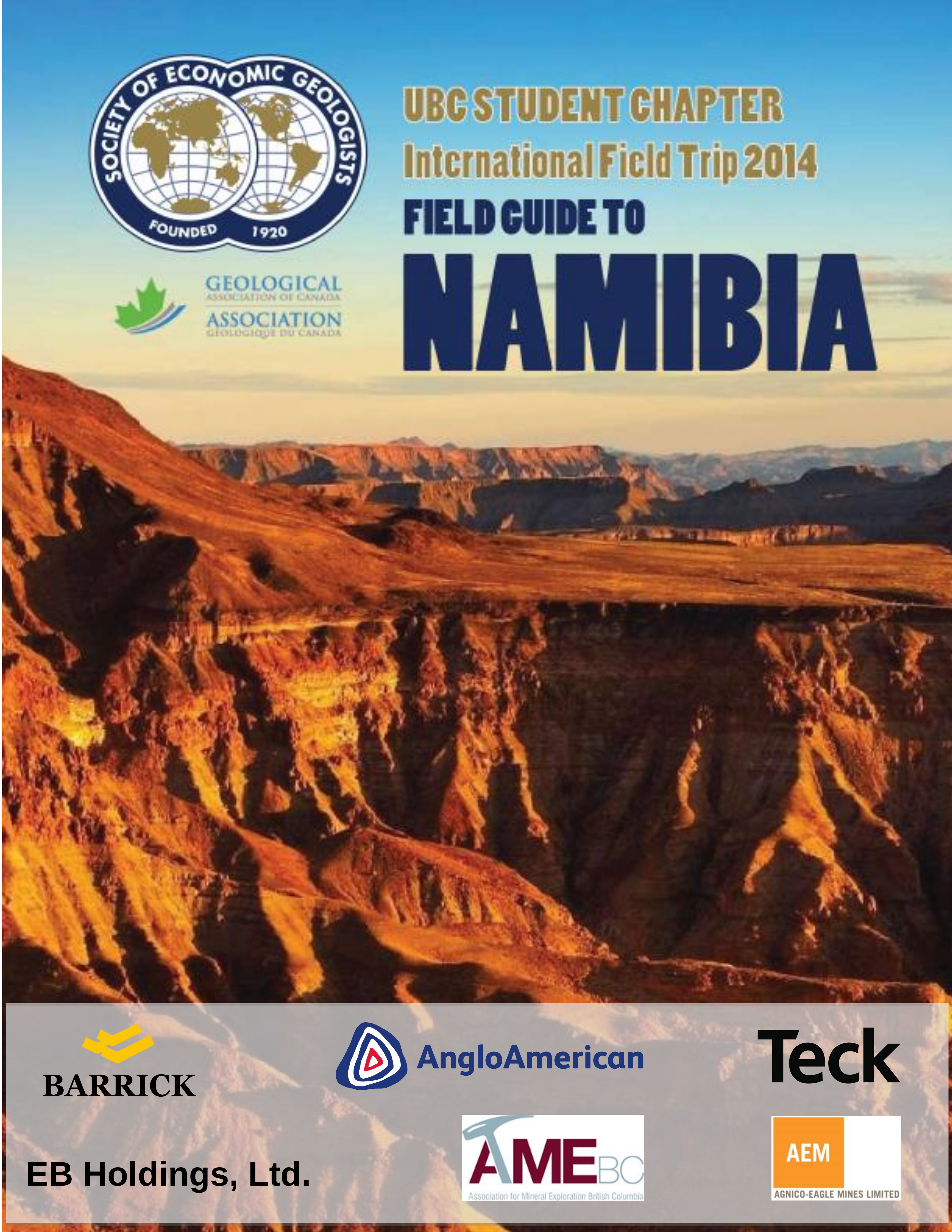

Society of Economic Geologists
Founded 1920

Geological Association of Canada
Association Géologique du Canada

UBC STUDENT CHAPTER
International Field Trip 2014

FIELD GUIDE TO NAMIBIA

BARRICK

AngloAmerican

Teck

EB Holdings, Ltd.

AMEBC
Association for Mineral Exploration British Columbia

AEM
AGNICO-EAGLE MINES LIMITED

Acknowledgements

We thank GlencoreXstrata, Teck Resources Ltd., B2Gold Corp., Kombat Copper, Sabre Resources, Namibia Rare Earths, Inc., and Swakop Uranium for their hospitality during mine and field visits.

Students are grateful to industry sponsors supporting the UBC SEG-GAC Student Chapter, especially to those industry members attending the field trip from Colorado Resources, KGHM, Minería Activa, and Namibia Rare Earths, Inc.

We also thank Dr. Ben Mapani at the University of Windhoek for introducing the participants to the geology of Namibia prior to beginning our tours.

Thanks also to the University of Oregon SEG Student Chapter and Curtis Marr, Fanny Yip, Sarah Jenkins, Judy Simonite, Arne Toma and Monica Spisar from MDRU at the University of British Columbia for their help with logistics and publicizing the trip.

Table of Contents

List of Participants

Last Name	First Name	Nationality	Affiliation
Brunetti	Paula	Chilean	UBC MSc Student
Bordet	Esther	French	UBC PhD Student
Gainer	Dan	Canadian	UBC Undergrad
Looby	Erin	American	UBC MSc Student
Rabayrol	Fabien	French	UBC PhD Student
del Real	Irene	Canadian	UBC MSc Student
Manor	Matthew	American	UBC MSc Student
Kramer	Rachael	Canadian	UBC Undergrad
Jusupov	Tim	Canadian	UBC Undergrad
Yarra	Raja	Canadian	UBC MSc Student
Boucher	Kaleb	American	UBC MSc Student
Jones	Stacie	Canadian	Queens MSc Student
Marquardt	Martin	Chilean	Mineria Activa
Dandy	Linda	Canadian	Colorado Resources
Nickerson	Dave	Canadian	Industry Professional
Balon	Edward	Canadian	Industry Professional
Coder	Joshua	Canadian	KGHM
Torres	Omar	Chilean	Industry Professional
Branson	Thomas	Canadian	Industry Professional
Schmidt	Uwe	Canadian	Consultant
Bizouerne	Frank	Namibian	Namibia REE
Mapani	Ben	Namibian	University of Namibia

Major Roads


Angola
Botswana
South A
Atlantic Ocean
Destinations
Northern Namibia
Central Namibia
Southern Namibia
Epupa Falls
Ruacana Falls
Marienfluss
Kaokoveld
Skeleton Coast N.P.
Etosha N.P.
Owamboland 4-O-Region
Kavango
Caprivi
Khaudum N.P.
Tsodilo Hills
Damara-land
Twyfel-fontein
Brandberg
Erongo
Spitzkoppe
Waterberg
Otjozondjupa
Nyae Nyae
Omaheke
Windhoek
Swakopmund
Walvis Bay
Sandwich Harbour
Namib Naukluft Park
Khomas
Sossusvlei
Naukluft
Hardap
Duwisib
Namib Rand Nature Reserve
Kalahari
Kgalagadi Transfrontier N.P.
Wild Horses
Quivertrees
Kolmanskop
Lüderitz
Karas
Fish River Canyon
Ai-Ais Richtersveld Transfrontier N.P.
Augrabies Falls N.P.
Orange River
N7 to Cape Town
0 100 200 300
KM
© Southern Domain

Itinerary Map

Itinerary

Date	Activities	Accomodation	Location	Contact	Description
Thursday, May 1st	Visit Daan Vijoen Game Park Dinner at Joe's Beerhouse	Hotel Uhland, Windhoek	147, Dr. Kenneth David Kaunda St	(00264) 61 - 389 700	5 min walk from city center
Friday, May 2nd	Visit University of Namibia Lecture by Dr. Ben Mapani Visit Geological Survey of Namibia	Hotel Uhland, Windhoek	147, Dr. Kenneth David Kaunda St	(00264) 61 - 389 700	5 min walk from city center
Saturday, May 3rd	Drive Windhoek to Noordoewer Lunch-stop in Gibeon Stop in Brukkaros Mountain	Felix Unite Provenance Camp, Noordoewer	Orange River, Highway C13	087-354-0578	Pack Lunch Restaurant in Hotel
Sunday, May 4th	Visit Haib Porphyry Drive to Rosh Pinah	Four Seasons Lodge, Rosh Pinah	2 Melkbos street, Rosh Pinah	(+00264) 63 274 416	Pack Lunch Restaurant in Hotel
Monday, May 5th	Visit Rosh Pinah Mine Drive to Fish River Canyon	Canon Roadhouse, Fish River	C 37, 20 km from main lookout in Fish River	+264 61 23 0066	
Tuesday, May 6th	Visit Fish Canyon Park Visit Ai-Ais Hot Springs Drive to Keetmanshoop	Central Lodge, Keetmanshoop	5th Street, Keetmanshoop	+264 63 225850	Breakfast Pack Lunch Restaurant in Hotel
Wednesday, May 7th	Drive to Ojiwarongo Stop in Mariental or Hardap Dam	Otjibamba Lodge, Otjiwarongo	B1 Road, Otjiwarongo PO Box 134,	+264 (0)67 303 133	Pack Lunch
Thursday, May 8th	Ojikoto Mine Drive to Tsumeb	Kupferquelle Resort, Tsumeb	Kupfer St. and Hage Geingob St	+264 67 220 139	Pack Lunch Restaurant, pool
Friday, May 9th	Visit Kombat Mine Visit Sabre Guchab Cu Project Drive back to Tsumeb	Kupferquelle Resort, Tsumeb	Kupfer St. and Hage Geingob St	+264 67 220 139	Pack Lunch Restaurant, pool
Saturday, May 10th	Drive to Tsumeb Visit Tsumeb Museum Vist Ojikoto Lake Visit Hoba Meteorite Etosha Wildlife Park night drive	Halali, Etosha Park	Located in Etosha Game Reserve	+264 - 61 - 246 427	Pack Lunch Restaurant in Hotel
Sunday, May 11th	Etosha Wildlife Park Drive to Outjo	Sâsa Safari Camp, Outjo	Turn off C38 onto M63, 4 km from Outjo	+ 264 81 129 0658	Breakfast included Pack Lunch
Monday, May 12th	Drive from Outjo to Lofdal Visit Lofdal Rare Earth Property	iGowata Lodge, Khorixas	King Justus Garoëb Ave, Khorixas, (South	+264 (67) 331592/3	Breakfast Pool in hotel
Tuesday, May 13th	Visit Husab Uranium Property Drive to Swapkomund	Hotel A la Mer, Swapkomund	4 Libertina Amathila Ave, Swakopmund	+264-64-404130	Breakfast included
Wednesday, May 14th	Drive to Windhoek Group Dinner	Hotel Uhland, Windhoek	147, Dr. Kenneth David Kaunda	(00264) 61 - 389 700	5 min walk from city center

Important things to note:

- Please keep your **boarding passes** and return them to Fabien. We will collect all boarding passes from students and industry members for tickets that were purchased by the UBC-SEG Student Chapter. We require boarding passes for receipt/accounting purposes. If you purchased your own flight, you may keep your boarding pass.
- We plan to purchase a ‘pay as you go’ cell phone upon arrival. This phone will be for emergency and mine contact purposes throughout the trip.

