abundance of niobium/tantalum-rich solid solutions within cassiterite grains increases from Uis towards Cape Cross. There is a general increase of independent niobium-tantalates towards the Atlantic Coast. Niobium- and tantalum-pentoxide concentrations in cassiterite (up to 2.5% Nb_2O_5 and maximum 6.4% Ta_2O_5) are highest in layered pegmatite-aplite from the Karlowa and Strathmore pegmatite fields. Cassiterite from Uis has the highest concentration of tin, with associated low tantalum and niobium values, whereas, towards the Atlantic Coast, niobium and tantalum substitution in cassiterite increases linearly with consequent decreasing tin values.

The most important by-products of tin mining are tantalum and niobium, but these are extremely difficult to recover when they occur as solid solutions in cassiterite. Recovery from the slag after smelting seems to be the only profitable process adopted to date. Minerals of the niobium-tantalum group which occur independently and as solid solutions in cassiterite, compositionally range from columbite (52% Nb_2O_5, 22% Ta_2O_5) to tapiolite (80% Ta_2O_5, 5% Nb_2O_5).

Unzoned rare metal pegmatites of the Uis-type give whole rock concentrations ranging from 200 to 1 600 ppm tin and 80 to 440 ppm niobium/tantalum, although some portions of the individual pegmatites at Strathmore and Uis contain up to 0.3% (Uis) to 2.5% (Strathmore) tin. “Layered” pegmatite-aplite (Hoffmann pegmatite) has the highest tin, tantalum and niobium concentration reaching up to 3.5% tin, 800 ppm tantalum and 500 ppm niobium.

Pegmatites belonging to the Karlowa swarm occur in two pegmatite fields in the central portion of the Cape Cross - Uis pegmatite belt, some 30 km south of the Brandberg complex. Most of the Karlowa swarm pegmatites are characterised by the occurrence of lithium minerals, although some pegmatites are of the unzoned Uis type. The Hoffmann pegmatite (HP 4) body belongs to the southern pegmatite field of the Karlowa swarm. In the past, the pegmatite has been worked to a depth of 3 m. Up to 1990 it was mined on a small scale, with the cassiterite-rich layers being hand crushed and sold to the Uis tin mine.

The Strathmore pegmatite swarm is located about 28 km east of Cape Cross and some 40 km northwest of Henties Bay. It consists of over 180 rare metal pegmatites which have intruded metasedimentary rocks of the Amis River Formation, of the Swakop Group. Both unzoned, mainly cassiterite-bearing pegmatites of the Uis type, and zoned lithium-rich, tin-niobium-tantalum pegmatites are present. Both pegmatite types have been mined for tin-niobium-tantalum and lithium-beryllium minerals at Strathmore (1980-1983) and at the Petalite Pegmatite (1961-1972).

The Petalite Pegmatite, or Molopo Mine, is the largest pegmatite within the central portion of the Strathmore pegmatite swarm and between 1966 and 1971, was mined for niobium-tantalum, cassiterite, lithium and beryllium minerals and book-mica. However, due to the lack of water and the fact that there was no final recovery section of the plant, no tin concentrate has ever been produced.

9.1.3 Nainais - Kohero pegmatite belt

The Nainais - Kohero pegmatite belt contains both zoned and unzoned cassiterite-bearing rare metal pegmatites. These pegmatites occur in a narrow, northeast-trending belt, up to 8 km wide and some 45 km long, which runs parallel to the Omaruru River. In the Nainais area cassiterite has been recovered from alluvial placer deposits along the Omaruru River bed and was later mined from rare metal bearing pegmatites. The cassiterite-bearing dykes cut obliquely across the “strike dykes” emplaced parallel to the northeast foliation of the schistose country rock. The richest “strike dyke” was worked at the “Quartz Kuppe” shaft, which was sunk close to the massive quartz core of a pegmatite body. The intermediate zone around the quartz core was mined for cassiterite, which occurs in a fine-grained quartz-albite rock with locally abundant tourmaline and small nests of albite-muscovite greisen.

The mined material assayed 0.91% tin. Most of the fine-grained cassiterite from the "layered aplite" replacement unit remained untouched during the early mining operations as its recovery was impossible at that time, and production ceased in 1945. Larger scale mining operations in the Nainais area resumed in 1979 (Tin Tan) but came to a close in 1986 due to the crash of the international tin price.


Historical Tin Processing

The Etemba pegmatites occur 1 to 2 km west of Nainais, some 2 km north of the Omaruru River. Extensive mining of a composite dyke situated to the east of the beacon common to the Etemba claims 3, 4 and 8, has resulted in a large cutting along the strike in which the two pegmatites are exposed.

The Nomgams pegmatite is exposed along a vertical cliff on the west bank of the Omaruru River at a bend in the river bed near the Otombawe waterhole. A plant with a capacity of 2 t/h operated at Nomgams in the 1930s. A concentrate with 70% tin was recovered. Situated on the northern bank of the Omaruru River, the cassiterite-bearing pegmatites of the Zinnwald I claim at one time constituted the most important tin mining operation in the "Central Tin Belt". The Humdigams pegmatites are characterised by their variable tin contents. Some well greisenised pegmatites have proved up to 8% tin whereas in other greisenised pegmatites cassiterite was found to be almost absent. A plant with a capacity of 10 t/h recovered a concentrate grading 68 to 73% tin up to 1945.

The Ganschow pegmatite swarm is situated 2 km northeast of Humdigams, near Tsomtsaub. Cassiterite has been recovered mostly from layered greisen replacement bodies which parallel the wall zone of the pegmatites. The Tsomtsaub pegmatite is situated some 3 km northeast of the Ganschow pegmatite, to the south of the Uis-Omaruru road. To the north and northeast of the Tsomtsaub pegmatite, the occurrence of quartz veins carrying ruby-red to yellowish and white cassiterite crystals has been reported, in sharp contrast to almost black cassiterite from the pegmatites.

The first tin occurrences in Namibia were discovered in Paukuab pegmatites. The Paukuab pegmatite swarm is situated 2.8 km north of the Omaruru-Uis road and consists of various cassiterite-bearing pegmatites. Cassiterite mineralisation is very erratic and only the Waldron pegmatite had sufficient mineralisation to be mined earlier in the last century. A concentrate grading 72% tin was produced by hand-sorting in the 1930s.

The Thelma pegmatite swarm consists of a set of parallel dykes striking northeast and dipping southeast. On the farm Okombahe 112, just south of the Uis-Omaruru road, a pegmatite, 1 km long and 1.5 m wide, has been explored for cassiterite by means of several shafts. On the farm Kohero 113, just 5 km north of the Uis-Omaruru road, over 250 t of cassiterite concentrate averaging 68% tin were produced by the Kohero Tin Mine before and shortly after the First World War. Cassiterite-bearing pegmatites intrusive into biotite schist and occasionally into marble have been reported from the farms Kompaneno 104 and Tjirundo 91, about 25 km northwest of Omaruru. Pegmatites hosted by marble and characterised by the occurrence of skarn-like massive tin oxide mineralisation have been reported from the farm Kompaneno 104. The pegmatite at the Crystal Tin Mine consists of quartzo-feldspathic rock which occasionally carries cassiterite. In one working, a 12-cm-wide band of massive cassiterite containing some 10 t of tin was extracted. Up to 1938, 28 t of high-grade tin concentrates were produced from the pegmatites, while 20 t of concentrate originated from the secondary, alluvial occurrences in the area.

9.1.4 Sandamap - Erongo pegmatite belt

Located on the farm Sandamap North 115, the Sandamap pegmatites are highly fractionated, zoned rare metal pegmatites. Along the contact between the intermediate and core zones, cassiterite occurs within greisenised portions (average grade 0.1% tin). The major replacement zone around the core is 1 to 2 m wide and locally consists of massive lithium-muscovite greisen with large lumps of cassiterite. The accessory mineral assemblage includes triplite, lithiophyllite and columbite-tantalite. Other cassiterite-bearing pegmatites occur at Cameron, Sidney and Borna.

The main workings of the old Carsie mine are situated in the central portion of the farm Davib Ost 61, north of the Davib River. A massive cassiterite lens of 235 kg, accompanied by columbite, wolframite, monazite and molybdenite was recovered from this locality. A number of unzoned, coarse-grained, quartzo-feldspathic pegmatites also occur along the western slopes of the Erongo Mountains on the farm Erongorus 166.

Cassiterite was first found in the Erongo area in 1910 on the farm Ameib 60, and subsequent prospecting and mining was generally confined to the northwestern and central portions of this farm. It is reported that alluvial tin was found in considerable quantities. After the exhaustion of the alluvial deposit, tin was recovered from a 30 m deep shaft. Cassiterite-bearing pegmatites intrusive into Pan African granite occur on the farm Brabant 68, on the southern slope of the Erongo complex. Cassiterite has been recovered from greisenised bands and pockets in the pegmatites, which are locally enriched in schörl and fluorapatite. In addition, appreciable quantities of eluvial cassiterite have been recovered from the sandy beds of dry river courses.

9.1.5 Tin deposits associated with Mesozoic anorogenic granites of the Damaraland Alkaline Province

Cassiterite occurrences genetically related to introcratonic granitic ring complexes have been reported from Klein Spitzkuppe, from Erongo and from Brandberg. All three complexes are situated in the central portion of the Damara Orogen. The presence of tin mineralisation within anorogenic ring complexes illustrates that in the Damara Province tin mineralisation may occur within more than one geological episode and under different geochemical conditions. Furthermore, it can be demonstrated that the central Damara Orogen is a tin-rich province.

Along the western slope of the Klein Spitzkuppe, about 5 km east of Brusius' camp, a gossanous zone in the Klein Spitzkuppe granite has been reported. Cassiterite occurrences are limited to vuggy, quartzose rock of the oxidation zone and are absent in the zone of supergene sulphides. Well-formed crystals of cassiterite occur together with malachite, chrysocolla, limonite, shattuckite, scorodite and chenevixite. The quartzose rock locally contains abundant crystals of tourmaline, sericite and tiny veins and fissures of hydrated copper compounds. The ore mineral assemblage of the supergene zone includes arsenopyrite, covellite and chalcocite. An occurrence of ruby-red cassiterite has also been reported from the eastern slopes of the Klein Spitzkuppe.

Occurrences of cassiterite genetically related to the Erongo granite has been reported from Kranzberg, Omaruru Townlands 85 and the farm Pistelwitz 128, and from nodular tourmaline segregations in the Erongo granite. In the tourmalinised Erongo breccia, on the steep northern cliff of the Kranzberg, a series of joints, of about 0.5 m wide and striking 6º northwest, contain cassiterite as well as wolframite mineralisation. The ore minerals are associated with a vuggy portion in the tourmalinised zone. In addition to coatings of opal, the cavity fill consists of quartz, tourmaline, beryl, fluorite, cassiterite and yellowish hydrocassiterite (varlamoffite). On the southern slope of the Kranzberg, and about 1 100 m southeast of the mountain, volcanic breccia pipes with disseminated cassiterite mineralisation have been reported, and the pipe on the slopes of the mountain contains a peripheral zone, rich in coarsely crystalline, ruby-red cassiterite. A number of cassiterite-bearing quartz-tourmaline veins occur some 4.5 and 5.8 km northwest of the Kranzberg respectively on the farm Pistelwitz 128 and have been mined for cassiterite. The veins are intrusive into Pan African granite and consist of bands of massive tourmaline and brownish-grey quartzose rocks bounded on both sides by dark, tourmaline-rich rock, up to 0.2 m wide. Cassiterite is found in the quartz-tourmaline and tourmaline-rich portions of the veins.

High concentrations of tin, zinc and other rare metals are known to be associated with silica-oversaturated, peralkaline fenites along the southwestern periphery of the Brandberg Alkaline Complex. Pyrochlore/REE mineralised aegirine-arfvedsonite bearing rocks of the Amis Layered Complex contain whole rock concentrations of up to 1 600 ppm tin and 1 800 ppm zinc. There is evidence that post-magmatic fluid phases, similar to fenitising fluids associated with carbonatites, introduced sufficient quantities of trace elements, enabling tin and zinc to enter the lattice of subsolidus minerals in a highly peralkaline environment (Diehl, 1992a).