- Emergency procedure:
  Daily check in with UBC will be done by sending an "OK" message using the SPOT device.
  The message will be received by the two designed UBC contacts 1) Curtis Marr and 2) Monica Spisar.
  The message will be sent everyday by Esther Bordet between 6 and 9 pm Namibia time, corresponding to 9 am and 12 am Vancouver time.
  We will rent a satellite phone from the rental car company.

List of Hospitals

Town	Hospital	Address	Contact	Services
Windhoek	Windhoek Medi-Clinic	Heliodoor Street, Eros, Windhoek,	+26 461 4331000 hospmngrwindh@mediclinic.co.za Emergency: +26 461 22 2687	24 hour Emergancey clinic, pharmacy
Windhoek	Windhoek Central Hospital	Ooievaar St, Windhoek, Khomas	+264 (0) 61 203 3037	
Windhoek	Katatura Hospital	Independence avenue & Hans Dietrich Genscher St.	+264 (0) 61 203 2589	
Rehobeth	St. Mary's Hospital (private)	185 Church Street, Rehoboth	+264 062 52 2006 reohosp@mweb.com.na	Emergencies after working hours
Noordoewer	Noordoewer Clinic	C13, Noordoewer, Karasburg (rural) (NORTH SIDE OF TOWN)	+264 63 297 109	
Rosh Pinah	Rosh Pinah Public Clinic Sidadi Private Clinic	Ondye Street, Rosh Pinah	+264 063 27 4911	
Ais-Ais	*no hospital, would rely on basic first aid and Keetmanshoop hospital (see below)			
Keetmanshoop	Keetmanshoop State Hospital	Kronlein, Keetmanshoop	+264 63 2209000	
Mariental	Mariental State Hospital	Hospital St., Mariental, Hardap	+264 63 245250	
Otjiwarongo	Otjiwarongo State Hospital	Sonn Street, Otjiwarongo, (intersects with Tuin Rd)	+264 63 245250 hospmngrotjiw@mediclinic.co.za	24/hour Emergency clinic,
Tsumeb	Tsumeb State Hospital Tsumeb Private Hospital	Off of B1, Tsumeb Rev. James Ngapurue St., Tsumeb	+264 067 22 4300 +264 67 224 3000	
Etosha	Basic clinics in park			
Outjo	Outjo State Hospital	Hospital Rd./Etosha St., Outjo, Kunene	+264(0)67 313 250	Emergency clinic, pharmacy
Swapkopmund	Mediclinic Swapkopmund	Franziska van Neel Street, Swakopmund	24 hour emergency: +26 46 441 2200 hospmngrcotta@mediclinic.co.za	
NOTE: Dialing 911 from anywhere in Namibia will connect you to the Windhoek control centre for emergency calls, where you will be redirected. You will save time by calling the emergency services in your town.				

Namibia General Information

Compiled by Irene del Real

Namibia is in Southern Africa, bordered by South Africa, Botswana, Angola, Zambia and the Atlantic Ocean. Formerly a German colony, Namibia was administered by South Africa under a League of Nations mandate after WWI, and annexed as a province of South Africa after WWII. Transition to independence finally started in 1988 under the tripartite diplomatic agreement between South Africa, Angola and Cuba, with the USSR and the USA as observers, under which South Africa agreed to withdraw and demobilise its forces in Namibia.

Namibia boasts remarkable natural attractions such as the Namib Desert, the Fish River Canyon Park, Etosha National Park and the Kalahari desert. The Namib Desert and coastal plains in the west, the eastward-sloping Central Plateau, the Kalahari along the borders with South Africa and Botswana and the densely wooded bushveld of the Kavango and Caprivi regions. Despite its harsh climate, Namibia has some of the world's grandest national parks, ranging from the wildlife-rich Etosha National Park in Northwestern Namibia, to the dune fields and desert plains of the Namib-Naukluft Park in Western Namibia.

Namibia extends from 17°S to 25°S latitudes: climatically the range of the sub-Tropical High Pressure Belt, arid is the overall climate description descending from the Sub-Humid (mean rain above 500 mm) through Semi-Arid between 300 and 500 mm (embracing most of the waterless Kalahari) and Arid from 150 to 300 mm (these three regions are inland from the western escarpment) to the Hyper-Arid coastal plain with less than a 100 mm mean. Temperature maxima are limited by the overall elevation of the entire region: only in the far south, Warmbad for instance, are mid-40 C maxima recorded.

Providing 25% of Namibia's revenue, mining is the single most important contributor to the economy. Namibia is the fourth largest exporter of non-fuel minerals in Africa and the world's fourth largest producer of uranium. There has been significant investment in uranium mining and Namibia is set to become the largest exporter of uranium by 2015. Rich alluvial diamond deposits make Namibia a primary source for gem-quality diamonds. While Namibia is known predominantly for its gem diamond and uranium deposits, a number of other minerals are extracted industrially such as lead, tungsten, gold, tin, fluorspar, manganese, marble, copper and zinc. Potential offshore gas deposits in the Atlantic Ocean are also planned for extraction in the future.

Namibia has the second-lowest population density of any sovereign country, after Mongolia. The majority of the Namibian population is of Bantu-speaking origin – mostly of the Ovambo ethnicity, which forms about half of the population – residing mainly in the north of the country, although many are now resident in towns throughout Namibia.

Other ethnic groups are the Herero and Himba people, who speak a similar language, and the Damara, who speak the same "click" language as the Nama.

In addition to the Bantu majority, there are large groups of Khoisan (such as Nama and San), who are descendants of the original inhabitants of Southern Africa. The country also contains some descendants of refugees from Angola. There are also two smaller groups of people with mixed racial origins, called "Coloureds" and "Basters", who together make up 6.6% (with the Coloureds outnumbering the Basters two to one). There is a large Chinese minority in Namibia.

Whites (mainly Afrikaner, German, British and Portuguese) make up about 6.4% of the population; they form the second-largest population of European ancestry, both in terms of percentage and actual numbers, in Sub-Saharan Africa after that of South Africa. Most Namibian whites and nearly all those of mixed race speak Afrikaans and share similar origins, culture, and religion as the white and coloured populations of South Africa. A smaller proportion of whites (around 30,000) trace their family origins directly back to German colonial settlers and maintain German cultural and educational institutions.

The official language is English. Until 1990, German and Afrikaans were also official languages. Long before Namibia's independence from South Africa, SWAPO had decided that the country should become officially monolingual, consciously choosing this approach in contrast to that of its neighbor South Africa (which granted all 11 of its major languages official status), which was regarded as "a deliberate policy of ethno linguistic fragmentation. Consequently, English became the sole official language of Namibia. Some other languages have received semi-official recognition by being allowed as medium of instruction in primary schools.

Half of all Namibians speak Oshiwambo as their first language, whereas the most widely understood and spoken language is Afrikaans. Among the younger generation, English is rapidly gaining hold. Both Afrikaans and English are used primarily as a second language reserved for public communication, but small first-language groups exist throughout the country.

Geology of Namibia

Compiled by Dan Gainer and Kaleb Boucher

Cratons: Late Archean to Mesoproterozoic Terranes

The Angola and Kalahari cratons are made up of Late Archean to Mesoproterozoic terranes. They are largely covered by modern sediments and are composed of different metamorphic complexes. Each complex includes a variety of intrusive, sedimentary and volcanic rocks that were later metamorphosed at high pressure and temperature (granulite to amphibolite facies).

- **Late Archean complexes (~2.6 Ga):** The minor Epupa metamorphic complex (East of Möwe Bay) is composed by granodioritic to dioritic amphibolite-facies gneisses.
- **Paleoproterozoic complexes (~2.0 to 1.8 Ga):** The Epupa, Huab, Frootfontein, Abbabis, Hohewarte and Kangas Paleoproterozoic metamorphic complexes are mainly composes of granitic rocks at granulite to amphibolite facies grades including migmatites. Those metamorphosed intrusions are unconformably overlain by volcanic and sedimentary rocks forming the Orange River Group, which was then intruded by late the subvolcanic gabbro to granites of the Vioolsdriff Intrusive Suite.
- **Mesoproterozoic complexes (1.45 to 1.0 Ga):** They include: a) granulite to upper amphibolite facies gneisses of the Namaqua Mesoproterozoic metamorphic complex, b) bimodal volcanic successions of the Sinclair Supergroup with interbedded red beds and lacustrine shales hosting Red bed Cu deposits, and c) post-tectonic granitoids and pegmatites.

Neoproterozoic to Cambrian belts:

The volcano-stratigraphy recorded a complex history that evolved from a) continental rifting, b) local spreading and the development of the Damara-Adamastor and related oceans, c) later closing of these basins, and d) associated metamorphism and syn- to post-tectonic magmatism. The main events can be summarized as follows:

Early rift-related magmatism (~850 to 750 Ma) is characterized by the alkaline and carbonatite intrusions in the area of Khorixas, which host the Lofdal rare earth element (REE) deposit. Magmatism is also responsible of the emplacement of pegmatites such as the Sn-rich Uis pegmatite.

The Damara Supergroup (~850 to 535 Ma) includes the Otavi carbonatic platform and two of best examples of "snowball earth" glaciation:, the ~750 Ma Chous Formation and the ~636 Ma Ghaub Formation. Volcanic-sedimentary sequences host the Namib and Jormbira Pb-Zn SEDEX and VMS deposits and Othihase and Matchless Besshi-type Cu-pyrite deposits. The Rosh Pinah exhalative Pb-Zn-Ag-(Cu) deposit and Skorpion Zn-oxide deposit are hosted in the Gariep belt.

The close up of the Kaoko-Damara-Gariep basins between 595 and 550 Ma produced deformation, low to medium grade metamorphism, and large-scale uplift and erosion. The Mulden Group was deposited on top of the Damara Supergroup rocks and locally on top of the Otavi carbonate platform karsts. Continental collision and possibly subduction occurred between 595 and 575 Ma and generated transpressional tectonics and local metamorphism.

Several syn- to post-tectonic granitic intrusions occurred between 565 and 470 Ma (peaked at 535 Ma) and are linked to the mineralization at the Tsumeb Cu-Pb-Zn, Rossing U, Navachab Au deposits, and several ores associated to pegmatites such as Uis (Sn), described in further detail in subsequent sections in this guide. Similar intrusions are present in the Kaoko belts while Cambrian alkaline anorogenic complexes are present in the Kuboos-Bremen line.

The orogenic process at the origin of the Damara-Gariep basin closure and its erosion produced clastic sedimentation in a foreland basin constituted by the Nama Group, which started at 555 Ma, including the well-known Ediacaran fauna.

Early Paleozoic Sedimentation:

Gondwana intracratonic sediments from the Karoo Supergroup were deposited during a long-term transition from a wet and glacial polar climate, to higher latitude ariditization. Sedimentation started with the glacial conglomerates of the Dwyka Group at 300 Ma and continued through the Permian to include the Ecca Group: rhythmic siltsones/shales with dropstones in the base; delatic sandstones, carboniferous shales and minor carbonates in the mid-section; and oxidized siltstones and sandstones near the Permian/Triassic transition on the top. This group includes the well-known Mesosaurus fossils. Its correlation with fossils in the Paraná basin in South America was one of key evidences to support the plate tectonic theory. Jurassic aeolian sandstones are interbedded with 180 Ma basalts of the Rundu and Rooiwal Formations and intruded by dikes and sills, associated with the Paraná-Etendeka large igneous province.

Early Cretaceous Magmatism:

The extrusion of the Etendeka-Paraná large igneous province is associated with the continental break up and the rifting of the southern Atlantic Ocean. Large volumes of basalts (up to 1 km thick) and less rhyolities (mostly pyroclastic) were extruded between 133 and 131 Ma, and peaked at 132 Ma. This magmatism has been linked to mantle plumes associated to the continental break up, and linked to Walvis Ridge with today's magmatic activity at Tristan Da Cunha Island in the Atlantic Ocean near the mid-ocean ridge.

The Etendeka volcanism overlaps syn- and post-intrusion forming the anorogenic ring complexes of the Damaraland and Lüderitz provinces between 137 to 125 Ma. These complexes are roughly circular in plan view and range from subalkaline to alkaline compositions, including some carbonatites. Several of these complexes have diverse subeconomic mineralization (rare earths, fluorite, and phosphates are the most common) such as the Okorusu fluorspar deposit.

Late Cretaceous to Early Tertiary:

Select kimberlite and carbonatite intrusions represent remnants of the most recent magmatic activity in Namibia. The Gibeon area contains more than 90 kimberlite pipes and can host microdiamonds, although not economic.

Cenozoic:

The Kalahari Group covers significant portions of northern and eastern Namibia and includes conglomerates to mudstones deposited by paleofluvial systems. Ground water calcretes, such as the Etosha calcrete, were formed during this period. Sedimentation in the Kalahari Group ceased between 4 to 6 Ma, when aeolian reworking produced the Kalahari dune system and eroded the Etosha pan. The sedimentation of the fluvial to marine sedimentary Namib Group was concomitant with the Kalahari Group sedimentation but it is mostly associated to paleodeltaic sedimentation of the Orange River and its interaction with the southern Atlantic Ocean.

References:

Eberele, D.G., Andritzky, G., Hutchins, D.G. and Wackerle, R. 2002. "The regional magnetic data set of Namibia: Compilation, contributions to crustal studies and support to natural resource management." South African Journal of Geology, 205, 361-380.

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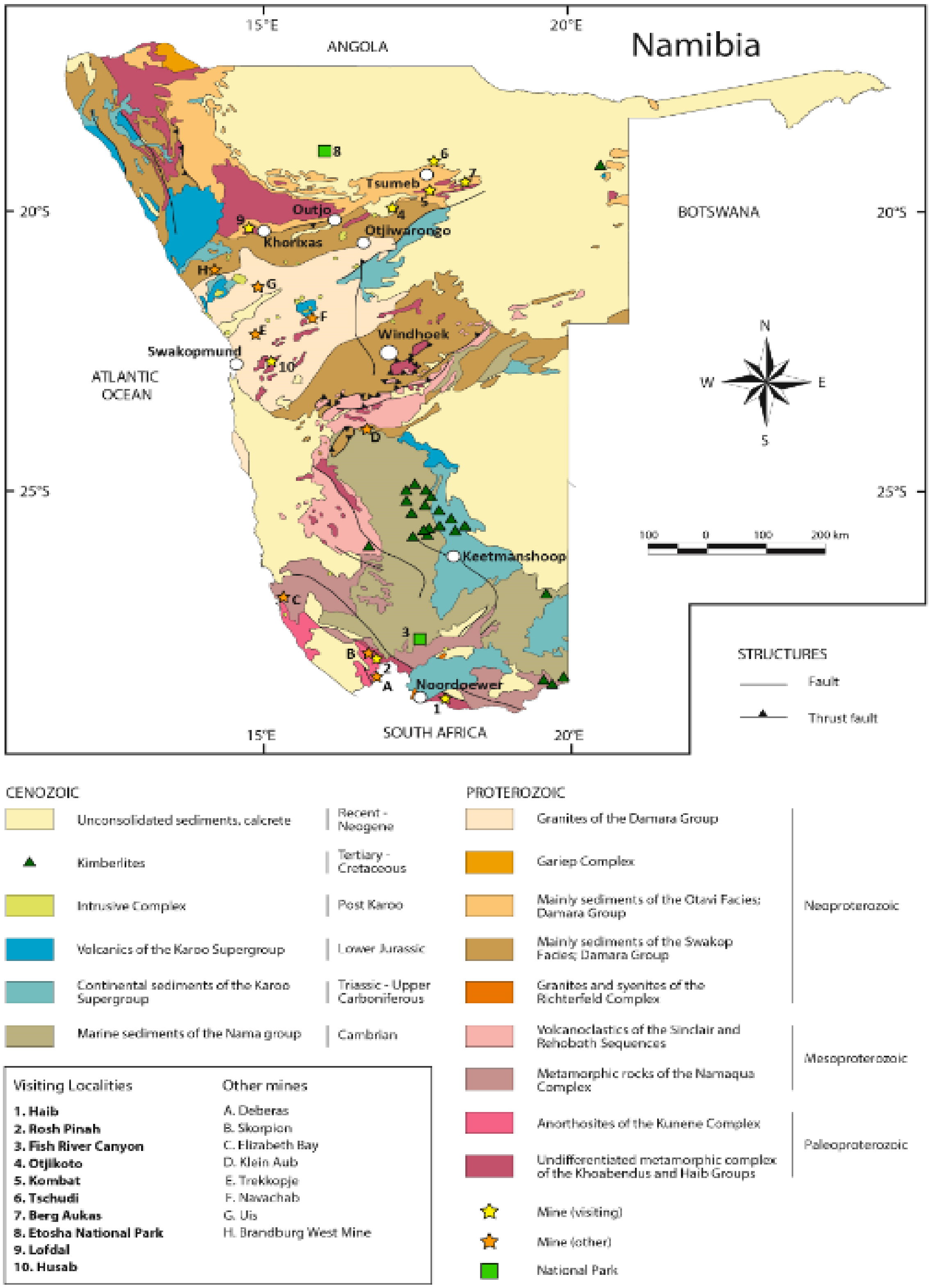
Miller, R. McG. The Geology of Namibia. Three volumes. Published by the Ministry of Mines and Energy Geological Survey of Namibia.

Gaucher, C., Frimmel, H. E., & Germs, G. B. 2010. "Tectonic events and palaeogeographic evolution of southwestern Gondwana in the Neoproterozoic and Cambrian." Developments In Precambrian Geology, 16295-316.



General geologic map of Namibia (modified from Schluter, T., 2006)

Day-by-day Trip Summaries:

May 1st: Jet-Lag Recovery

Compiled by Irene del Real

As the 1st of May is a holiday we will have half this day off so people can get a good rest after the long plane trip. Everybody is free to have lunch wherever they want.

After lunch (~1:30) we will go to the **Daan Vijoen Game Park**, this is an optional trip so if anybody feels that they need more rest they are free to stay in the hotel. The game park has more than 200 species of birds plus some wildlife like baboons, mountains zebras, springboks and elands. It's an ideal place to go for a hike or just enjoy the afternoon outside the city. During the evening we will have our first group dinner at Joe's Beerhouse and enjoy some local cuisine.

May 2nd: University of Namibia

Compiled by Erin Looby

Today we are visiting the University of Namibia in Windhoek. The school was founded in 1992. Presently, the school has approximately 13,000 students enrolled each year, and it comprises eight faculties.

We will be speaking with Dr. Ben Mapani, a senior lecturer at the University. Dr. Mapani's geologic interests include the tectonic evolution of cratons and mobile belts; structural control of ore deposits; environmental effects of tailings and rocks on water and soils.

Windhoek is also home to the Geological Survey of Namibia. At their headquarters is the National Earth Science Museum (weekdays 8:00– 13:00 and 14:00 –17:00). This is an option for an afternoon activity if there is interest and time permits.

May 3rd: Travel to the South

Compiled by Rachael Kramer

Lunch-stop in Gibeon

On our long drive to the southern part of the country we will be stopping in the town of Gibeon for lunch. A famous meteorite named after the town fell 200-220 million years ago and fragments of the meteorite are dispersed over an elliptical area 275 kilometres (171 mi) long and 100 kilometres (62 mi) wide. The term "Gibeon" encompasses the whole meteoritic material fallen from the sky during this fall. This material is classified as iron meteorite belonging to the chemical group IVA.

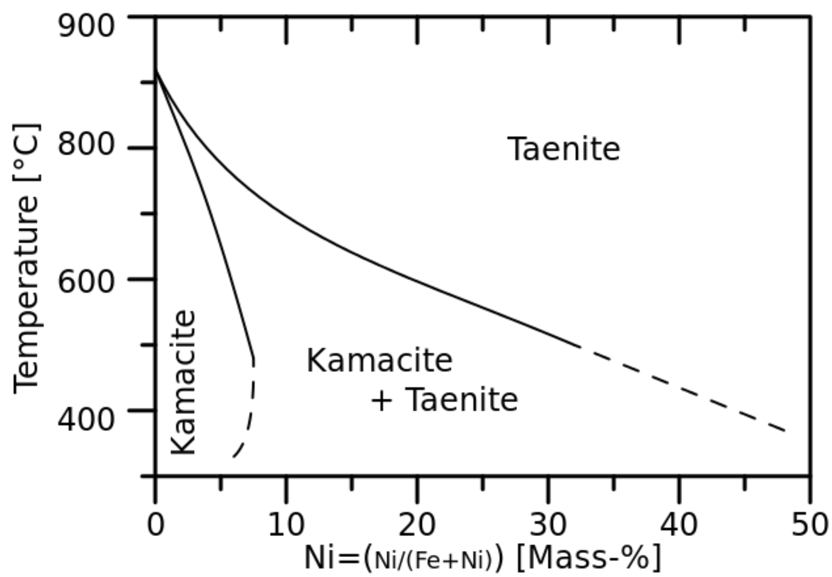
Gibeon meteorites are composed of an iron-nickel alloy containing significant amounts of cobalt and phosphorus. The crystal structure of this meteorite provides a classic example of fine octahedrite and the Widmanstätten pattern is appreciated for its beauty both by collectors and designers of jewelry.


Gibeon Meteorite showing Widmanstäatten pattern

Widmanstätten patterns, also called Thomson structures, are unique figures of long nickel-iron crystals. They consist of a fine interleaving of kamacite(α-(Fe,Ni); $Fe^{0+}{}_{0.9}Ni_{0.1}$) and taenite (γ-(Ni,Fe)) bands or ribbons called *lamellae*. Commonly, in gaps between the lamellae, a fine-grained mixture of kamacite and taenite called plessite can be found.

Iron and nickel form homogeneous alloys at temperatures below the melting point, these alloys are taenite. At temperatures below 900 to 600°C (depending on the Ni content), two alloys with different nickel content are stable: kamacite with lower Ni-content (5 to 15% Ni) and taenite with high Ni (up to 50%). Octahedrite meteorites have a nickel content intermediate between the norm for kamacite and taenite, this leads under slow cooling conditions to the precipitation of kamacite and growth of kamacite plates along certain crystallographic planes in the taenite crystal lattice.

The formation of Ni-poor kamacite proceeds by diffusion of Ni in the solid alloy at temperatures between 700 and 450°C, and can only take place during very slow cooling, about 100 to 10,000°C/Myr, with total cooling times of 10 Myr or less. This explains why this structure cannot be reproduced in the laboratory.



Phase diagram above shows how the pattern forms. First meteoric iron is exclusively composed of taenite. When cooling off it passes a phase boundary where kamacite is exsolved from taenite. Meteoroic iron with less than about 6% Nickel (Hexahedrite) is completely changed to kamacite.