9.2 Gold

The 1917 discovery of the Ondundu hydrothermal gold deposits 90 km northwest of Omaruru in the Otjihorongo area marked the first, and only, true Namibian "gold rush". The bulk of the production came from alluvial and eluvial workings during the first production period from 1922 to 1927. Limited underground mining was carried out where free-milling oxidized ore was encountered. Up until 1945, the total production of the Ondundu deposits amounted to 617.5 kg of unrefined and later refined gold. No production took place from 1946 to 1961. Production finally ceased in 1963. More recent prospecting activities took place from 1984 to 1990, and currently the area is under license once again.

Gold-bearing quartz veins are confined to an area of some 10 km^2. The country rocks comprise impure phyllite and quartz-feldspar-mica schist of the Swakop Group, Kuiseb Formation. These are folded into tight synclines and anticlines. The veins are parallel to the bedding planes of the metasediments and range in width from about 2 to 60 cm, with individual shoots reaching lengths of 100 m on average. Two distinct generations of quartz veins are developed. The older is by far the most frequent. It consists of greasy grey quartz, similar to gold bearing quartz veins throughout the World. The younger type is usually barren or carries only traces of gold. The gold mineralisation is confined to the quartz veins, which also contain pyrite, arsenopyrite and subordinate chalcopyrite, siderite, marcasite, argentiferous galena, auriferous metallic copper and manganese. The gold carries approximately 3% silver (Hirsch & Genis, 1992).

Gold has been known on Sandamap 64, 32 km west of Usakos, since the 1930s. More recently small gossanous stockworks of fold-related quartz veins in schist were found to be auriferous. A few minute specks of gold were also found in the mineralised greisenised selvages of a pegmatite vein in the Paukuab/Baukwab area, 67 km west of Omaruru (Haughton *et al.,* 1939). On Tjirundo Süd 149, 30 km north-northwest of Omaruru, Haughton *et al.* (1939) noted small, scattered specks of gold in vein-quartz reef in grey tourmaline granite with visible gold occurring in limonite-rich cavities.

9.3 Lithium-Beryllium

The pegmatitic deposits of lithium and beryllium minerals in Namibia occur mainly in the Karibib - Usakos pegmatite district. The lithium minerals mined in this area in the past, include petalite, amblygonite, montebrasite, spodumene and lepidolite. Spodumene and eucryptite are associated with some rare metal pegmatites within the Cape Cross - Uis pegmatite belt. Most beryl has been produced from zoned rare metal pegmatites in the Karibib-Usakos Districts, almost all pegmatites in the area are associated with some form of lithium and beryllium minerlisation.

The Etiro pegmatite is located about 20 km north of Karibib, on the farm Etiro 50, and is the largest pegmatite of the Etiro pegmatite swarm. The steeply-dipping body is some 850 m long and between 4 m and 28 m wide. The pegmatite belongs to the group of lithium-beryllium rare metal pegmatites and shows well-developed internal zonation. The fine- to medium-grained wall zone is composed of quartz, microcline-perthite, biotite, muscovite, schorl, albite and apatite. The wall zone grades into an intermediate zone (0.3 to 5m wide) consisting of albite, quartz, microclineperthite, euhedral pink beryl, apatite and schorl, with accessory topaz, columbite-tantalite and monazite. Cleavelandite and saccharoidal albite-rich portions occur mainly in pockets in the vicinity of the quartz core and are commonly associated with subhedral to euhedral beryl. Topaz and columbite-tantalite are also found within muscovite-bearing veins and pockets. Microcline-perthite and quartz are the main constituents of the core zone. Accessory minerals along the contact between the inner intermediate zone and the core include apatite, columbite-tantalite, amblygonite, triplite, bismuth minerals, tourmaline, brazilianite, morinite and eosphorite. Lepidolite from the same zone shows high lithium concentrations of 4.4 to 6.98% Li_2O (Diehl, 1992b).

The Molopo Mine is the largest pegmatite within the central portion of the Strathmore pegmatite swarm and was mined for niobium-tantalum, cassiterite, lithium and beryllium minerals and book-mica from 1961 to 1972 (see 9.1.2). Lithium mineralisation occurs as blocky masses of white, altered petalite along the margin of the core in the southern and northern portions of the pegmatite. The petalite is partly replaced by nodular aggregates of porcellaneous eucryptite, albite and radially oriented aggregates of tourmaline. About 12 t of lithium minerals and 2.5 t of beryl were recovered in 1961 and 1962 (Diehl, 1992b). Northwest of the Okombahe settlement, euhedral, greyish-green beryl crystals are associated with the greisenised inner intermediate zone around the quartz core of a pegmatite.

In the vicinity of the Kleine Spitzkuppe, aquamarine and topaz have been found in cavities and pockets in pegmatites within Mesozoic A-type granite. In the course of extracting semi-precious stones, small quantities of common beryl were also recovered (see 8.2). During exploration for tungsten mineralisation in the Krantzberg area, several vugs and cavities containing pale green to white crystals of beryl were discovered. The beryl is associated with fluorite and quartz. In the valley below the Krantzberg mountain, a fluorite-quartz-beryl-mineralised vein was reported. Although beryl constituted about 40% of the rock, the vein petered out at a depth of 1.2 m (Diehl, 1992b)

9.4 Copper

The Ondundu prospect is situated 40 km north of Omatjette in Damaraland. It was probably discovered and opened up during exploration of the Ondundu Gold Field which is located a few kilometres to the south. The area is underlain by mica schist within intercalated quartzite beds of the Kuiseb Formation. The strata are folded into a southward-plunging anticline in which several steep copper-bearing quartz veins have been emplaced along joints striking east. The veins are spaced about one metre apart and range between 10 and 60 cm in width. At the southern workings, a strike length of 500 m has been proved; a similar reach holds for the northern workings. Old shafts indicate that mineralisation extends to a depth of at least 24 m. The quartz veins contain malachite, chrysocolla, bornite, chalcopyrite, pyrite, hematite, limonite and ankerite, while the country rock is also impregnated with malachite. During 1960 the Ondundu Copper Co. recovered 197 t of hand-picked ore with a copper content of 15 to 20% from the southern workings. In October 1962 6.3 t of concentrates (70% copper) were reportedly produced by means of a leaching process.

Several quartz-copper veins cutting gneiss and schist of the Huab Complex in the Copper Valley area have been explored and intermittently worked on a small scale. The discontinuous quartz lenses with sporadic concentrations of galena, chalcocite and native gold appear to be confined to subsidiary faults and shear zones in which the original rock is locally altered to chlorite-sericite schist, talc, brown carbonate and epidote. The Copper valley prospect is situated on the north-western portion of farm Mesopotamie 504, some 65 km north-west of Khorixas. Prior to 1924, six trenches wre opened up in a group of copper-bearing quartz veins. During the period 1950 to 1952, more than 1 000 t of hand-cobbed ore grading 20 to 30% copper were produced by opencast mining. An ore sample from one of the copper occurrences on Mesopotamie contains a surprising variety of minerals. The include native copper, cuprite, chalcocite, malachite, azurite, chrysocolla, plancheite, a very rare black mineral with a spinel-type structure, a yellowish-green mineral close to calciovolborthite, native bismuth, bismite, bismuthite, beyerite, clinobisvanite, namibite, galena, scheelite, cupro-tungstite, iodagyrite and embolite.

In the southeastern portion of the farm Onguati 52, 15 km north-northwest of Karibib, copper mining started in July 1950, and stopped again in May 1953. About 150 t of hand-sorted ore was produced during this period. In 1960 the mine produced 319 t of hand-sorted ore before closing down again at the end of 1963. The grade averaged 20% copper and 71.8 g/t silver. During 1961 the deposit was reinvestigated by geophysical surveys and six diamond drill holes totalling 307.5 m. In April 1972 operations were resumed and the mine was active until the end of April 1977. The total production amounts to 3 404 t of concentrate averaging 19 to 22% copper, which was sent to Nababeep for smelting.

The ore, capped by gossan, occurs as gashveins of quartz, 2 to 60 cm wide, in a local fold in marble of the Karibib Formation. The veins are confined to the axial plane of an anticline plunging west-southwest. They are distributed en echelon in swarms, pinch and swell, dip steeply and vary in length from 6 to 60 m. The ore consists of malachite, chrysocolla, chalcopyrite, pyrite and chalcocite. The bulk of the gossan is hematite which replaces chalcopyrite and is locally altered to finely laminated jasper. An increase in the copper content with depth was proved by diamond drilling. The main adit follows the mineralised zone for some 60 m along strike, while underground workings reached a depth of 130 m below collar (Schneider, 1992).

9.5 Tungsten

Like many high-level granites, the Erongo granite is associated with mineralisation. Tourmalinisation is widespread and greisen-type tungsten, tin, fluorite and beryllium mineralisation is found locally. By far the most important mineral deposit is the Krantzberg tungsten deposit near the northeastern margin of the complex. The Krantzberg Mine was a major tungsten producer in Namibia and it is estimated that approximately 1 million tons of ore were extracted before closure in 1980 for economic reasons. Ferberite, fluorite, cassiterite, beryl, as well as molybdenum-, iron- and copper-sulphides are common ore minerals at Krantzberg. This mineralisation appears in replacement-type greisen rocks and quartz-tourmaline breccias. The mineralisation took place when boron- and fluorine-rich hydrothermal fluids induced extensive selective replacement of pre-existing Damaran granites by quartz, sericite, topaz and tourmaline. The formation of the hydrothermal fluids has been connected with the emplacement of the Erongo granite (Pirajno & Schlögl, 1987; Pirajno, 1990).

The Brandberg West Mine has been exploited for tin and tungsten (see 9.1.1). Wolframite-scheelite mineralised veins are reported from the Paukuab area situated about 2.8 km north of the Omaruru-Uis road and a few kilometres north of the Okombahe settlement in Damaraland. The quartz veins occur together with cassiterite-bearing rare metal pegmatites (see 9.1.2) hosted by biotite schist of the Kuiseb Formation. The Paukuab quartz veins form lenticular, highly irregular veins that consist of quartz, feldspar, tourmaline together with accessory, patchily distributed woframite, scheelite and copper and iron sulphides. A total of 11.3 t of wolframite-scheelite was produced during 1937 and 1938.

On the farm Okarundu Nord West 118, south of the Kohero pegmatite swarm, a number of narrow (up to 4 cm wide) tourmalinised quartz veins carry accessory wolframite and scheelite. The tourmalinisation occurs preferentially along the selvages of the veins. Tungsten ore occurs partly in tourmaline and partly in quartz-rich portions of the veins. Accessory minerals are iron and copper sulphides together with native bismuth and its oxidation products. A total of 0.82 t of wolframite-scheelite concentrate was produced in 1936 (Diehl, 1992c).


Historical Dimension Stone Quarry

9.6 Dimension stone

The area between Usakos, Karibib and the Swakop River is known for vast occurrences of marbles of the Karibib Formation, Swakop Group, Damara Sequence. Near Karibib, large reserves of white, reddish, brownish-yellowish and grey marble of dimension stone quality are present. The rocks are either unicoloured or banded, folded, flamed or brecciated.

The first attempts to quarry Karibib marble date back to the early years of the century when the "Koloniale Marmorsyndikat" was founded. In 1912 the mining rights were handed over to the "Afrika-Marmor-Kolonialgesellschaft" and several quarries, such as the Dernburg Hill quarry and the Capra Hill- or Town quarry were subsequently opened up. A couple of hundred tons of high-quality marble were produced and shipped to Germany. With the outbreak of World War I, production stopped. After World War I, marble was mined on a small scale by various companies, but no large-scale quarrying took place until recently (Diehl, 1992d).


Historical Dimension Stone Transport

9.7 Diamonds

Namibia is renowned for the quality and quantity of gem diamonds produced from marine terrace gravels along its barren desert coast. Since their discovery people have been amazed by their occurrence, which caused Wagner (1914) to state: "For that in the wildest parts of one of the most desolate and useless tracts of land which the earth can show, bare surfaces of rock should in places be as thickly studded with lustreous gems as are the show cases of a jeweller's window, surely puts to shame even the celebrated legend of Sindbad the Sailor. It is almost as if Nature, conscious of her injustice to this portion of the African Continent, had added the diamonds as an afterthought by way of making amends".

The Namibian diamond deposits occur along the Atlantic coast. Although ranging from late Cretaceous to Quaternary in age, the main deposits are Pleistocene and younger. Though the legendary wealth of the diamond deposits stems from a few fabulously rich surface concentrations stumbled across during the first few months after the initial discovery at the start of the last century, the bulk of the deposit has a much lower grade. The diamond industry has been the single most important source of income in Namibia, due to the size of the ore body - in excess of 400 million t.

The first account of diamonds along the Skeleton coast was made in 1910 when a land surveyor of the German Schutztruppe allegedly found a 2.5 carat diamond at Cape Cross. An extensive investigation of the beach gravels between Swakopmund and the Kunene River mouth was undertaken between 1943 and 1947. Trenches were dug every 400 m at right angles to the coast wherever gravels were found. Some 2354 diamonds weighing 295.4 carats were recovered during these prospecting operations. The best areas were those called Huab South and Huab North, Terrace Bay and the so-called prospects 58 and 59, although grades in these areas were low. It is interesting to note that no diamonds were found south of the Ugab River. Only isolated deposits are present between the Sechomib River mouth, the northernmost occurrence, and the Hoanib River.


Diamond

Remnants of two main raised marine terraces occur frequently along the Skeleton Coast. The lower occupies a position about 3 to 5 m above sea level, whereas the upper is between 8 and 10 m above sea level. Very few diamonds have been recovered from the lower terrace, but stretches of the upper terrace are diamond-bearing. A few remnants of raised marine terraces occur at elevations of 15 and 23 m above sea level, but none of these has yielded diamonds. The best development of the upper of the two main terraces extends from about 13 km north of the Uniab River mouth to 8 km south of the Hoanib River mouth. It only extends some 6.5 km north of the Hoanib.

At Toscanini three terraces occur. The middle one is diamondiferous. The diamonds are concentrated in that part of the terrace where weathered and fragmented boulders are slightly submerged. Grades of up to 26 carats/100 t occur here. In 1962/63, 405.84 carats of diamonds were recovered. In 1972, a new recovery plant was erected at Toscanini; however, not a single diamond was recovered (Schneider & Miller, 1992).

10. Current Mining and Exploration

Today, Namibia features amongst the most important mining countries in sub-Saharan Africa, and a substantial portion of her GDP is produced through mining. The area of the proposed Geopark includes a number of current mining operations, which could also be of interest for the visitor.

Current Mining Operations

10.1 Navachab

Following an exploration agreement between Anglo American Prospecting Services Namibia and Randgold in March 1982, the Navachab gold deposit was discovered in October 1984 during a base metal geochemical followup programme 10 km southwest of Karibib. Small gossan fragments collected from the site returned assay values of up to 11 g/t gold. Exploration drilling began the following year. A total of 14 721 m of diamond drilling (164 holes) and 2 930 m of reverse-circulation drilling (56 holes) was completed. An appraisal in 1986 was followed by a feasibility study in 1987, after which a decision was made to proceed with the development of the mine. Construction work began in 1988 and the first bar of gold was poured in December 1989.

The Navachab Gold Mine is now a wholly owned subsidiary of Erongo Mining & Exploration Limited, an Anglo Gold Ashanti Ltd owned company. The opencast operation was brought into production at a cost of N$ 85 million. Currently, full production of 1.3 Mt of ore per year is mined at a grade of 2.56 g/t gold. Approximately 2 650 kg of gold is produced each year.

The gold deposits are associated with northwest–southeast trending strike-slip fault systems and associated subsidiary splays. Footwall rocks are Nosib Formation quartzites and arkoses and Chuos Formation mixtites that occur on the south-eastern edge of the mining area. Spes Bona Member biotite schists, interbedded with para-amphibolites and scattered marble lenses, form the immediate footwall. Abundant syngenetic pyrrhotite, and to a lesser extent pyrite, is present in the footwall rock types.


Navachab Open Cast

The Okawayo Member that hosts the main orebody locally consists of a 35-m-thick banded calc-silicate marble at the base (MC unit), a 5-m-thick amphibolite (MDMV unit), a 50-m-thick marble (M unit) and a 35-m-thick mottled dolomitic marble (DM unit) at the top. The metasediments strike northeast–southwest and dip 70° to the northwest, plunging 22°N. The Oberwasser Member interbedded siliclastic and metamorphosed volcanoclastic rocks immediately overlie the Okawayo Member carbonate unit.

The footwall sequence and base of the Okawayo Member are intruded by numerous steeply dipping, northwest–southeast striking equigranular aplite and pegmatite dykes.

The marble-hosted gold-skarn mineralisation is related to multistage mineralisation. Some 800 m northeast of the main orebody, greisen and pegmatites are localised around a late-stage, bismuth-, fluorite- and boron-rich diorite, which is interpreted to be a possible heat source for the final concentration of the low-grade gold mineralisation.

The bulk of the gold is present in fractures along grain boundaries in the calc-silicate minerals, accompanied by very fine quartz. Rare coarse gold is contained in a quartz-rich calcite-biotite gangue. Native gold accounts for more than 85% of the total gold, with most of the reminder occurring as maldonite (Au_2Bi). The gold to silver ratio is approximately 15:1. Sulphides, mainly pyrrhotite with accessory pyrite, minor chalcopyrite and sphalerite are locally abundant and even massive. Scheelite is occasionally associated with the sulphides. The sulphides do not host gold mineralisation although they are often in close proximity.

None of the minor minerals is present in sufficient quantity to warrant recovery and, as far as is known, do not interfere in gold extraction.

Blocks of ground of about 30 000 t are selected as blasthole batches that are designed not to cross over geological or obvious ore/waste boundaries. Mining of 4.5 Mt per year is done in two 9-hour shifts per day, weekdays only. Blasting of benches to the required size of 700 mm is done using slurry explosives. A computerised grade control system is used to monitor samples taken from the blastholes. Roughly 10 000 samples per month are analysed in the Navachab laboratory, which has a two-day turn-around. Selective mining is practised, with ore and waste blocks delineated after each blast and before removal to various stockpiles and waste dumps. The marginal ore is stockpiled. All ore with grades higher than 0.6 g/t is also stockpiled according to rock type.

Gold pouring at Navachab

The primary crusher situated at the stockpile area reduces the ore to minus 200 mm. The ore is then transported to the plant by a 1-km-long conveyor where it is stored in a 3 500 ton silo. A carbon-in-pulp process is used to recover the gold from 110 000 t of ore per month. Approximately 90% of the gold is recovered, that contained within the maldonite being unresponsive to cyanidisation. The bulk liberation size of the gold is 5 to 10 mm. The ore is milled to about 78% passing 74 mm. Critical-size pebbles are removed from the mill load and crushed before being returned to the mill feed. The slurry is thickened before being passed through seven leach tanks where it is agitated in a cyanide solution to dissolve the gold. The slurry is then mixed with granular activated carbon, which adsorbs the gold, in a further series of tanks. The gold-loaded carbon is separated from the pulp solution and pumped into elution columns. Here it is washed in acid prior to the gold being desorbed by contact with a hot alkaline cyanide solution containing 3% NaCN and 4% NaOH. The dissolved gold is washed from the carbon with hot water.

The pregnant solution is recirculated through two electrowinning cells, operated at approximately 6 V and 18 to 20 A. The gold is deposited on steelwool cathodes. The goldbearing steelwool passes into a calcining furnace and the calcined gold is then smelted and cast into 22-kg bars, 90% pure. The gold is exported to Switzerland for refining. Approximately 7% silver is recovered as a byproduct on refining Burnett, 1992).

10.2 Cape Cross Salt

In Namibia, salt is produced by solar evaporation operations in coastal pans. Numerous such pans are scattered along the west coast from the Orange River in the south to the Kunene River in the north. Pans elongated parallel to the coast and situated near the high water mark range in size from less than 10 000 m² to over 60 km²; more than 30 are larger than 70 000 m². The pans are commonly separated from the sea by sand or rocky bars or a combination thereof. Because the west coast is an emerging shoreline affected by the Benguela

Current flowing northwards, sandspits grow northwards from headlands across embayments, giving rise to lagoons. The lagoons become silted up with sediments supplied by the sea and wind, and occasionally by torrential rivers as well as by salt precipitated by solar evaporation. The pans thus formed usually have a brown, virtually flat surface, generally situated only a few centimetres to one metre above mean sea level. Brine in the pans is replenished by sea water washing in during spring tides or percolating through the sand bars. In some pans tidal fluctuations also have an effect on the brine level.

Covering an area of about 41 km², the Cape Cross Salt pan is located some 130 km north of Swakopmund. Part of the pan is held under claim, but not all of this is productive. Most of the claims are situated in the eastern half of the pan where the increase in salinity of the brine is 25%, compared to 9% in the lagoon near the shore. This increase is caused by the presence of fossil rock salt on the eastern side.

The brine level is about 60 cm below the pan's surface. The production procedure is simple. Trenches and pits are dug in rows and allowed to fill with brine; after crystallisation, the salt is harvested. It has been estimated that the Cape Cross salt pan, if fully utilised, has a potential of about 1.3 million t per annum. At present it is the thirdmost important producing pan in Namibia (Schneider & Genis, 1992).

10.3 Dimension Stone

A number of dimension stone quarries exist in the area of the proposed Geopark. They have been established for test mining of marble and granite. Only one quarry operates on a larger scale, the granite quarry at Klein Spitzkuppe, which produces a beautiful yellow granite termed "Namib Sun" and an equally beautiful white variety called "Namibian Pearl.

Marble Quarry

10.4 Uis Tantalite

During the time, when the Uis Tin Mine was still in operation, tin and tantalum concentrates, that were produced by small scale miners in the area were bought up by the mine. After the closure of the mine, a cooperative of small miners was formed, and tantalite concentrates are now produced from various pegmatites in the area and processed in a small plant at Uis.

10.5 Exploration

Taking Namibia's high mineral potential into consideration, a number of companies are actively involved in exploration in the proposed Geopark area. These exploration activities are utilizing the available data from the high-resolution airborne geophysical surveys of the Geological Survey of Namibia, and focus on base, rare and precious metals. A few licenses also cover industrial minerals, semi-precious stones and dimension stone.

Very interesting exploration activities are carried out along the coast, both onshore and in shallow water offshore. Further south, between Oranjemund and Lüderitzbucht, Namibia hosts the World's largest deposit of alluvial diamonds, which are of exceptional high gemstone quality. The potential for similar deposits further north has been recognized, as is evident in the historical diamond mining at Toscanini, despite the fact that stones are expected to be smaller and fewer. As a result, almost the entire coastline of the proposed Geopark, both onshore and offshore, is covered with exploration licenses for diamonds, and companies actively prospect the marine terraces for their precious stone content.

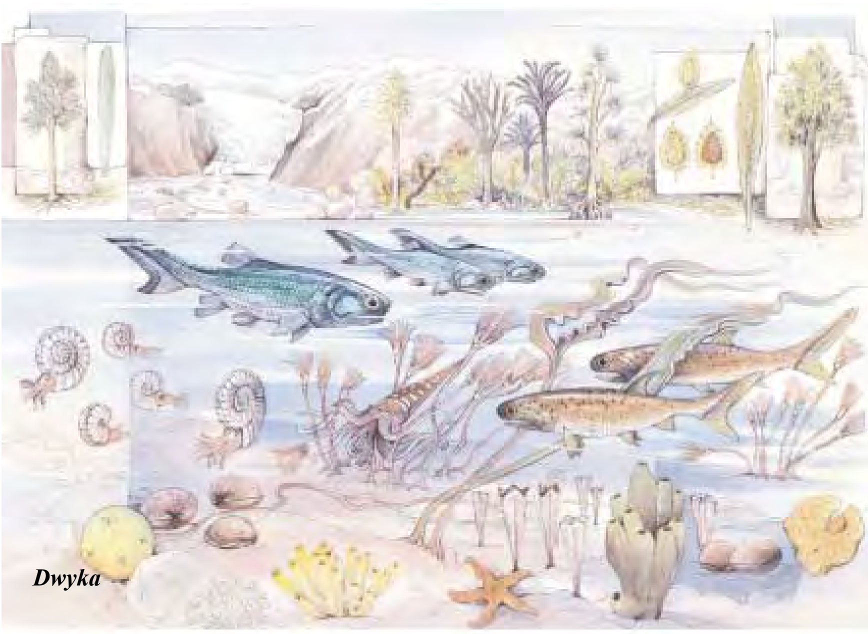
11. Palaeontology

The evolution of life during Gondwanaland times includes important milestones, such as the development of the famous Glossopteris flora, conquering the land by the first amphibians, and the rise of the dinosaurs.