Brukkaros Mountain

This carbonatitic volcano dominates the skyline to the west of the main road between Mariental and Keetmanshoop. The name 'Brukkaros' is the German equivalent of the Nama name *Geitsigubeb*, referring to the mountain's supposed resemblance to the large leather apron traditionally worn by Nama women around their waist.

See appendix for more information

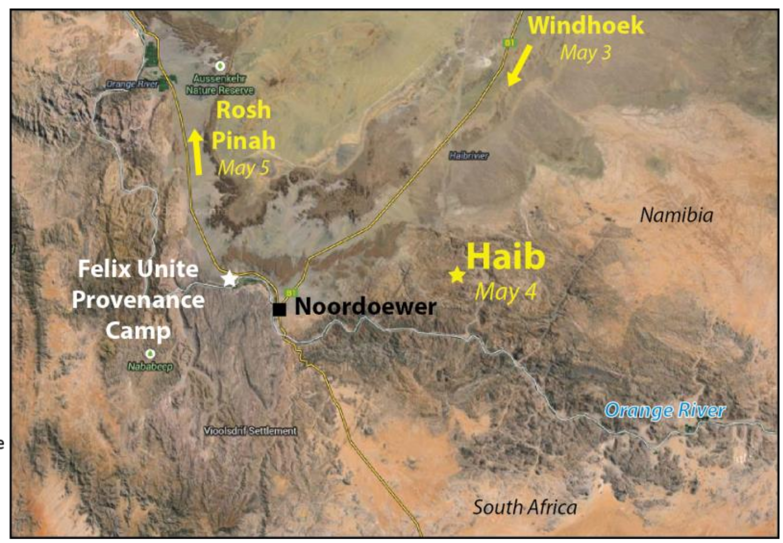
May 4th: Haib Porphyry

Compiled by Fabien Rabayrol

Departure from Felix Unite Provenance Camp hotel at 8:00 am. Visit from 9 am to 4 pm on site that will include map and section review, core review, and outcrop visit. Return to Rosh Pinah at 6 pm.

History:

Although discovered at the end of the 19th century by German prospectors, the first mining operations were completed by the prospect-owner George Swanson after World War II. Development phases were then conducted by different companies that successively include Falconbridge of Africa, Rio Tinto Zinc Corp, the Namibian Copper Joint Venture, and Deep South Mining Company. Teck Resources Ltd. (70%, operator) and the joint-venture of Deep South Mining and Afri-Can Marine Minerals Corp (30% for both) have owned Haib since 2008.



Left: Map of Namibia; Right: Location map of the Haib deposit and accommodation at the Felix Unite provenance Camp.

Description:

Haib is located in the Karas region in southern Namibia, 8 km from the Orange River and the South African border, 650 m above sea level. Haib is a low-grade porphyry Cu-Mo deposit hosted within a 1.80 Ga quartz-feldspar porphyry (QFP, quartz diorite composition) and feldspar porphyry (FP, andesitic composition) as a part of the Vioolsdrif volcanic suite in the Richtersveld province. The sequence underwent low grade regional metamorphism (greenschist facies). A potassic hydrothermal alteration zone coincides with the main mineralized area, and is surrounded and overprinted by phyllic and propylitic alteration haloes. Silicification, sericitisation, chloritisation and epidotisation are widespread. Mineralization includes disseminated sulphides such as chalcopyrite, molybdenite, and bornite, as blebs and veinlets within the host rock. Hypogene mineralization is overlain by near-surface Cu-rich supergene zone (<30 m) that includes, among others, malachite and azurite.

The Namibian Copper Joint Venture company confirmed the indicated resources of the Haib deposit to be of the order of between 244 Mt at 0.37% and 292 Mt at 0.46% Cu in 1996. These are historical data as prepared before the NI 43-101 publication. More recent drilling carried out by Teck in 2010 intercepted mineralization along 824 m at an average grade of 0.285% Cu.

Left: Haib deposit; Right: Cabanas from the Felix Unite Provenance Camp

Safety:

Personal field boots, hat and long-sleeve shirt only; disclaimer to sign up on site before going to the field.

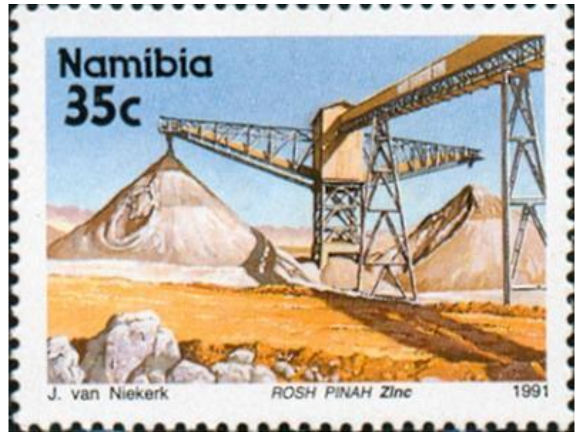
References:

Afri-Can Marine Minerals' website:
http://www.afri-can.com/files/ssparagraph/f1059364167/haib_43_101_oct_2004.pdf

Barr, J. M., and Reid, D. L., 1993, Hydrothermal alteration at the Haib porphyry copper deposit, Namibia: Stable isotope and fluid inclusion patterns: Communs Geological Survey of Namibia, v. 8, P. 23-34.

May 5th: Rosh Pinah Pb-Zn-(Cu-Ag) Mine

Compiled by Erin Looby



History:

The Rosh Pinah Mine is located in southern Namibia, 20 km north of the South African border. The deposit was discovered in 1963 by M.D. McMillan from the University of Cape Town (Page and Watson, 1976). Subsequent to its discovery, an intensive drilling program run by the South African Iron and Steel Industrial Corporation lead to commencement of mine production in 1969 by the subsidiary company, Incor Zinc Ltd. Presently, GlencoreXstrata owns 80.1% of Rosh Pinah and the present measured and indicate resource is 10.2 Mt with 7.9% Zn, 1.9% Pb, and 37 g/t Ag (GlencoreXstrata, 2013).

Description:

The deposit is situated in the Kapok, or Rosh Pinah formation of the Gariep Belt. Rocks of the former are thought to have formed in a continental rift setting in anoxic conditions (Frimmel and Lane, 2005) with bimodal volcanism. The formation consists of siliciclastic and minor carbonate rocks (~720-~750 Ma; Meert and Van der Voo., 1994), and felsic volcanic lava flows and pyroclastic deposits (~750 Ma; Frimmel et al., 1996). Evidence points towards the Rosh Pinah forming at the same time as sedimentation (Frimmel et al., 1996). Host rocks and the deposit were deformed and metamorphosed to upper greenschist to amphibolite facies at ca. 545 Ma (Frimmel et al., 1996).

Sphalerite, galena, chalcopyrite and pyrite mineralization is stratabound and strataform, and hosted in silicified shale, arenites and dolomitized carbonates. Copper is genetically linked to rift related felsic volcanism, while the source of Pb and Zn are assumed to be from the Mesoproterozoic basement (Frimmel and Lane, 2005). Ore fluids may have originated from rifting magmatism (Frimmel and Board, 2000).

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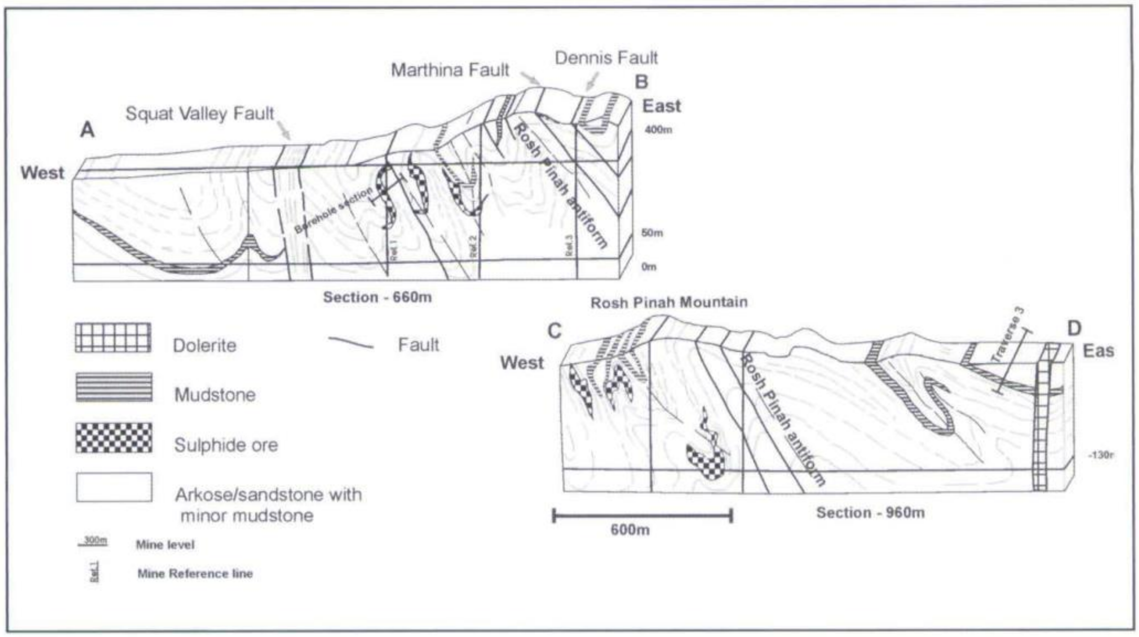

Figure 5. Post-depositional deformation as seen along sections through the type areas of the Rosh Pinah Formation (for locality see Figure 6). Compiled from borehole intersections (unpubl. data Kumba Resources).

References:

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Page, D. C., & Watson, M. D. (1976). The Pb-Zn deposit of Rosh Pinah Mine, South West Africa. Economic Geology, 71(1), 306-327.

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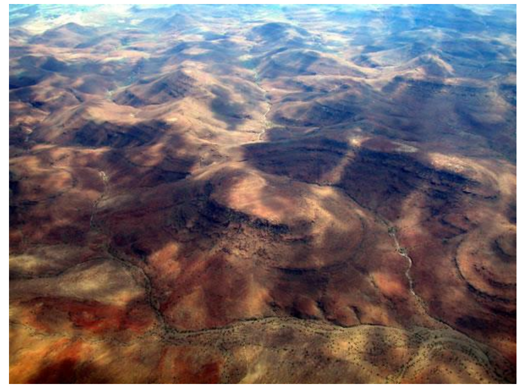
May 6th: Fish Canyon Park

Compiled by Esther Bordet



We will arrive at the Canyon Roadhouse, near the Fish River Canyon, on the evening of May 5th. Facilities at the Canyon Roadhouse include a restaurant, bar, swimming pool. Breakfast is included.

The day of May 6th will be devoted to visiting the park and its surroundings. There will be a few options on how to spend your day at the Fish River Canyon:

The Fish River Canyon is the second largest canyon in the world, for a total of 160 km long and up to 27 km wide. Depth can reach 550 m in some places. Dolomite strata that form the Fish River Canyon are about 650 Ma.

Fish River Canyon viewpoint

The Canyon Roadhouse is located about 30 km from the main lookout point at the Fish River Canyon, Hobas, so we will be able to drive there and enjoy astonishing views of the canyon. In addition, the park hosts rare plants (there are 100 endemic succulents), several species of mammals, such as wild horses, Mountain Zebra (Hartman Zebra), kudu, leopard, springbok, troops of Chacma baboons and isolated groups of klipspringers. Bird-life includes pelicans, black eagles, fish eagles, kingfishers, lovebirds, wild ostrich and various species of waterfowl and wading birds. Bring your camera and binoculars!