11.1 Life in the Dwyka Iceage

For climatic reasons, the Dwyka environment was not an inviting place to be, and the Namibian Dwyka deposits thus generally tend to be poorly fossiliferous. Nevertheless, a few rich assemblages have been found in the mudstones and shales indicative of the intermittently warmer climate, and bear witness to the diversification of life that had occurred. Trace fossils are relatively abundant in the Dwyka Group. They were made mainly by fish and crustaceans. The same rocks also contain radiolaria, foraminifera, worms, corals, mussels, brachiopods, snails, moss animals, sponges, starfish and fish, as well as fossil wood.

Of special interest are the fishes found in the Dwyka Group, since they represent the oldest vertebrates found in Namibia. All fishes found in the Dwyka belong to the order of paleoniscoids. This group of fish, which existed up to the end of the Jurassic, encompasses primitive jawed, bony, ray-finned fishes characterised by inclined gills, strong teeth and strong pectoral fins. Their fossils are preserved in the centre of silica-phosphate nodules and are laterally compressed. They are generally well articulated, which suggests that there were no large predators of the paleoniscoids, apart from their own species (Schneider & Marais, 2004).



11.2 Forests of the Past: Verbrandeberg and Tsarabis Formations


Verbrandeberg Formation Forrest

Southern Africa had moved away from the polar region towards the end of the Dwyka period as a result of continental drift. Also, the global climate as such became warmer during the Permian as the CO_2 content in the atmosphere increased, possibly due to lower levels of abstraction by tropical vegetation, which declined dramatically during that period, perhaps as a consequence of less rainfall, as well as the effects of ocean and wind currents, which were in turn related to events like drift from the poles. The combination of these factors resulted in the melting of the glaciers and eventually the end of the Dwyka ice age in the mid-Permian, about 270 million years ago. The highlands initially retained their ice cover and spawned Alpine-like glaciers, which cut long and deep glacial valleys in northwestern Namibia. Fjord-like environments developed, and rivers carried the water of the melting glaciers towards the coast of an inland sea, which covered large parts of today's South Africa and extended further north. Large deltas formed at the mouths of these rivers, and the swamplands which developed along the river banks were rapidly colonised by the *Glossopteris* flora. Since sediments were deposited quite slowly, peat bogs could form, which later led to the development of the coal seams. The enormously rich coal deposits of South Africa developed in the main Karoo Basin during the same period. In general, the climate became more temperate and was characterised by periodic heavy rainfalls and flooding of the swamplands (Schneider & Marais, 2004).

The Verbrandeberg Formation contains abundant plant remains. Numerous fragments of leaves and bark occur in claystone units, whereas silicified and calcified leaves, twigs, trunks and fructifications are concentrated on top of sandstone units. They have been identified as *Glossopteris* sp. And *Cyclodendron leslii*. The Tsarabis Formation preserves spectacular silicified and calcified tree logs, which resemble *Araucaria* sp. And seven Cordait species. *Calamites* sp and Lepidodendron bark also occur. The fauna is restricted to fragments of acrolepid and elasmobranchid fish, but trace fossils are abundant (Holzförster et al., 2000).


Glossopteris

11.3 Conquering the Land: The Huab Formation

Rocks of the Huab Formation and age equivalent rocks in Namibia are the oldest rocks that contain fossils of animals that actually left the water to move on land. Their pioneering effort was, however, not a total success, since they were still dependent on the water environment for their reproduction. This fact is reflected in the name "amphibia", which means "both lives" and refers to the two different environments in which these animals lived. Only the reptiles, descendants of the amphibians, truly conquered the land at a later stage.

Mesosaurus Sea

The most famous fossil of this period is the aquatic reptile *Mesosaurus tenuidens*. It lived in an extensive inland sea which had limited or no access to the open ocean, the co-called "Mesosaurus Sea". It extended from the southern margins of South Africa to northern Namibia and westwards into Brazil and Uruguay. This sea probably represented a transition from marine to brackish or freshwater conditions. *Mesosaurus* was one of the first reptiles that actually returned to the water, and the earliest known deep-sea going tetrapod. On average, it was a mere 40 to 50 cm long, but rare and incomplete specimens suggest a length of up to 1 metre. The animal had a long tail which was flattened from side to side and possibly had fins running along its whole length, top and bottom. Although it generally resembled a lizard, it had a long and narrow head, with nostrils high on the snout, near the eyes. It therefore only had to break the surface of the water to breathe and see. The pointed snout sported long, thin, pin-like teeth on elongated jaws. It can be presumed that these teeth were not strong enough to bite prey, but were rather used to filter algae and soft-bodied organisms or krill-like small crustaceans from the water. Being an aquatic animal, the feet on the shorter forelegs and longer hind legs were in all likelihood webbed. The tail and hind legs propelled the animal through the water, while the forelegs were used for steering it. *Mesosaurus* could easily bend from side to side, an adaptation common in water-dwelling vertebrates.

Mesosaurus

The significance of *Mesosaurus* lies in the fact that it also occurs in the Irati Formation of Brazil and therefore provides proof of the fact that South America and Africa were once part of one big landmass, Gondwanaland. The Huab and Irati Formations were deposited at that time and when *Mesosaurus* lived in the embayments of the large inland Mesosaurus Sea (Schneider & Marais, 2004).

11.4 Connecting Namibia and Brazil in the Latest Permian: Lake Gai-As

The Gai-As Formation, deposited in the so-called Lake Gai-As, contains some interesting fossils. Fluctuations in both the salinity and alkalinity of the lake water promoted the formation of algal mats along the margins of Lake Gai-As. These are today preserved in the form of stromatolitic limestones. Fossil remains of other inhabitants of the lake, as well as those of land-based fauna and flora which were washed into the lake, were deposited together with the sediments.

Lake Gai-As

Invertebrate fossils are represented in the Gai-As Formation by the freshwater bivalve *Leinzia similis*, which also occurs in the Rio do Rasto Formation in Brazil, deposited at the same time. This provides proof of the huge extent of the lake. *Leinzia similis* was a filter-feeder and lived in shallow water on the water-sediment interface. It had a small, triangular shell with an average size of 2 cm and a maximum size of 4 cm. The shells display a coarse, concentric ornamentation. *Leinzia* preferred finer-grained sediments in distal offshore settings below the storm-wave base.

The Gai-As Formation also contains remains of the palaeoniscoid fish *Namaichthys* and *Atherstonia*. *Atherstonia* had a fairly primitive skull morphology and a robust trunk, and reached a length of up to 35 cm. The typical interlocking enamel-like scales of the early actinopterygians were quite large and externally marked with coarse oblique lines. Particularly along the dorsal margin, these scales were very large and deeply overlapping. The strong fins had bifurcating rays. *Atherstonia* was a predator, as is evidenced by the numerous relatively large, needle-like teeth arranged in two vertically inclined series, comprising a row of large conical inner teeth and numerous small outer teeth in the upper and lower jaw margins. These teeth must have been a powerful tool that enabled *Atherstonia* to crush its prey, which most probably comprised invertebrates and other, smaller fish.

Atherstonia

Very few tetrapod remains have been described from the Gai-As and Doros Formations to date. However, remains of the oldest member of the amphibian group known as the Stereospondyli were found in 2000. These fully aquatic predators evolved from earlier temnospondyl amphibians, and during the Triassic became the most widespread and largest amphibians ever to have lived. Whereas the largest of these attained a length of some 6 metres, the Gai-As specimen was only 2,5 metres long. These animals had relatively short legs in relation to their long bodies and featured a flattened head with nostrils and bulging eyes facing upwards, enabling them to breathe and see while semi-submerged in the water. On account of their habitat, stereospondyl amphibians had adaptations for an aquatic lifestyle such as the lateral line sensory organs one finds in fish.

In places, extensive bioturbation in the form of burrows such as *Planolites*, *Skolitos*, *Beaconites*, *Palaeophycus* and *Rosselia* indicates that a variety of invertebrates other than *Leinzia similis* were also present, but the animals themselves have not been preserved in the fossil record.

On land, the shores of the lake would have been vegetated by the typical Permian *Glossopteris* flora, including Glossopteridales, Cordaitales, ferns, cycads and conifers. Petrified wood is quite common in the Gai-As Formation, but since no leaf material has been recovered as yet, it is not possible to reconstruct these plants. The wood has been assigned to the genera *Podocarpoxylon* and *Araucarioxylon*, which most probably represents conifers (Schneider & Marais, 2004)

11.5 Living on the Edge: The Twyfelfontein Formation

The sedimentological sequence of rocks within the Twyfelfontein Formation points to environmental conditions that became increasingly unfavourable for living creatures. While the basal conglomerate, the Krone Member, was deposited under arid conditions by flash floods in rivers that flowed periodically, the overlying sandstones were laid down in an even drier climate where rivers ran only after occasional rains – comparable to the environment of the present Namib desert. The main unit was deposited exclusively by wind in a desert environment, and volcanic activity eventually added to the already harsh and inhospitable conditions. It therefore comes as no surprise that the fossil record of the Twyfelfontein Formation is poor.


Twyfelfontein Formation

Nonetheless, a bone-bed with a number of vertebrate remains has been reported from the basal Krone Member conglomerate. These remains consist predominantly of actinopterygian scales and teeth and bone fragments of therapsids believed to be derived from older, reworked Karoo sediments. One find, however, is interpreted as an authentic fossil from the lowermost Twyfelfontein Formation. It is an oval-shaped tooth belonging to an ornithischian dinosaur, probably of the family of the Hypsilophodontidae or a similar member of the infraorder ornithopods of the order ornithischians. These small, light-weight, two-legged herbivores lived in social herds and were fast runners. Hypsilophodonts were among the most successful dinosaurs and spread to every continent except Asia. They prepared nests for their eggs and probably administered some form of parental care, at least before hatching. Nevertheless, the animal to which the tooth belonged must have been one of the last of its kind, since the worsening environmental conditions in a thirstland made up of shifting sand dunes, interrupted only by extremely limited ephemeral water courses and – at a later stage – by fissures producing hot lava and poisonous gases, were certainly not conducive to the survival of animal life.

Trace fossils of the genus *Skolithos* are present at some of the interfaces of the fluvial and aeolian sandstones and the main aeolian unit, occasionally together with traces of rootlets. These trace fossils comprise unbranched, vertical to steeply inclined cylindrical burrows with a massive, structureless fill. *Skolithos* typically occurs in association with laterally extensive surfaces separating individual phases in dune development, and was most probably inhabited by worms or by tube-dwelling insects, arachnids or other arthropods. Unfortunately, body fossils are seldom preserved, and there have been no finds of body fossils in the Twyfelfontein Formation (Schneider & Marais, 2004).

11.6 The Dawn of the Age of Dinosaurs: The Etjo Formation

Rocks of the Etjo Formation are related to similar desert conditions as the ones described for the Twyfelfontein Formation. Elsewhere in Namibia they contain many traces of fossils, and there is a great potential to find more fossils in age-equivalent rocks within the proposed Geopark area. A description of the fossils of the Etjo Formation is therefore given here.

In the Etjo Formation, the lower gravel and sandstone unit has yielded little evidence of life so far. There is only a moderately diverse range of trace fossils of burrowing organisms which occurred in still or flowing water. In the middle unit, however, a prosauropod dinosaur, *Massospondylus*, has been discovered. *Massospondylus* is one of the oldest known dinosaurs and grew to a length of about 6 metres. This quadrupedal dinosaur had a long neck and blade-shaped slicing teeth, which indicates that it fed on vegetation well above ground level. The forelegs were considerably shorter than the hind legs, which suggests that, although it normally walked on four legs, it may at times have moved on the two hind legs while feeding or defending himself. *Massospondylus* swallowed small stones to assist the digestion of rough plant matter in the stomach, similar to many modern birds and crocodiles today. Other than *Massospondylus*, the only fossils found in the middle unit are the trace fossils *Planolites* and *Palaeophycus*.

The upper unit of aeolian sandstones is well known for dinosaur footprints and trackways. There are a number of localities in the Etjo Sandstone that contain dinosaur footprints; of these, the farm Otjihaenamaparero 92 in the Otjiwarongo District is the most impressive. The site has been declared a National Monument, and the footprints are protected by law. The sands which formed the upper Etjo sandstones accumulated under arid conditions as wind blown dunes. Numerous reptiles lived in the interdune areas, but as the climate became drier, these animals were forced to concentrate near waterholes, small lakes and rivers fed by occasional rains and thunderstorms. Inevitably, their feet left imprints in the wet sediment around the water. Later, these imprints were covered by other layers of wind-blown sand and were preserved as trace fossils when the sand solidified into rock due to the pressure that built up as they became buried ever deeper.

At Otjihaenamaparero, two crossing trackways consist of more than 30 imprints with a size of approximately 45 by 35 cm. The longer trackway can be followed for about 28 metres. There is a distance of some 70 to 90 cm between individual imprints. In addition, there are a number of individual imprints as well as some tracks comprising smaller imprints of about 7 cm length and a path length of 28 to 33 cm (Gührich, 1926). All tracks clearly show the form of a three-toed, clawed foot, and from their arrangement it is deduced that they were made by the hind feet of a bipedal animal. Unfortunately, no body fossils have been found in the area so far, and one can therefore only use comparison with other sites for identification.

Dinosaur Footprints

Although about 900 dinosaur species are known through the discovery of body fossils worldwide, only a few dozen footprint types have been discovered and identified. From these it can be concluded that the Otjihaenamaparero dinosaur which made the bigger imprints, possibly belonged to a large carnivorous theropod dinosaur species, and most likely to the family of the Ceratosauria. The dimensions and the depth of the imprints suggest that the dinosaur had an appreciable size of about 3 m in length. Ceratosaurians were the earliest known highly specialised meat-eaters. They had very strong hind limbs which allowed them to run fast while maintaining a very narrow gait. They ran with the body forward and the tail held out nearly horizontally as a counterbalance. It is estimated that they could possibly run as fast as 40 km/h.

The smaller tracks were most probably made by the small Ceratosaurian *Syntarsus*. *Syntarsus* was about the size of a secretary bird, and lived and hunted in flocks. It was a ferocious hunter, and definitely built for speed. Neck, tail and legs were long and slim, and the tail made up about half of the body length. Research done on bone tissue of *Syntarsus* has revealed that this animal had a high metabolic rate, but was not necessarily warm-blooded. It may occasionally have hibernated to overcome periods of severe drought.

Other trackways from the Etjo Formation at Waterberg have been linked to *Massospondylus* and two other prosauropod dinosaurs; one from the same family as *Massospondylus*, the plateosauridae *Quemetrisauropus princeps*, and one from the family Melanosauridae, *Prototrisauropus crassidiitus*. They were both herbivores, and could grow to a length of 7 m and 10 m, respectively. Their small heads and very long necks allowed the animals to browse on plants well above the ground. They had a massive body with a long tail. While *Quemetrisauropus* was bipedal, *Prototrisauropus* walked on four legs.

Tracks of cynodonts also occur in the same area. They have been interpreted to belong to *Tritylodon* and *Pachygenelus*. Both were very advanced cynodonts. *Tritylodon* had a very mammal-like lower jaw and complex upper and lower post-canine teeth capable of crushing and slicing food during feeding. It was so close to the mammalian level that it was actually classified as a mammal by early researchers. *Pachygenelus* was slightly larger, but other-wise very similar to *Tritylodon*, and both animals were herbivorous. Amongst others, they might have provided the prey for the carnivorous dinosaurs of the time (Schneider & Marais, 2004).

12. Fauna

The proposed Geopark belongs to a habitat where rare animals, such as desert elephants, black rhinoceros, desert lion and giraffe occur in a unique desert environment together with more common species. All of them show, however, a perfect adaptation to their environment, which includes special behaviour to deal with the geological conditions.

12.1 Desert Elephant

Amongst the wildlife present in the proposed Geopark, desert-dwelling mammals such as the elephants play an important ecological role within their habitat, such as for example dispersing seeds and reducing bushlands (Barnard 1998). They are not a separate subspecies of the African elephant (*Loxodonta africana*), but belong to the savanna elephant subspecies (*L.a. african*) as opposed to the forest elephant (*L.a. cyclotis*). Desert elephants have adapted well to live and roam within the dune and ephemeral river environments respectively. A unique behavioural phenomenon for the desert environment within the Geopark is their ability to slide down dunes and river embankments if required. Their feet are adapted for moving across dunes and rocky terrain likewise. Alluvial aquifers and sandy river courses provide year-round groundwater even in the most remote areas of the Geopark where elephants migrate to over vast distances of up to 70 km between feeding grounds and scattered waterholes. They have adapted to survival in the desert by behaviour, tradition and also physiology. Because their food is so widely scattered the desert elephants are required to spend more energy, and time, on the move in search of food. Their daily movements may cover a distance of about 25 km and the ecological role they play in their environment is considerable. They dig for water in the riverbeds, and therefore act as "hydrogeologists", during periods of drought other wildlife as well as birds and insects depend on these waterholes for their survival (Hall-Martin, 1988). The total number of desert elephants roaming within the proposed Geopark area are estimated to be less than 200 (Hearn, 2003).

Desert elephant

12.2 Black Rhinoceros

The black rhinoceros (*Diceros bicornis*) is a red data mammal, and their species is threatened almost entirely due to the luctrative black market trade in rhino horn. In general, rhino species are under severe threat and it is important to note, that Namibia has Africa's largest unfenced black rhino population, and about 97% of the world's population of the subspecies *bicornis* (Barnard 1998). Rhino management in Namibia includes anti-poaching patrols, translocation, custodianship programmes and the dehorning of rhinos as a deterrent to poachers. Within the proposed Geopark area less than 30 black rhinoceros are estimated to inhabit the gravel plains and ephemeral rivers.

Desert rhinos, like desert elephants, utilise plants and waterholes efficiently and are well adapted to life in the arid environment. They can survive in areas with less than 100 mm mean annual rainfall. Like desert elephants, black rhinos must also move great distances in search of food. Because of scarce water availability, they might only drink every third or fourth night. They eat a wide range of plants for food. Within the proposed Geopark area it was found, that black rhinos utilise 74 out of 103 plant species present, amongst them several which contain high levels of soluble tannins (Loutit 1987). They tend to rub their skin against rocks, which is revealed by the presence of so-called rubbing stones, which can occasionally be found within the proposed Geopark area. These rubbing stones are large boulders, which may be well polished through the repeated rubbing by the animals.

12.3 Other herbivorous wildlife

Various antelope species can be found within the proposed Geopark area. Though the diversity is rather low because of the aridity of the area, population numbers have increased over the past 20 years (NACSO, 2004). Amongst the large, medium-sized and small antelopes present are Damara dik-dik (*Madoqua kirkii)*, duiker (*Sylvicapra grimmia)*, steenbok (*Raphicerus campestris)*, klipspringer (*Oreotragus oreaotragus)* and springbok (*Antidorcas marsupialis)* as well as gemsbok (*Oryx gazella)* and kudu (*Tragelaphus strepsiceros)*. They are browsers and grazers, and depend upon both, silence, secretiveness and concealment as well as upon vigilance and mutual warning to avoid predation. The springbok is one of the most widespread arid zone antelope found in the proposed Geopark area. They occur in small scattered herds on the gravel plains of the Namib and are well adapted to live under desert conditions. They are highly mobile, like other desert-adapted animals and will quickly form large aggregations in areas where rain has fallen and created an abundant supply of green forage. Gemsbok are found throughout the Namib plains and in the Escarpment mountains. Like the springbok, they are also a true desert-adapted animal of open and sparsely vegetated areas. They can sustain long periods without any water, and have a special adaptation to deal with extreme high temperatures. Gemsbok are predominantly grazers. Like elephants, they can dig and enlarge waterholes in sandy riverbeds. Gemsbok are found in small herds or as individuals to maximise foraging efficiency over a large area. Kudu distribution appears to be limited by available water and as a consequence they are found mainly along river courses. In general, they keep to bush-covered hills and gorges, the denser mopane woodland and broken terrain. They are alert and wary, and stay well within reach of cover.


Giraffe

Giraffe (*Giraffa camelopardis*) are found scattered throughout the proposed Geopark area, mainly associated with the ephemeral riverbeds. However, numbers are on the decline mainly because of hunting. This resulted in a westward movement into increasingly drier areas. Giraffe are dependant on the vegetation of the river valleys, as the inner Namib plains are fairly barren, although they are also well adapted and can live for extended periods without drinking. Endemic mountain zebra (*Equus zebra hartmannae)* are found in the Escarpment zone and on the inner Namib plains. Zebra are extremely agile and sure-footed in rugged terrain, and can climb up the steepest slopes in search of grass, or to small fountains and pools. They are excellent diggers in riverbeds in search of water.

The proposed Geopark area is also home to mammals such as porcupine (*Hystrix africaeaustralis)* and pangolin (*Manis temminckii)* and a population of warthog (*Phacochaerus aethiopicus)* both inhabiting the Escarpment valleys and plateau areas. They are specialised feeders, living largely on roots and termites, which are dug out of their nests with powerful claws. Dassie or rock hyrax (*Procavia capensis)* are found in their typical hyrax habitat of jumbled rocks and boulders, rocky outcrops and cracks in rocks. Squirrels (*Xerus inaurus*) occur on the plateau, in the western Escarpment area, especially in rocky areas, the endemic *Xerus princeps* is more common.

12.4 Carnivorous wildlife

Numerous species of carnivores are found within the proposed Geopark area. The number of large cats, however, has been depleted, because they kill lifestock (Hall-Martin, 1988). Brown (*Hyaena brunnea)* and spotted hyaena (*Crocuta crocuta)* prey on large as well as on small mammals and occasionally birds like ostriches, but also eat plant material during periods of drought. The brown hyaena can be found along the beaches of the Atlantic Ocean and in the seal colonies where they search for carrion. Black-backed jackals (*Canis mesomelas)* are widespread, and their abundance is mainly due to their less specialised diet. They occur along the coastal areas and do compete with the brown hyaena for carcasses of fish, seabirds and seals. In addition, side-striped jackal (*Canis adustus*) and Cape Fox (*Vulpes chama*) can be found.


Lion footprint

The lion (*Panthera leo*) is an extraordinary animal still roaming the areas of the proposed Geopark, although it is in constant danger of being steadily reduced by shooting and poisoning, because of its stock-killing habit. Though unusual, they do migrate to the coast where they also feed on seal carcasses which they drag as much as over 2 km away from the cold beaches to more sheltered hummocks or reed beds. Lion living along the coast use the ephemeral rivers for moving back inland towards the escarpment. Like the other desert-dwelling animals it is especially adapted to cope with lack of water, scarcity of food and high temperatures. Cheetah (*Acinonyx jubatus)* and leopard (*Panthera pardus)* are thinly spread in the Escarpment zone and the inner Namib plains. They are considered stock-raiding predators as well. They prey on springbok, steenbok and ostrich, all of which can be hunted well in the open habitat with its good visibility. Smaller cats, such as the African wild cat (*Felis lybica)* are widespread. Like the leopard, the wild cat is a solitary, secretive animal which is seldom seen.