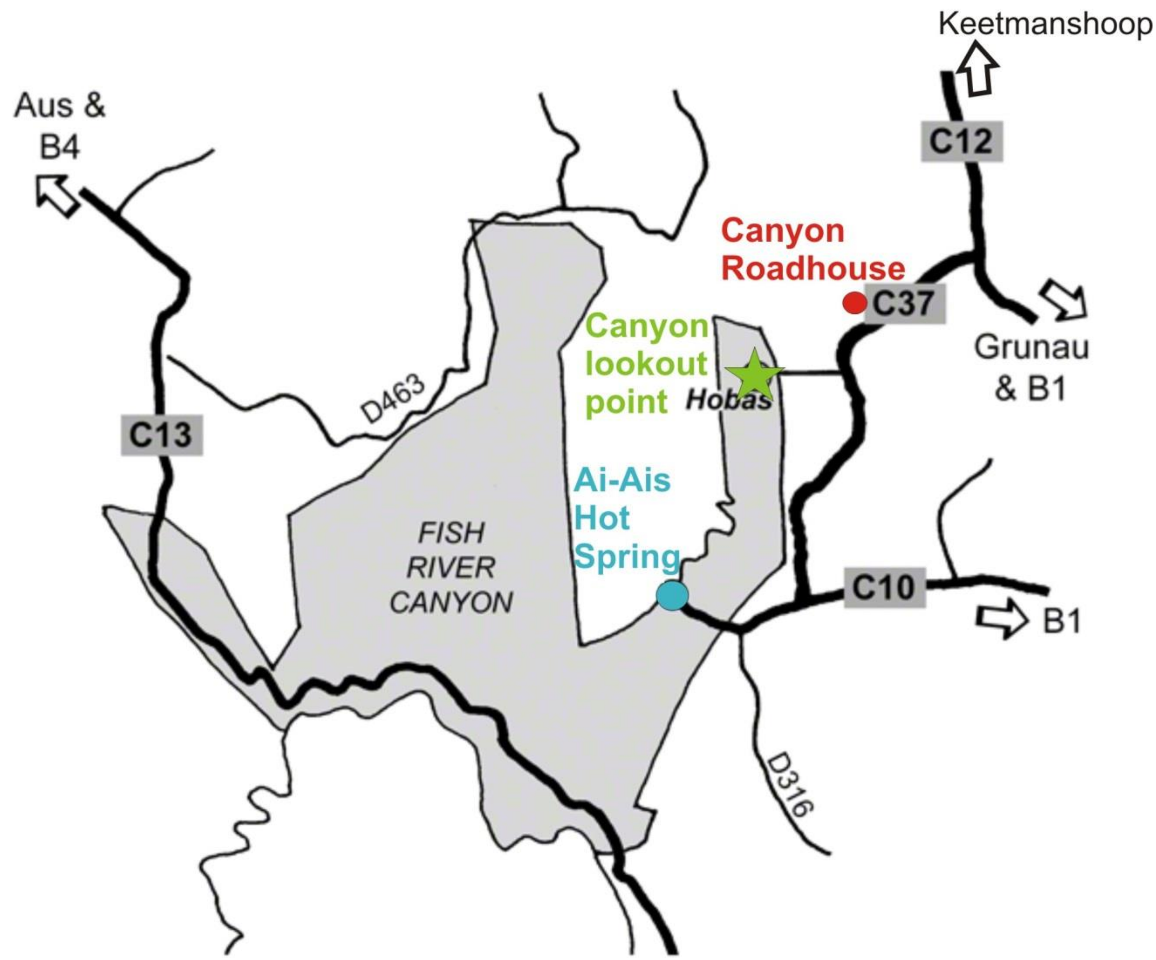
Please note that hiking inside the canyon can only be done if you are in possession of a hiking permit. We are not recommending hiking down the canyon. Also, watch out for scorpions and bring lots of water! Please note: “Picking of plants, removal of seeds, rocks, crystals or driftwood is an offence”.

For more information refer to appendix or visit http://www.namibian.org/travel/namibia/fish_river.html

Ai-Ais hot springs (at Ai-Ais Hot Spring Resort)

Depending on how much time we spend in the canyon, we could consider spending some relaxing time at the Ai-Ais Hot Spring Resort, about 60 km south of the Fish Canyon lookout.

We will hit the road again around 3 pm, drive to Keetmanshoop (about 3 hours drive) and spend the night of May 6th at the Central Lodge in Keetmanshoop (right). The Central Lodge is situated in the historical centre of Keetmanshoop. There is a fully equipped and licensed restaurant that is open throughout the day, an outdoor swimming pool, secure parking, and email facilities. Breakfast is included.



May 7th: Drive to Ojiwarongo

Compiled by Rachael Kramer

Stop in Mariental or Hardap Dam

The Hardap Dam, Namibia's largest dam, was first proposed in 1897 by German geologist Dr. Theodor Rehbock. Construction began 63 years later following a number of surveys. The 252 km^2 game reserve surrounding the dam was later proclaimed in 1968. The name Hardap derives from the Nama word meaning 'nipple' or 'wart', which is how the surrounding area of low conical-shaped hills appeared to the early inhabitants. The dam has a surface area of 25 km^2 and provides water to irrigate 2500 hectares of wheat, maize, lucerne, cotton, grapes and vegetables, all cultivated on small holdings. The dam is also an anglers' paradise, being well stocked with species such as yellowfish, carp, mullet and catfish. The Hardap dam is 15 km north of the town of Mariental.

May 8th: Ojikoto Mine

Compiled by Tim Jusupov

Preliminary Itinerary:	Otjikoto Mine , May 8, 2014
08:00	Arrival Otjiwarongo B2Gold core shed
08:00 - 09:00	Geology presentation and discussion
09:00 - 11:00	Otjikoto deposit and Wolfshag zone core display & discussion (B2Gold core shed)
11:00 - 12:00	Drive to Otjikoto Mine
12:00 - 13:15	Safety induction & process plant construction tour
13:15 - 13:45	Lunch at construction camp– B2 will arrange
13:45 - 15:45	Open pit & site tour (may need to schedule around a blast)
15:45 - 17:30	Tailings facility overview -> Game farm – pan, treehouse and education centre
19:00 - 19:30	Arrival in Tsumeb

History:

The Otjikoto deposit was discovered under calcrete cover in 1999 during a base metal exploration program that tested a strong airborne magnetic anomaly interpreted as a base metal and gold skarn target around a deep-seated granite batholith. The discovery drillhole targeted a ground magnetic and IP anomaly. Soil geochemistry was not used as it was believed that the thick calcrete would mask base metal responses. Limited RAB drilling did, however, intersect anomalous gold values below the calcrete in the area.

The Otjikoto gold deposit with probable reserves of 29.4 Mt @ 1.42 g/t gold (1.34 million ounces gold) is currently being developed by B2Gold Corp. The Otjikoto open pit gold mine is expected to produce an average of 112,000 ounces gold per year over an initial 12-year life.

Resource definition drilling is currently being completed on the new Wolfshag zone discovery, adjacent to the Otjikoto deposit on the northeast (down-dip) side. The current Wolfshag zone inferred resource is 6.8 Mt @ 3.2 g/t (703,000 ounces gold) and is expected to increase the production and/or life of the Otjikoto mine.

Regional Geology:

The meta-sedimentary units in the Otjikoto region were deposited in the Northern Rift (intracratonic rift) followed by the continental Outjo Sea of the Neoproterozoic Damara Orogen. The Northern Rift/Outjo Sea depositional basin has been divided on a tectonic-stratigraphic basis into the North Zone (NZ) and the north Central Zone (nCZ).

The Otjikoto deposit is hosted by deep water turbiditic sediments of the Okonguarri Formation (Swakop Group). The Okonguarri Formation is underlain by "Snowball-Earth" diamictite, carbonate markers and intercalated iron formations of the

Chuos Formation (approximately 730 Ma to 720 Ma) and conformably overlain by the Ghaub Fm diamictite and cap carbonate (635 Ma). The Ghaub Formation is in turn overlain by carbonate dominated Karibib Formation. Thick marble units of the Karibib Formaiton are the only outcropping units in the Otjikoto area, which is covered by thick calcrete (10 to 15m).

The Otjikoto area was deformed during the collision of the Congo Craton and the Kalahari Craton resulting from subduction and closure of the Khomas Ocean, to the southeast, from approximately 580 Ma to 542 Ma. Peak deformation (D2) between 550 and 545 Ma resulted in the reactivation of northern marginal faults of the intracratonic Northern Rift to develop the major Khorixas-Gaseneirob Thrust (KGT) and associated north-vergent folding and thrusting of the NZ sedimentary package.

The post-tectonic regional metamorphic peak in the Damara Orogen is dated at 535 Ma. Peak metamorphic grade is generally upper greenschist in the north-eastern part of the Damara Orogen. Indications of higher grade metamorphism in the Otjikoto area (upper amphibolite) could be related to later peak D2 deformation and peak metamorphism (poorly dated at ca. 514 Ma), as well as granite emplacement in the nCZ (and in parts of the adjacent NZ).

The granite emplacement and doming took place in a backarc environment with a compressive stress regime marked by dextral shearing and rotation. The Navachab gold mineralization (in the Southern Central Zone) was deposited during the period from 515 Ma to 495 Ma. Some Damaran lineaments and structures were rejuvenated during Karoo and early-Cretaceous events.

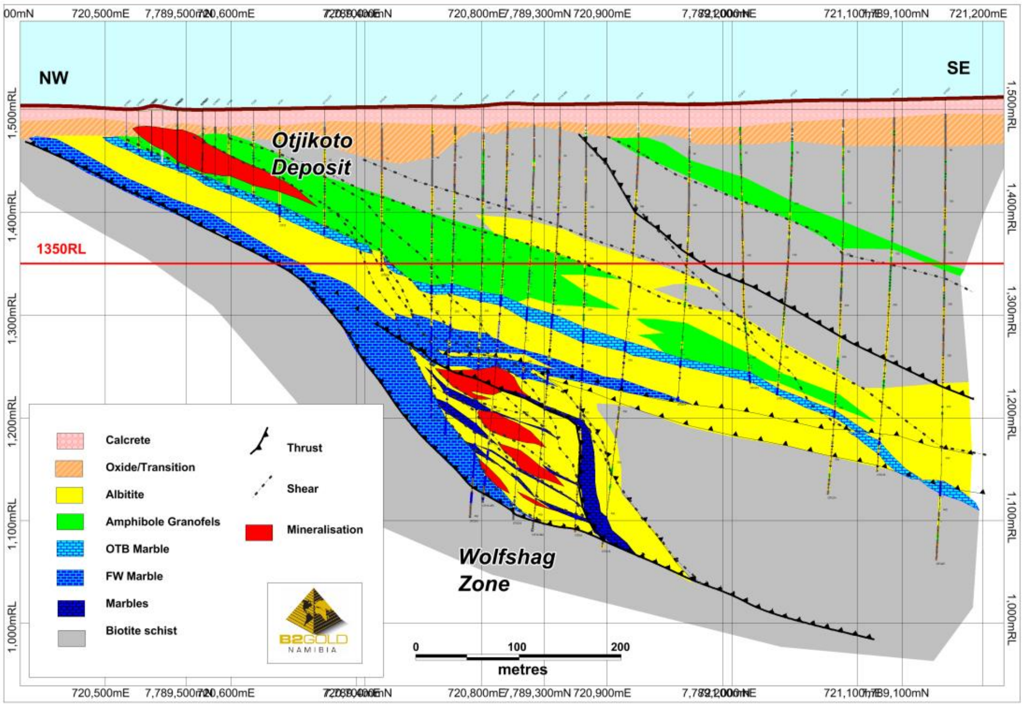
Geology:

The Otjikoto area mineralization is principally hosted by strongly albitized meta-greywacke units intercalated with coarse-grained marbles and biotite garnet schist.