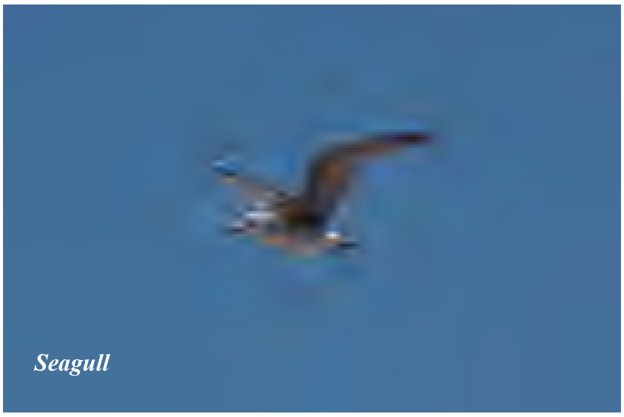
The largest colony of Cape Fur Seal (*Arctocephalus pusillus*) can be encountered at Cape Cross and is a popular tourist attraction. The seals use the rocky shore as breeding ground and resting place, and utilize the lagoonal environment north of the rocky cape, where large schools of fish occur, as feeding ground.

Smaller carnivores include baboon **(***Papio ursinus)* communities inhabiting mainly the Escarpment areas, genets (*Genetta genetta)*, several mongoose species (*Cynictis penicillata*, *Galerella sanguinea*, *Mungos mungo*) and suricates (*Suricata suricata*).

Although rare in the proposed geopark area, the Namib golden mole (*Eremitalpa granti*) inhabits the Namib Desert coastal areas where it prefers to live in lose sandy areas and sand dunes. The species is very well adapted to ”swim” through loose sand, which is a distinctive feature that this species is known for. It has no ability to dig and live in underground tunnel systems, is nocturnal and feeds mainly on insects, lizzards and arachnids. The spectrum of other small mammals found in the proposed Geopark area is wide and includes rats, mice, tree rats, hares, springhares, gerbil, bats, shrews and elephant shrews. Wherever different habitats meet, such as for example a rocky inselberg rising out of a gravel plain, there are opportunities for these animals to exploit the food and shelter resources of both environments and to compensate for the disadvantages of one by capitalising on the advantages of the other (Hall-Martin, 1988).

12.5 Birds

The proposed Geopark area supports an abundant variety of birds. Many are dependent on the nutrient-rich coastal waters of the cold Benguela Current, others totally depend on the life-line of the ephemeral rivers, and some are totally adapted to a life in the desert. Resident and migrant bird species can be divided into certain ecological groups, namely the seabirds and waders along the coastline and at brackish and fresh water pools where the ephemeral rivers meet the Atlantic Ocean, for example at the Uniab Riverdelta. A second group consists of highly adapted desert-associated birds such as for example the larks. Further groups include species, which are more usually found in higher rainfall areas on the central plateau, but also comprise birds of arid and semi-arid areas. About 250 different bird species occur within the proposed Geopark area of which the following belong to the more prominent ones.



Seagull

Common seabirds of the Skeleton Coast are cormorants (*Phalacrocorax capensis*, *Phalacrocorax carbo*), gulls (*e.g. Larus dominicanus*, *Larus cirrocephalus*, *Larus novaehollandiae hartlaubii*), pelicans (*Pelecanus onocrotalus*), endemic subspecies of the Blacknecked Grebe (*Podiceps nigricollis*), Greater (*Phoenicopterus rubber*) and Lesser Flamingos (*Phoenicopterus minor*), Sandpiper (*Calidris ferruginea*, *Tringa hypoleucus*, *Tringa stagnatilis*), and terns (e.g. *Hydroprogne caspia*, *Sterna hirundo*), including the very rare Damara tern (*Sterna balaenarum*), which nests on gravel flats and is vulnerable to disturbance. Endemic desert-associated birds, common throughout the Namib include Gray’s (*Ammomanes grayi*) and Stark’s lark (*Spizocorys starki*) and Rüppell’s korhaan

(*Eupodotis vigorsii*), trac-trac chat (*Cercomela tractrac*), Herero chat (*Namibornis herero*) and the ostrich (*Struthio camelus*), the latter one well adapted to the gravel plains and well-known for swallowing stones to aid digestion. These bird species possess many morphological, behavioural and physiological adaptations which allow them to cope well with the arid environment. Amongst these adaptations is the colouring of ground birds. Specialised colouration in desert birds matches them with a particular background colour, such as a red lark on red sand and generalised cryptic colouring, such as a mottled pattern which fits any background. Many desert species match the soil colour of their chosen habitat which provides them with a measure of protection against predators.


Hornbill

Most of the common birds in the area of the Escarpment and east of it include the Cape bunting (*Chalcomitra amethystine*), common waxbill (*Estrilda astrild*), masked weaver (*Ploceus velatus*), Cape sparrow (*Passer melanurus*), white-tailed shrike (*Lanioturdus* torquatus), pied crow (*Corvus albus*), laughing dove (*Stigmatopelia senegalensis*), Namaqua dove (*Oena capensis*), crowned guinea-fowl (*Numida meleagris*), babblers (*Turdoides bicolor*), lappet-faced vulture (*Torgos tracheliotus*) and several species of ducks and teal. Other endemic species include pale-winged starling (*Onychognathus nabouroup*), which can be found in huge flocks of hundreds of birds in ephemeral rivers like the Hoanib and Uniab. Also endemic along the ephemeral rivers are crimson-breasted shrike (*Laniarius atrococcineus*), falcon species, red-billed francolin (*Francolinus adspersus*), black korhaan (*Eupodotis afra*) and black-throated canary (*Serinus astrogularis*). Parrots (*Poicephalus rueppellii*, *Agapornis roseicollis*) and hornbills (*Tockus nasutus*, *Tockus flavirostris*, *Tockus monteiri*) are found fairly commonly throughout the area. A relatively rare bird is the endemic warbler called “rock-runner” (*Acrocephalus beaticatus hallae*), a small passerine living in a typical habitat of jumbled rocks, scrub and grass tufts in mountians like the Brandberg.

12.6 Reptiles

The proposed Geopark area has a rich and distinctive reptile fauna including snakes, tortoises and lizards which inhabit the Namib and the adjacent Escarpment in sand dunes, gravel plains, sheet rock and elevated rocky habitats. However, it is anticipated that there are quite a number of reptile species possibly not yet discovered in the Namib and in the rugged Escarpment mountains.


Agama

Some known species have very small distribution ranges such as an endemic, vegetarian, sand-diving lizard, the Desert Plated Lizard (*Angolosaurus shoogi*), living in sandy dune areas. It is unique, since there are only very few herbivorous reptiles. The endemic Damara rock agama (*Agama planiceps*) has been seen *rock-hopping* across rivers in flood (Barnard 1998).


Sidewinder

Peringuey's Adder (*Bitis* peringueyi) also known as the sidewinder, is famous for its sidewinding form of locomotion, moving across the sand by throwing its body sideways into loops. It buries itself in the loose sand for protection against the sun, leaving only the eyes exposed to watch for prey such as lizards and geckos. In doing so, it is perfectly camouflaged, as its skin looks exactly like the dune sand. It can also stick out of the sand and look like a twig. The sidewinder is endemic to the Namib desert and has a unique feature in that its eyes can see through 360°, Side-winding adders are also able to drink condensed fog off their own bodies. (Hebbard, 2005).


Palmatogecko

Another well adapted reptile is the translucent pink gecko (*Palmatogecko rangei*), which also digs into the sand like the side-winding adder, but to escape predators rather than catch prey. Namibia has an exceptionally rich and distinctive gecko fauna which is substrate dependent. Unfortunately, sandy and rocky substrates are vulnerable to habitat destruction such as desertification, bush encroachment and deforestation, large and small scale mining operations and the breaking apart of rock crevices by mineral collectors and scientists. Other unique, endemic reptiles include the geckos *Pachydactylus fasciatus*, *Pachydactylus hochii*, *Pachydactylus scherzii* and *Pachydactulys goniasensis*, which only occurs in the Brandberg, as well as the namib day gecko (*Rhoptropus* sp.) and the barking gecko (*Ptenopus carpi*) with its distinctive calling during the time of sunset.


Barking Gecko

The Namaqua Chameleon (*Chamaeleo namaquensis*) is perfectly designed for existence in desert conditions. The large, terrestrial reptile uses a peculiar stalking style to walk, which assists in coping with the hot surfaces on which this ground-living animal roams. The colour changes according to the substrate, and mimics the appearance of the sand and gravel plains, as well as the dune sands (Hebbard, 2005).

12.7 Insects

The Namib gravel plains and adjacent Escarpment areas have a rich and varied insect fauna of which it is thought that only 5% and 20% respectively have been catalogued yet. Many insect groups still await taxonomic revision and more comprehensive collecting (Barnard, 1998). Insect families include decomposers, herbivores, predators and parasites.

Various insects have adapted well to life in the dune environment, such as tenebrioid beetles, crickets, wasps, spiders and ants. They show many adaptations of form, physiology and behaviour to cope with problems of living in a desert environment. Arachnids such as the "dancing white lady" do escape predators by folding themselves up into a ball and rolling down the sides of dunes. Some beetle species have mechanisms whereby they can trap and utilise fog, either by digging small trenches in the sand; others can do this water harvesting (fog-basking) by standing on their heads in the fog to allow it to collect and condense on their bodies and then run down to their mouths. Some of the tenebrionid beetles are white instead of black, as a temperature-regulating mechanism.

Insect decomposers are often diverse in arid environments (Scholz & Holm, 1985).Within the proposed Geopark, termites and dung beetles are amongst the most important decomposers. Dominant herbivores are caterpillars and grasshoppers. Soil arthropods aerate the soil and allow nutrients and water to penetrate. Termite mounds support distinctive vegetation communities, and beetle larvae, ants, mites, springtails, bees, flies and wasps all play an essential role within the various ecosystem of the proposed Geopark.

13. Flora

The flora in the proposed Geopark area is part of the Semi-desert and Savanna Transition (Escarpment) Zone with low annual rainfall. The plant communities range from woodlands and savanna through shrublands to grassy plains with succulents and dwarf shrubs. Annual grasslands depend on rainfall, but in the Namib, plants are scattered and adapted to survival in areas where it seldom rains. The ephemeral riverbeds support far more vegetation than the plains on either side, from dense reedbeds to shady acacia forests. Riparian forests in these large river beds include large Ana trees (*Acacia albica*), leadwood (*Combretum imberbe*), mopane (*Colophpspermum mopane*), camel thorn (*Acacia erioloba*), ebony (*Euclea pseudebenus*), figs (*Ficus sp.*) and palms (*Hyphaene petersiana)*.

A number of environmental factors have an influence on the type of vegetation. Moisture derived from rain, fog or subterranean flow is the most important determinant. Topography is important in so far as it affects the distribution of rainfall and runoff or drainage – especially within the catchment areas of the ephemeral rivers. The physical properties of the soils (sand, clay, loam) are major indicators regarding the availability of water and are of importance in determining the type of vegetation. The presence or absence of certain indicator plants shows a prevailing and uniform pattern. The distribution of mopane and terminalia species is generally more abundant towards the east in aeras with higher rainfall. Various commiphora species inhabit the Geopark area, some (*C. anarcadifolia*) are normally only found on rock outcrops on the edge of the Namib, whereas others do not occur east of the desert margin (*Adenolobus garipensis*). Various perennial grass species are dependent on the annual rainfall, and form part of the important grazing, that the wildlife relies on.

Lichen

The Namib gravel plains along the coastline are influenced by the Benguela system. They represent the only area within the proposed Geopark with vast lichen fields, supported by the coastal mist zone and representing the most arid vegetation communities. An area northeast of Wlotzka's Baken has one of the most extraordinary lichen communities in the world. Less obvious, but numerous are the endolithic lichens which occur in both the mist zone and to the east of it. They grow inside porous rocks and cracks, and therefore represent a clear relationship between life and rocks.