Albitized units are classified into the following rock types: albitite is a fine grained massive granofels composed of albite (~ 70%), dolomite (~15%) and variable amounts of ankerite, amphibole, tourmaline and quartz. Albbio is gradational between albitite and biotite schist depending on the amount of fine to medium grained biotite and degree of albitization. Amphorn (and Garampho) are highly albitized, massive granofels with medium grained amphibole (and garnet). The texture of the rock indicates post peak metamorphic growth of amphibole (and garnet) at the expense of earlier mafic minerals in Albitite and Albbio. Bbandamp is strongly laminated with an overall composition similar to Amphorn.

The OTB marble has a constant thickness of ~10m, is recrystallized, and dips at 25 degrees to the east, forming the main structural/stratigraphic marker in the deposit area.

The Footwall marble, which is thicker but less regular, occurs about 30m below the OTB.



Geology and mineralization of the Otjikoto deposit and Wolfshag zone

Gold in the Otjikoto deposit occurs in pyrrhotite-pyrite-magnetite veins with variable amounts of carbonate minerals and coarse-grained garnet and notably low quartz content. The veins are characterised by massive sulphides ± magnetite and have brittle-ductile textures indicative of compressive stain with a tensional component. They are principally hosted by albitized rocks (mainly Amphorn and Bbandamp) in the OTC unit directly above the OTB marble. Higher grade en echelon shoots, which plunge at about 15 degrees to the SE, are defined by higher concentrations of sheeted veins. Coarse-grained gold is common.

The Wolfshag zone is situated below the Footwall marble and consists of shallow dipping, SE plunging stacked shoots that have been intersected over a distance of 1.6 km. The mineralized shoots are hosted by albitite units with intercalated thin marble units between thicker marble units to the east and west. The main WA shoot is 60 to 100 m wide and 15 to 30 m thick. Gold occurs in calcite-pyrite ± magnetite veins and replacement zones. The brittle veins, which are characterized by blotches of coarse-grained pyrite, generally occur in massive albitite units and are the most important gold hosts. Ductile replacement zones with finer grained magnetite and pyrite are generally associated with thin calcareous metasediment and marble bands. Tension gash veins are minor but important gold hosts at both deposits. The higher grade Wolfshag zone has less coarse gold.

Structural control on the mineralization is interpreted to be early thrust/fold duplex structures (peak D2 deformation) that have influenced the development of later dextral shear zones.

Albitization is thought to have been an early alteration event associated with thrusting. The gold mineralization and amphibole-garnet alteration at Otjikoto and carbonate (calcite and ankerite) alteration at Wolfshag are interpreted to be related to the post peak metamorphic shearing event.

The striking differences between Otjikoto and Wolfshag are ascribed to differences in host rock composition and competency. Otjikoto host rocks are interpreted as albitized mafic greywacke while the Wolfshag host rocks are albitized interbedded carbonate-rich greywacke.

May 9th: Kombat Copper and Sabre Resources

Compiled by Esther Bordet

We will first visit the Kombat Mine, ran by Kombat Copper, a Canadian copper exploration and development company. The Kombat Mine is located about 50 km south of Tsumeb. We will spend about 3 hours at Kombat visiting their surface facilities (underground is currently flooded) including mine infrastructure and a small iron-manganese open pit. We will eat a packed lunch and travel along strike to Sabre's property.

At Sabre, we will get an outline of their exploration projects in the region. Core from their Guchab Cu project (~10km along strike from Kombat) will be displayed, and we will then visit the Guchab Cu deposit (i.e., outcrop and historic surface workings) during a ~3 km hike atop rugged dolomite karst. Depending on time, there will be an opportunity to view drill core from Golden Deeps' Deblin Cu deposit, and also from MVT-style Zn-Pb deposits.

After the visit, we will drive back to Tsumeb and spend another night at the Kupferquelle Resort.

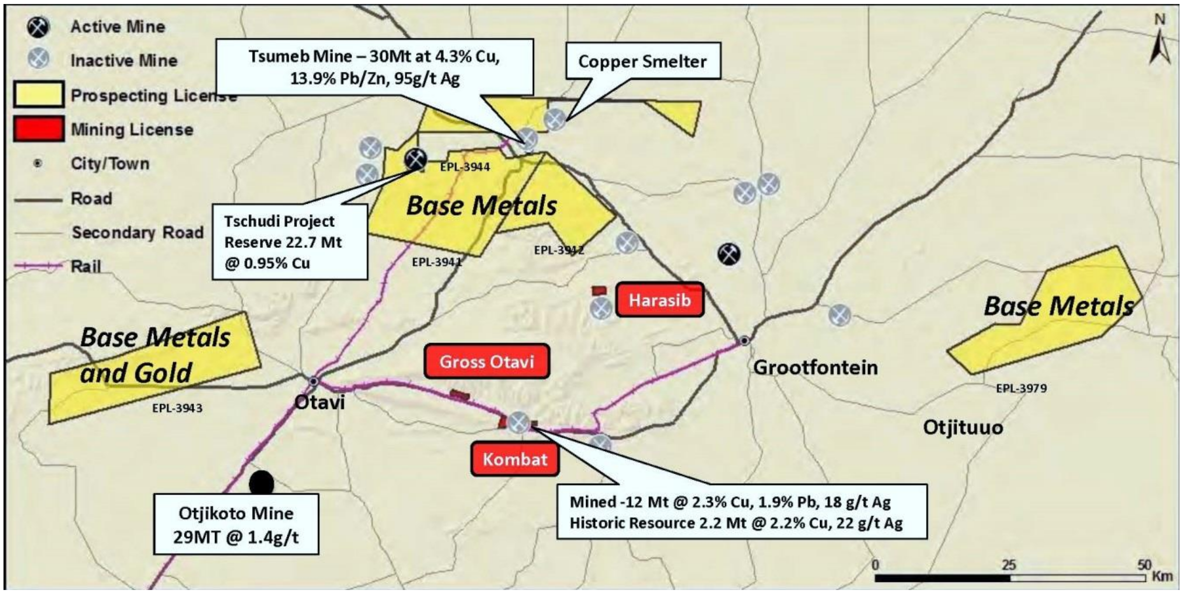
Geology:

Kombat is a high-grade copper project, with a historic production of 8.7 Mt Cu at 3.3%, plus Ag, Pb, and Zn. The mine was operational from 1963 to 2009. Since 2014, Kombat Copper has focused at bringing the mine back into production, with a potential open pit style of mining. Recent exploration drilling intersected 6.03 m of 1.55% Cu, 6.03% Pb, 4.09% Zn and 18.4 g/t Ag.

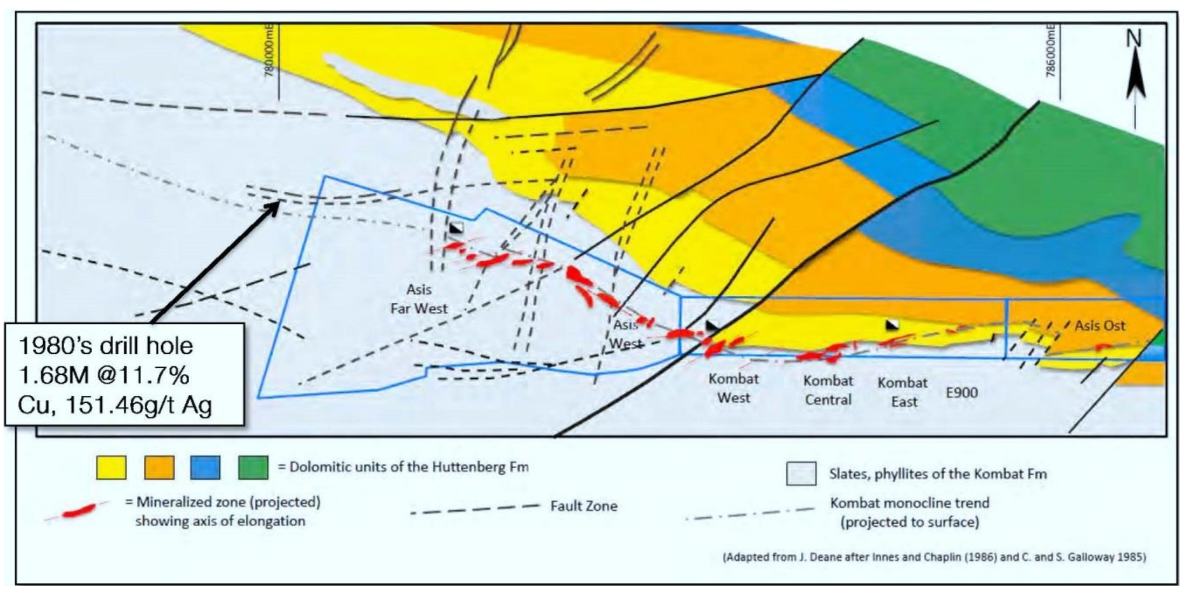
Kombat is situated on the northern flank of the Otavi Valley Syncline, along the same strike to the southwest of the Tschudi deposit (50.1 Mt at 0.86% Cu and 10 g/t Ag). The Kombat Mine is hosted in a Late Proterozoic carbonate platform sequence. Mineralization is hosted in the dolostone of the Hüttenberg Formation, and more specifically occur as lenses below monoclinal flexures on the contact between phyllite of the Kombat Formation and the Hüttenberg Formation. The ore loci are further defined by breccia bodies in dolostone and a variety of structural controls (e.g. steeply-dipping zones of shearing, net-vein fractures, joints, and fracture cleavages).

Ore types comprise an epigenetic, hydrothermal and metasomatic replacement, as well as fracture-fill Cu-Pb-(Ag) deposit. Different types of mineralization are described such as the massive/semi-massive sulphides, mineralized net-vein fractures system, Fe-Mn oxide/silicate assemblage and mineralized fracture fillings.