Welwitchia

Another very unique endemic species is the "living fossil" *Welwitschia mirabilis*, a member of the Gymnosperm family. Fossil records show, that *Welwitschia* is related to pre-historic flora, and it is a befitting coincident, that today it is also found near accumulations of petrified wood, belonging to a 270 million year old Gymnosperm species.

14. Intangible Heritage related to Geological Features

In many places of the World, myths, legends and believes are inseparably intertwined with geological features, and in particular mountains. The large number of rock art sites in mountainous areas, such as the Brandberg and Spitzkuppe for example, are ample proof that the ancient inhabitants of the proposed Geopark were attracted by these geological features. Unfortunately, Namibia's intangible heritage is poorly documented at this stage, making research difficult. It can, however, be anticipated, that scientific investigations of this important part of Namibia's heritage will reveal new insights.

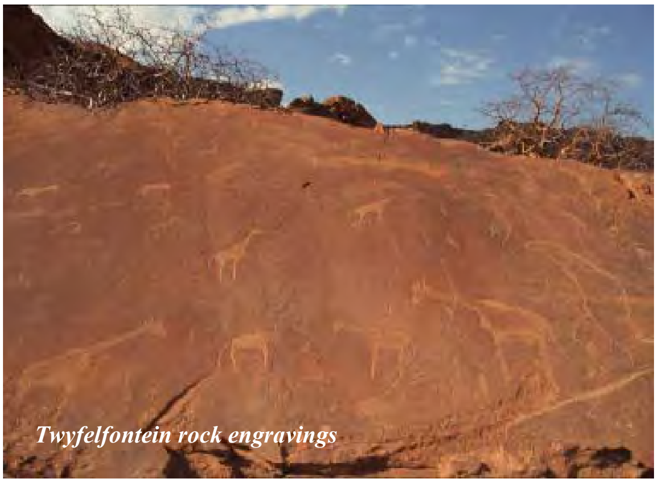
It is, however, already known that certain groups within the Damara-speaking community of Namibia believe that the mighty Brandberg is the place where their departed ancestors reside. At times, special ceremonies are conducted to honour these forefathers and to ask for their forgiveness, because the mountain is today utilized for rock art tourism and hiking.

15. Cultural Sites

A rich and diverse heritage of ancient cultural sites is present in the proposed Geopark area. Rock engravings, rock paintings and artefacts bear witness to the fact that the area has been inhabited for thousands of years. Because of the harsh desert environment, however, humans were forced to adapt and utilise geological features, such as the Brandberg, for example, where they could find water as well as shelter. Because of this intimate connection between geological features and survival, many of them are richly decorated by ancient art.

15.1 Twyfelfontein

Twyfelfontein lies in a valley running northwards and carrying a small tributary of the Huab River. The valley is bounded by sandstones of the Etjo Formation and shales of the Gai-As Formation, Karoo Sequence, that are underlain by dark Kuiseb Formation schists of the Damara Sequence. The geological juxtaposition of porous aeolian and fluvial sandstones on impermeable deposits resulted in the formation of a freshwater spring. The name "Twyfelfontein", meaning "doubtful spring", originated because it only carries water episodically, the porous aeolian sandstone being limited in volume and only holding a limited amount of water after good rainy seasons. Undoubtedly, people have for a long time been attracted to the area by this small spring which brings a great variety of game to the area, which hunters can observe unseen from a terrace some 50 m above the spring itself.



Twyfelfontein rock engravings

The rocks of the Etjo Formation, a thick bedded aeolian sandstone, weather into large blocks, often with clean flat faces. These large blocks provided great shelter and the large flat faces, the old dune slip faces, the "canvas" for rock art. In 1952, this rock art at Twyfelfontein was proclaimed a National Monument.

With almost 2000 recorded images, Twyfelfontein or Ui-ais, as it was originally called, is the largest known rock engraving site in Namibia, and one of the largest in Africa. Most of the engravings, as well as a small number of paintings, are well preserved and their subject matter is easily identifiable. The most prominent species are giraffe (234) and rhino (121), followed by zebra (75), oryx (50), ostrich (40), elephant (24), and cattle (29). In contrast to the rock painting sites in the same area, this and other engraving sites have virtually no human figures. However, they include many more birds than the painting sites and it is interesting to observe that most of the birds are the so-called striding species, such as the ostrich, rather than perching species, such as sparrows. This suggests that the birds may in fact represent people. There are many other indications that the engravings are not simple naturalistic representations, and the clearest, but most easily overlooked example, is the engraving of a lion which has five toes, like a human, rather than the usual four.


Twyfefontein rock engravings

At Twyfelfontein, the rock engravings occur in eight small clusters, on the high terrace and in the small ravine to the west. The whole area is littered with stone artefact debris, mainly vein quartz and indurated shale, which would have been carried from far afield. The small spring at this site probably served as an essential water supply for thousands of years, with hunter-gatherer communities eventually giving way to livestock farmers. In years of plentiful rain, the area to the west would have been used until the onset of the dry season, and smaller rock engraving sites are found as far away as the edge of the Namib Desert. The distribution pattern of these sites indicates a network of alternative hunting grounds and the routes which connected them. Interestingly, the archaeological evidence shows that the animals most commonly hunted were small antelope, hyrax and even lizards, rather than the large species depicted in the engravings which apparently had more ritual than subsistence value (Kinahan & Schneider *In:* Schneider, 2004).

Twyfelfontein has been placed on Namibia's tentative list for inscription as a World Heritage Site, and a dossier for submission to UNESCO is currently being prepared.

15.2 Brandberg

The archaeology of the Brandberg has been the subject of serious research for more than eighty years. Detailed surveys of the rock art have recorded more than 1000 sites, some with a hundred or more individual paintings. Although the most famous site, the Maack or "White Lady" Shelter, has given rise to several fanciful interpretations, systematic excavations in other parts of the mountain show that the area was inhabited by hunter-gatherer communities until the first appearance of nomadic livestock farming about 1000 years ago. Small bands of hunters evidently lived in the upper parts of the mountain during the dry season when little water or food could be obtained in the surrounding desert. The structural geology of the mountain, with its well-developed sheet joints, provides many small aquifers and where these emerge, rock painting sites are


White Lady shelter

never far away.

In the rock art of Brandberg, human figures comprise more than 40% of the images and among the many animal species depicted giraffe are often the most numerous. Few of the animals featured in the paintings are represented in bones recovered from archaeological excavations. Indeed, very few of the species in the paintings actually occur on the mountain itself which is far too rugged for most of them to ascend. This and other evidence, such as artifacts of crystalline quartz, marine shells and some metal objects, suggests that the people who inhabited the Brandberg also inhabited a far wider area. A clearer pattern of movement arose with the development of pastoralism when stock camps were established at remote waterholes and the herds were pastured far into the Namib Desert after the summer rain. In the dry season, however, pastoral communities would retreat to the upper Brandberg with its reliable waterholes and nutritious pastures, usually camping in the same places as their hunter-gatherer predecessors (Axel Schmitt, Rolf Emmermann & John Kinahan *In:* Schneider, 2004).

Like Twyfelfontein, the Brandberg has been put on Namibia's tentative list for inscription as a World Heritage Site.

16. Proclaimed National Monuments

A total of 112 National Monuments are proclaimed within Namibia, excluding 6 provisional proclamations, which are only proclaimed for a limited period of five years (Vogt, 2004). These National Monuments comprise heritage sites of geological, environmental, archaeological, cultural and historical importance of which 19 proclaimed National Monuments can be found in the proposed Geopark area. They are the Phillipp's Cave on Farm Ameib, Usakos; the Paula Cave on Farm Okapekaha, Omaruru; the Brandberg, Erongo Region (see 7.1 and 15.2); rock paintings and engravings at Twyfelfontein, Kunene Region (see 15.1); the Petrified Forest near Khorixas, Kunene Region (see 7.5); the Bushman Paradise Cave, Spitzkoppe, Erongo Region (see 7.6); the Burnt Mountain on Farm Verbrandeberg, No. 52, Kunene Region (see 7.7); the Franke Tower, Omaruru; the rock paintings on Farm Etemba, Omaruru; the replica of the original cross at Cape Cross, Swakopmund District; the battlefield around the Franke Tower, Omaruru; the façade of the Rösemann Building, Karibib; the Kubas Station Building, Karibib; the Rhenish Mission House, Omaruru; Erf 46 & "Hälbich Buildings", Karibib; "Haus Woll", Karibib; "Hotel zum Grünen Kranze", Karibib; "Proviantamt", Karibib; Kaiserbrunnen, Karibib and the Roman Catholic Church, Omaruru. In addition, all shipwrecks along the Skeleton Coast, that have been in Namibian waters for more than 40 years, are protected National Monuments.

Skeleton Coast Shipwreck

While only eight of these National Monuments have a geological connotation, and only two are true geological sites, they are all of significance for the tourism sector. The monuments are located in towns, on farms and in the communal areas and fall under the administrative jurisdiction of the National Heritage Council of Namibia.

National Monuments

17. Existing Infrastructure

Infrastructural facilities such as water and electricity supply as well as different transport services are limited due to several environmental constraints. Amongst them are vast areas of desert with a complete lack of permanent surface water, episodic rainfall at unpredictable intervals and large distances separating scattered settlements, communities and smaller villages. The harsh climate conditions and sparse water resources need to be considered carefully in any proposed development relating to activities such as ecotourism .

Track

However, scenic spots and unique geological heritage sites within the proposed Geopark area are well accessible. Travel routes and relating information (food, lodging, etc.) are available to the public and serve as an important tool to guide visitors. The use of off-road vehicles (4x4) of all kinds and sizes places no limitations on the accessibility of the area. Except of the area between the Ugab River and Terrace Bay, which comprises the southern part of the Skeleton Coast National Park, no restrictions are in place, nor do any regulations prohibit visitors from driving anywhere and by any means. However, the vulnerability of the environment needs to be taken into consideration, and regulation of access might be a future option.

17.1 Transport Services

The existing road infrastructure within the proposed Geopark boundaries is made up of a combination of

- tarred and unsurfaced main roads
- unsurfaced secondary and farm roads
- tracks, both gravel and sand
- closed and private tracks

Most of the major and smaller settlements are linked to each other mainly by gravel roads, which are maintained by the Namibian Roads Authority. Accessability to all geological as well as cultural sites and National Monuments is excellent. In some remote areas, the limited infrastructure does, however, require the use of 4x4 transport.


Secondary Road

The road network is maintained and partly upgraded on a regular basis, as is the construction of new roads. The prevention of erosion-related damages, the installation and repair of cattle grids and small drainage structures, and the construction of bridges insure a good road network necessary to cater for an increased number of tourists, both, self-driven and those who book a package and travel in a group by bus.

In addition to the road network, air traffic plays an ever increasing and important role in the tourism sector in Namibia, because of the vast distances involved in traveling the country. An estimated number of 50 unmanned airstrips are located within the proposed Geopark area, including a number of privately owned landing strips on farms. All of them cater for small to medium sized aircraft to be able to handle both, fly-in safaris as well as emergency services, which play an ever increasing role with motor accidents on the increase.

17.2 Telecommunications

A good postal and telecommunications network exists in all three Regions, including even remote areas. This network (operated by Telecom Namibia and MTC) is complemented with fixed and mobile radio stations, as well as through the installation of booster stations to allow for increased cellular coverage.

17.3 Water and Electricity Supply

All water currently used within the boundaries of the proposed Geopark is either tapped from underground resources through boreholes or from storage dams. The careful utilisation of the scarse and limited water resources plays an important role in every socio-economic development. Drinking water standards are equally important as is the reliable availability to developments such as lodges, rest camps, settlements, communities and tourist attractions.

Water handpump near a natural spring

The availability of a save and secure water supply to all relevant stakeholders within the area is essentially secured, however, being situated in an arid environment, the ever increasing demand for this precious commodity (non-renewable as well as renewable) needs to be carefully monitored.

As far as electricity supply is concerned, only Usakos, Karibib, Khorixas, Uis and Omaruru are linked to the National Power Grid (Nampower). In the remainder of the area, electricity is generated by means of diesel generator and solar power, the latter one becoming increasingly important for developments such as lodges and rest camps. It is envisaged, that power from the national grid will in future also be supplied to communities such as Twyfelfontein and other settlements. No hydro-electrical power is generated, since the area lacks perennial rivers and only has ephemeral streams.