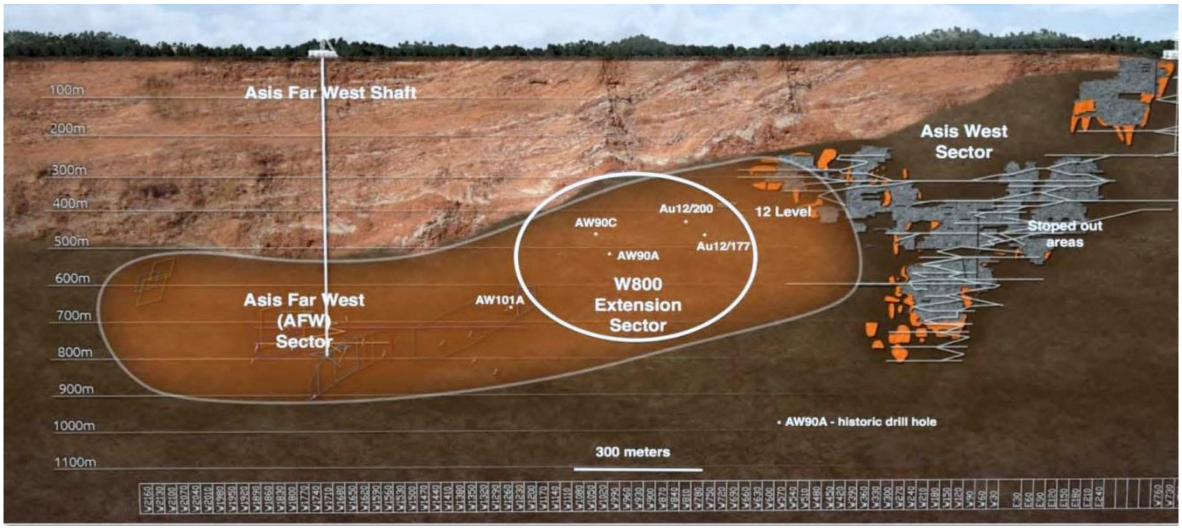
Pre-mineralization alteration, including calcitization, Mn-alteration, silicification, is promoted by the presence of sedimentary and tectonic breccia, and vein fracturing.



Map of Kombat area.



Cross Section of Kombat mineralized zone.



Cross Section of kombat Asis area.

References

http://www.kombatcopper.com/

Minz, F. The Kombat ore deposit, Otavi Mountainland (Northern Namibia), 18 p.

May 10th: Tsumeb Museum and Hoba Meteorite

Compiled by Paula Brunetti

This day will start in Tsumeb, one of Namibia's most charming towns. Tsumeb is the capital city of the Oshikoto region in northern Namibia and is the closest town to Etosha National Park.

Tsumeb hosts a world-famous Cu-Pb-Zn-Ag-Ge-Cd mine, renowned for a wealth of rare and unusual minerals. Between 1905 and 1996, the mine produced about 30 million tons of ore yielding 1.7 Mt copper, 2.8 Mt lead 0.9 Mt zinc, as well as 80 t germanium. The average ore grade was 10% Pb, 4.3% Cu, 3.5% Zn, 100 ppm Ag, 50 ppm Ge. The mine closed in 1996 for economic reasons.

Various geological attractions are available near by the town; the Tsumeb Museum, Lake Otjikoto and the Hoba Meteorite.

Around noon we will be driving to Etosha National Park.

Option A

Planned Schedule	Activity
9:00-9:40	Tsumeb Museum
9:45-11:00	Drive to Hoba Meteorite
11:00-11:45	Hobe Meteorite Visit
12:00-15:30	Drive to Etosha Park

Option B

Planned Schedule	Activity
9:00-10:15	Tsumeb Museum
10:45-11:30	Lake Otjikoto
11:30-14:00	Drive to Etosha Park

Tsumeb Museum:

Located on Main Street next to the Lutheran Church, facing the park, this museum houses excellent display of the area's rare minerals and mining history, as well as cannons and other artifacts recovered from Lake Otjikoto.

Otjikoto Lake:

In such a dry country as Namibia natural water occurrences were always of special importance. Therefore, the two lakes (Otjikoto and Guinas Lakes) have been well known to the native inhabitants, the Bushman, since ancient times, long before the lakes were 'discovered' by two European explorers in 1851. 'Otjikoto' is the Herero word for 'deep water'. Both lakes are situated in the approximately 700 million year-old dolomite rocks on the northwestern side of the Otavi Mountains. They represent typical karst lakes with the development of dolinen.

Dolinen (i.e., sinkholes) are very common karst phenomena. They are formed if karst cavities develop at a shallow depth below the earth's surface. By the continuous increase in the size of the cavities, their roofs were no longer able to carry the covering rock load. The roofs cave in and round, funnel-shaped collapse craters are formed, which are called dolinen. If the floor of the dolinen lies deeper than the groundwater level, or the groundwater level rises, then these dolinen are filled with water and therefore karst lakes are formed on the surface.

(Left) Germanium bearing Beudantite contrasting well against gunmetal-grey and brightly iridescent crystals of Chalcocite, both upon a Germanium bearing Sulphide matrix. (Right) Otjikoto Lake.

Hoba Meteorite:

The Hoba Meteorite is located in Grootfontein, in the Otjozondjupa Region of Namibia. The Hoba Meteorite is the largest known single meteorite of its kind lying on the surface of the earth. Its mass is estimated at around 60 metric tonnes and measures 2.95m x 2.84m. The thickness varies between 75 and 122cm.

The Hoba Meteorite, is classified as an ataxite, and consists of 82,4 % iron, 16,4 % nickel and 0,76% cobalt, as well as traces of carbon, sulphur, chromium, copper, zinc, gallium, germanium and iridium.

Intergrowths of its main minerals kamacite (Ni-Fe alloy with 57 % Ni) and taenite (Ni-Fe alloy with up to 65 % Ni). As minor constituents it also contains the more rare meteoritic minerals schreibersite [(FeNi) P], troilite [FeS] and daubreelite [FeCrS]. In-situ oxidation has created a 30 cm thick layer of magnetic, dark-brown iron shale composed of limonite, magnetite and trevorite [NiFeO], which separates the meteorite from the surrounding calcrete.

Hoba Meteorite site.

References:

http://completenamibia.com/Geology.Sites.Northeast.htm
http://www.namibian.org/travel/meteorites/hoba-meteorite.html
http://www.mme.gov.na/gsn/posters/geological-attractions/

May 11th: Etosha Wildlife Park

Compiled by Dan Gainer

Background Information:

The Etosha Pan is a vast, bare, open expanse of shimmering green and white that covers around 4,800 km², nearly one quarter of Etosha Park. At 130 km long and up to 50 km wide in places, it is the largest salt pan in Africa and is even visible from space. The pan was originally a lake but over time the Earth's climate forced the rivers that once fed the lake to change course and flow into the Atlantic Ocean.

In the language of the Ovambo tribe, Etosha means 'great white place', a name passed on to the first Europeans to come across this "immense hollow", Sir Francis Galton and Charles Andersson in 1851, with the help of travelling Ovambo traders. The area was originally inhabited by the Heli/ om- people who were well-known hunters and gatherers and co- existed in harmony with huge herds of wildlife in the area. It was only in 1851 when the pan first became known to Europeans. Explorers Charles Andersson and Francis Galton reached a cattle post called Omutjamatunda, which is today called Namutoni. The two explorers provided the first written account of the pan.

It is believed that this natural mineral pan was first formed over 100 million years ago**.** About 16,000 years ago, the Kunene River in Angola would have flowed all the way to Etosha, forming, for some time, a huge and deep lake. But the river would later change its course due to tectonic plate movement and head for the Atlantic, causing the lake to slowly dry up and leaving the salt pan behind.

San Legend has it that the formation of the Etosha Pan resulted from a small village being raided and everyone slaughtered except the woman. One of the women was so upset by the death of her entire family that she cried until her tears formed a massive lake that eventually dried up and left behind a huge white pan.

Salt springs on the pan have now built up little hillocks of clay and salt that is used by some of the park's wildlife as salt licks. In the wet season, parts of the pan form rain water pools and in particularly wet years the entire pan becomes a lake once more, standing at about 10cm deep and drawing thousands of migrating flamingos.

Etosha Pan is designated as a World Wildlife Fund Ecoregion and was also used as a backdrop during the filming of 2001: A Space Odyssey.

Wildlife:

The large mammals in Etosha National Park include lion, leopard, elephant, rhino, giraffe, wildebeest, cheetah, hyena, mountain and plains zebra, springbok, kudu, gemsbok and eland. Among the smaller species you will find jackal, bat-eared fox, warthog, honey badger and ground squirrel. The park is home to 114 species of mammals**.**

See appendix for more information

May 12th: Lofdal Rare Earth Property

Compiled by Matt Manor

The Lofdal rare earth element (REE) project is located 31 km northwest of Khorixas (450 km northwest of Windhoek) in northwestern Namibia, Africa. Namibia Rare Earths, Inc. is currently in the exploration stages of delineating a heavy REE (HREE)-enriched (i.e., Eu, Gd, Tb, Dy, Y) deposit, a commodity highly sought after in today's market.

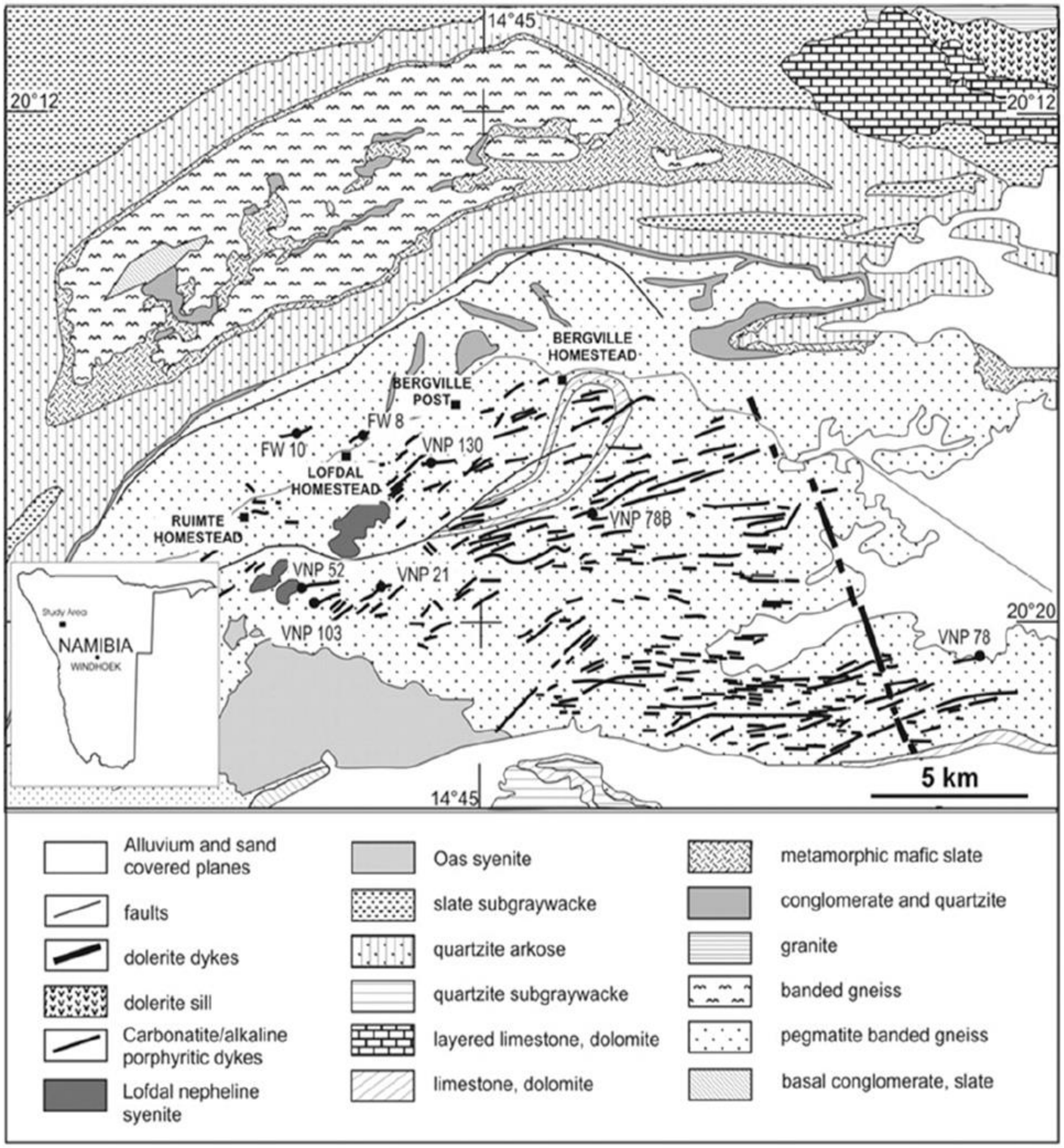
Itinerary	
6:30 am	Depart Outjo for Khorixas
8:00-8:30 am	Arrive in Khorixas and Namibia Rare Earth's core facility; geological overview of the region and project.
10:30 am	Leave for Lofdal property
11:00-5:00 pm	Field tour of the Lofdal property (bring sack lunches)
5:00 pm	Depart for Khorixas for evening at iGowata Lodge