17.4 Accommodation

Facilities at a community based camp site

A great variety of accommodation facilities exists within the boundaries of the proposed Geopark. They comprise hotels, lodges, guesthouses, guest- and hunting farms, camp sites and resorts in National Parks. Accommodation for individual travelers as well as for groups is available at affordable rates in the towns and near proclaimed heritage sites. Communal conservancies established camping and lodge-type facilities in more remote areas to allow visitors easier access to geological and cultural hotspots, such as Spitzkuppe, Brandberg, Petrified Forest and Burnt Mountain. Accomodation within the proposed Geopark also caters for professional trophy hunting, wellness and cultural tourism demands and a variety of tourism activities such as mountain climbing (Brandberg and Spitzkuppe), hiking, fishing safaris along the coast, and fly-in safaris to remote areas for game and landscape viewing.

New accommodation facilities are in the process of being established in various communal conservancies together with private investors to meet an increasing demand of tourism into the area. A majority of established accommodation facilities are linked to airfields and do cater for basic supplies such as fuel and consumables.

Lodges and Campsites

18. Socio-economic Aspects

Small scale mining products

As already stated, the proposed Geopark falls within three of Namibia's administrative regions, namely Erongo, Kunene and to a lesser extend Otjozondjupa. The eastern part is dominated by extensive farming, whereas the western part has little to no agricultural potential at all. Commercial as well as subsistence agriculture is practiced in the form of cattle and small stock farming, in addition to game farming and hunting activities. The dualistic structure of the farming sector within the proposed Geopark boundaries is due to the limitations, the arid climatic conditions place on the area. Various communities have been living in remote parts of the proposed Geopark for centuries and settlements and economic activities have a long history. Current mining is extensive within the Erongo, Brandberg and Spitzkoppe areas and along the coastline. Although mining activities for commodities such as salt, gold, semi-precious stones and dimension stones are numerous, small scale mining dominates, rather than large-scale operations. The dependency of the small miners on the limited chances to secure regular employment is high.

18.1 Tourism

The tourism sector plays already an important and vital role in the area of the proposed Geopark. The well maintained infrastructure caters for an increasing number of lodges, safari operations, hotels, hunting and guest farms and rest camps. In addition, Community Based Tourism Development forms an important part of the economic development in all three regions with several communal conservancies established in the area.

A total population of appoximately 15.000 people live within the boundaries of the eight conservancies. In addition the estimated population of Karibib (5.000), Usakos (4000), Omaruru (7.000), Khorixas (7.000), Uis (1000) and those living within the commercial farming areas towards the east of the Geopark (app. 6.000), a total population of app. 45.000 do live within the proposed Geopark parameters (National Planning Commission, 2003; NACSO, 2005). Given the potential of the spectacular scenery, rich cultures and burgeoning wildlife population, it is interesting to note, that the recent growth in tourism coincided with the development of the conservancies. Increased private sector investment into lodges is continuing to attract tourists. The most successful type of income generating projects, however, seem be those managed in partnership between communities and commercial tour operators or nonprofit organizations (NACSO, 2004).). This is also reflected in the fact that recently the Damara Camp, a joint venture between a private owner and a local community's trust, has won the prestigious "Tourism for Tomorrow Conservation Award 2005".


Craft shop

Although tourism activities are growing fast, conservancy staff and members of communal conservancies are still largely ill equipped to deal with all aspects of the business. Skills in the area of financial management and business planning, marketing, as well as a good knowledge and understanding of the tourism industry remain important areas of training (NACSO, 2004). In addition, tourism activities outside the communal conservancies, within the commercial free hold land title area towards the east also play a very important role for the economy. Their contribution is generated through commercial stock farming by commercial area farmers, game farming, trophy hunting lodges and safari operations, guest farms and wellness resorts, all of which are privately owned and managed. Within the eastern part of the proposed Geopark, freehold conservancies were established with the main aim to promote collaborative conservation and management of wildlife which differs from the focus on use and benefits in communal conservancies, where conservation has been linked with rural development. Many freehold farms benefit directly from wildlife by harvesting game, trophy hunting and tourism without being affiliated to any conservancy. However, economic activities on freehold land are equally important to the development of the proposed Geopark. Major communities and settlements such as Karibib, Usakos, Omaruru, Uis and Khorixas are important service centres for visitors to the proposed Geopark for general services and supplies such as fuel, food and emergency services. Tourism is therefore the major economic activity within the proposed Geopark aimed to benefit the local communities.

18.2 Conservancies

The main aim of the conservancies is to allow local communities to better manage their own environment while also enabling them to benefit from their resources. Conservancies are part of the Namibian Community Based Natural Resource Management (CBNRM) programme and were established within the mandate of this programme. Community-based tourism (CBT) aims to empower local communities by utilising and sustaining their natural resources. Communal conservancies are located almost exclusively in communal areas where no free-hold land titles exist. These areas are managed by communities or individual entrepreneurs from outside or within the community itself, with the aim to earn an income from the natural resources. 'Communities' are by definition groups of people who identify a common interest in certain issues, and need not necessarily comprise an entire village. The improvement of the general livelihoods of a majority of the people is being achieved through the recognition, that wildlife and other natural resources be utilized to diversify rural economies by means of developing natural resources based industries. Amongst them are activities such as the running of rest camps and craft shops, guided tours to scenic spots and other spots of interest, such as geological and/or heritage sites, or catering.

Craft shop with clay sculptures

There is, however, still scope for further controlled development to generate additional income and certain places are as yet undeveloped. Although wildlife remains a prominent focus of natural resource use and management, many conservancies are actively managing other natural resources such as plant foods (melon seed, marula oil), fish, honey, pastures or rangeland and livestock. The coordination and delivery of services and support to communities in remote areas is another form of better managing available resources. Other important resources to be managed are for example joint anti-poaching efforts, the sharing of quotas for game hunting between conservancies as well as annual game count activities.

Financial benefits of the eight communal conservancies are derived from managing campsites, craft sales, mineral and rock sales, joint venture tourism, game sales, meat distribution, trophy hunting and interest earned. Incomes vary greatly between conservancies, both in terms of how much they earn and the sources of revenue. Within the proposed Geopark however, most of the eight conservancies were able to increase their income considerably in recent years and continue to do so.

At present, eight communal conservancies are located within the proposed Geopark boundaries (NACSO 2004):

1. //Huab	2. Otjimboyo	3. Sorri-Sorris	4. Torra
5. Tsiseb	6. Doro !Nawas	7. Twyfelfontein-Uibasen	8. # Gaingu

Conservancies

Substantial amounts of money are being generated through the conservancies and are being utilised to benefit social projects (renovation of schools and supporting local kindergarten), creating new jobs and skills training of staff, supporting small agricultural projects (maintenance of water points for game), making available small stock loans and funding vaccination campaigns. Money generated is also used for conservancy running costs, capital development projects (tourist information centers) and to supply meat to neighbouring conservancies and traditional leaders for important local festivities (NACSO 2004). In addition to own income generated by the communal conservancies, donor funding also provides inputs, mainly as 'in-kind' contributions, such as staff, vehicles and other kinds of support. Within the proposed Geopark, the Tsiseb Conservancy is the largest one in terms of the area proclaimed (8.083 km²) and located within the Erongo region, with Uis as the major settlement and service center for tourists visiting the area.

19. Legislation

19.1 Present situation

Tourism attractions within the proposed Geopark need to be protected and save-guarded through legislation. Scenic spots of geological heritage in particular are vulnerable because of vandalism, pollution, poor protection measures, and weak access control to yet unproclaimed heritage sites. Government policies for community-based tourism provide a framework for communities to benefit from tourism, but legislation does not give communities and conservancies adequate rights over access and control of tourism in their respective areas of operation.

Under the emerging Parks and Wildlife Management Bill, it will be possible to use the "Protected Landscape" category for the proclamation of a Geopark. In section 27, the said Bill states that

(1) The Minister of Environment and Tourism may, by notice in the Gazette, declare any area of land and adjoining waters specified in the notice to be:
    (e) a protected landscape, to maintain the harmonious interaction of nature and culture, through the protection of areas where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/ or cultural values, and to promote the continuation of traditional human practices in such areas.

The Bill furthermore states in section 28, that
(1) Before declaring a protected area under section 27, the Minister of Environment and Tourism shall cause a survey to be undertaken in order to ensure that:
    (a) areas or objectives of aesthetic, ecological, geological, prehistoric, archaeological or special scientific interest, historic sites and such other areas are taken into account.

The Bill therefore present an excellent opportunity for the proclamation of a Geopark, and no additional legislation would be required. It needs, however, to be taken into account, that the area covers a variety of land tenure systems (see 18.), such as communal farm land, free hold farmland, a National Park, National Monument areas and conservancies. The latter three have clear management authorities, and the relevant legislation must be taken into consideration in addition to the Parks and Wildlife Management Bill.

It is also anticipated that the upcoming Parks and Wildlife Management Bill will enhance rights and obligations for communities and conservancies. At the same time raising of public awareness and education programmes related to geoscientific disciplines need to be increased in schools and communities with the assistance of the media, NGO's, government agencies, tourism and other private sector enterprises, to ensure, that the population living within a Geopark fully understand the benefits and advantages of such area and conservation thereof. By popularising geo-scientific interesting sightseeing spots, more tourists will be attracted, resulting in increased general income through tourism.

19.2 Proposed administration of the Geopark

The managerial authority for a Namibian Geopark should rest with the authority responsible for protected areas, namely the Namibian Ministry for Environment and Tourism, in close cooperation with the national Geological Survey of Namibia (GSN), an established research organization with qualified staff capable of working at geological heritage sites and other geological sites. An independent Namibian Geopark Advisory Board should be established under the umbrella of these two entities and membership status awarded to recognise all stakeholders, agents and entities (local communities, conservancies, local government authorities, NGO's, farming, tourist and hotel businesses, mining companies, National Monuments Council and other relevant government agencies and professional societies). Such approach must ensure, that funding tools and logistical support be put in place through the support and commitment of all stakeholders. The already established Environmental Trust Fund could be engaged in securing funds as well.

20. Management Plan

A Management Plan will have to adress the key management objectives and the associated management measures. Key management objectives will be:

(i) to maintain the integrity of the Geopark area in its geological and geographical setting
(ii) to present the Geopark area and its geological attractions in a professional and informative way
(iii) to promote the earth sciences and related research in the area
(iv) to develop sustainable tourist attractions and thereby contribute to the socio-economic development of the area
(v) to provide appropriate training and employment

Associated management measures should be:

(i) Proclamation of the Geopark under the upcoming Parks and Wildlife Management Bill
(ii) Training and appointment of management and support staff
(iii) Inclusion of the Geopark in UNESCO's Global Network of Geoparks
(iv) Facilitation of business planning and a common vision for all stakeholders
(v) Implementation of a database management system
(vi) Environmental monitoring
(vii) Local enterprise participation schemes
(viii) Promotion of research (not limited to the earth sciences)
(ix) Promotion of geo-tourism in Namibia and abroad
(x) Awareness creation of the earth sciences through publications, sign boards and professional tour guides

21. Conclusion

The proposed Geopark comprises significant geological features such as rocks, fossils, unique mountainous and desert landforms and soils, all of which need to be conserved as 'Geological Heritage'. They are of aesthetic, cultural and scientific significance and are recognized as having profound nature conservation values. Africa's first Geopark could strive to recognize and actively promote the conservation of healthy geo-environments; education in Earth Sciences and promoting sustainable economic local development through the envolvement and participation of local communities. Geotourism within the proposed Geopark is a major economic activity, making use of geoscientific and geomorphological attractive features such as rock formations, minerals, fossils and unique landscapes, as a tool for public education and recreation. Their specific geological, mineralogical, geophysical, geomorphological, palaeontological and geographical features are complementing the local archeological, ecological, historical and cultural values.

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Appendix 1:

Operational Guideline for National Geoparks seeking UNESCO's assistance