Geology:

The Lofdal REE deposit is hosted by carbonatite dikes of a silicate-carbonatite intrusive complex of the Damara Supergroup (850-535 Ma), which intruded the Archean Huab Metamorphic Complex in the mid-Neoproterozoic during rifting between the Congo and Kalahari cratons (Gaudet, 2013). The deposit covers over 200 km^2 and is dominated by one large and four small plugs of nepheline syenite and associated breccia and fenite (Fig. 1). Distinctive features of nepheline syenite include brown zircon crystals (<1 cm), biotite books (<2 cm), alkali feldspar crystals (<1 cm), and interstitial nepheline (~40% near plug centres). Heavy REE (HREE) and minor light REE (LREE) enrichment is invariably concentrated in over 100 calcite-carbonatite dikes that measure 0.5-25 m in width and <5 km in length. The HREE enrichment includes Dy, Tb, Eu, and Y (concentrated in xenotime, YPO_4). The LREE concentrations are among the lowest in the world and result in xenotime crystallization from 600-450°C as hydrothermal overgrowths on zircon (Wall et al., 2008).

Exploration:

Namibia Rare Earths, Inc. acquired the 740 km^2 Lofdal property in 2005. Outcrops are abundant and easily accessible for sampling. Geochemistry results from over 4,000 rock samples show four major structures, including the Area 4 zone, where fluids with HREE enrichment migrated (Fig. 2). Over 14,400 metres of drilling in a 50 km^2 area was completed from April 2011 to present, including 10,025 metres on the Area 4 prospect. Initial assessment of the deposit shows the highest % HREE in the world (85.5%). Area 4 contains 8.73% Total Rare Earth Oxides (TREO) with 98.4% HREE enrichment. There is an overall indicated resource of 900,000 tonnes, with a grade of 0.62% TREO and 86% HREE enrichment. The resource approaches 2 Mt with a lower grade threshold, however ore would then require on-site processing.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VNP 78B
VNP 52
VNP 21
VNP 103
Study Area
NAMIBIA
WINDHOEK
20°20
VNP 78
5 km
14°45
Alluvium and sand covered planes
faults
dolerite dykes
dolerite sill
Carbonatite/alkaline porphyritic dykes
Lofdal nepheline syenite
Oas syenite
slate subgraywacke
quartzite arkose
quartzite subgraywacke
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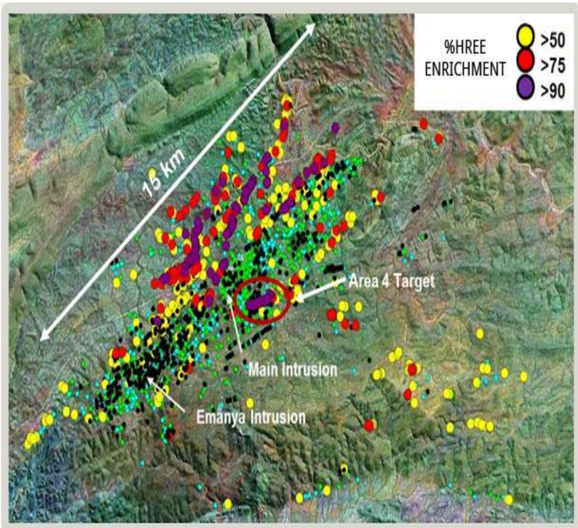
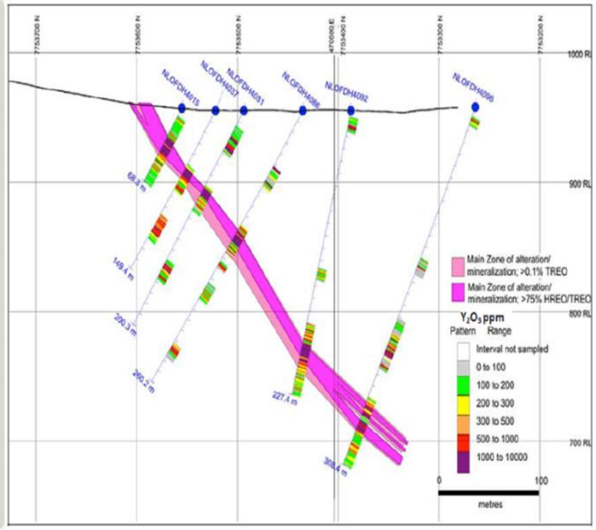
basal conglomerate, slate





Satellite map of the Lofdal property displaying HREE enrichment in four distinct structures (purple dots).

Results from drilling of a 15-17 m wide carbonatite dike at the Lofdal property (from Swinden and Burton, 2012).

See appendix for more information on the Khorixas area

References:

Gaudet, M.A., 2013. Mineralogical study of uranium and niobium mineralization at the Main intrusion of the Lofdal Carbonatite Complex, Namibia, Africa. Unpublished M.Sc. Thesis, Dalhousie University, 1-110.

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Swinden, H.S. and Burton, D.B., 2012: Lithogeochemistry of the Lofdal Carbonatite Complex, north-central Namibia: Unusual late stage hydrothermal HREE enrichment (abstract). Geological Association of Canada, Abstracts, v. 35.

Wall, F., Niku-Paavola, V., Storey, C., Müller, A., and Jeffries, T., 2008. Xenotime-(Y) from carbonatite dykes at Lofdal, Namibia: Unusually low LREE:HREE ratio in carbonatite, and the first dating of xenotime overgrowths on zircon. Canadian Mineralogist, 46, 861-877.

May 13th: Husab Uranium Property

Compiled by Paula Brunetti

This day will review one of the largest deposits of Uranium in Namibia, located 60 km northeast of Walvis Bay in Namibia.

Husab is located within the Alaskite Alley, an area that is endowed with several world-class uranium deposits. The Husab mine is in construction stage by Swakop Uranium, near the town of Swakopmund in the Erongo region in western-central Namibia.

The 8 km uranium mineralization on the Swakop Uranium area has been confirmed as the highest-grade, granite-hosted uranium deposit in Namibia and one of the world's most significant discoveries in the last decades.

Once in full production, Husab, which has the potential to produce 6 800 tonnes of uranium oxide per annum, will be the second-largest uranium mine in the world. The mine has a potential life of more than 20 years (Swakop Uranium).

Planned Schedule	Activity
7:00 -12: 30	Drive from Khorixas to Husab. Lunch
12:30 -13:30	Husab Presentation
13: 30- 15: 30	Core Revision
15:30- 17:00	Transect along Swakop river?
17: 30	End of the day. Drive to Swakopmund

Geology:

The uraniferous granite occurrences discovered so far are situated in the Central Zone of the Damara Orogen between the Omaruru and Okahandja Lineaments. Rifting between the Kaapvaal and Congo Cratons was followed by closure of the basin during late Neoproterozoic and early Paleozoic. This resulted in the creation of the Damara Orogenic Belt. Mineralization is associated with structural and intrusion-associated settings formed during the major thrust deformation that closed the orogen.

Uranium-bearing alaskites, similar to those at the Rossing uranium mine, are present in the Ida mine area, and elsewhere within the project area. The extensive fluorspar veins developed at the defunct Husab fluorite mine are also known to be uraniferous.

The uranium mineralization occurs as primary uraninite together with minor secondary uranium minerals in shallow, partially oxidized, or unusually high grade zones, within, and on the contacts of alaskitic granite dykes intruding the sheared contact zone between Rossing Formation marbles, and underlying Nossib Group amphibole-pyroxene schists.

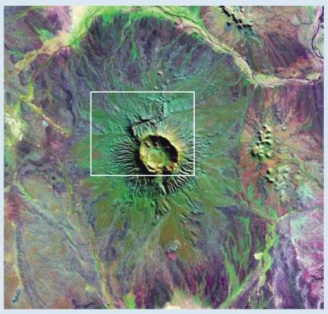
Swakop Uranium has defined indicated mineral resources of 241Mt at 480ppm for 257 Mlbs U_3O_8 at Zones 1 and 2 of the Husab Uranium Project, and inferred mineral resources of 125 Mt at 400 ppm for 110 Mlbs U_3O_8 at Zones 1, 2, 3 and 4. Total Probable reserves stand at 205.0 Mt ore at 497ppm U_3O_8 for 224.8 Mlbs U_3O_8 (Infomine)

APPENDICES

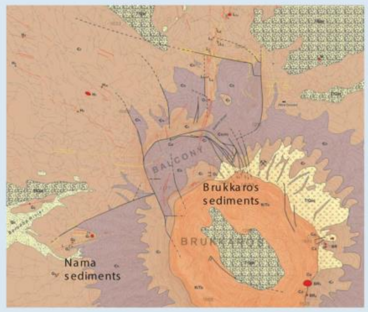
B R U K K A R O S

An impressive inselberg rising some 600 m above the surrounding plain and 1600 m above sea level, Gross Brukkaros is the only mountain releaving the monotony of the flat country between Mariental and Keetmanshoop, which is part of the Nama-Karoo Basin. It has a basal diameter of ca. 7 km, and with its steep-sided ring-shaped ridge bordering a central depression, seems the typical shape of an extinct volcano, but actually is the erosional remnant of a completely different volcanic structure. Because of its landmark-character, which makes it visible from afar, and several other unique features noted by early explorers, Brukkaros has attracted scientific and general interest for more than a hundred years. Although often by-passed, a hike to the top is rewarded with grandiose views of the surrounding country.

Aerial view of Brukk aros , showing its volcano-lik e morphology



Satellite imag e of Gross Br ukkar os and surr oundings; box indicates area co vered b y geological map

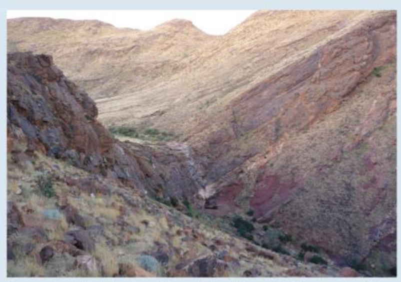


Detailed geological map of Gross Br ukkar os; the innermost centre of the structure within the ring of Brukk aros sediments is filled with Cenozoic debris flows (after M. Werner , 2001)

Formation of a Mountain

The evolution of Brukkaros began ca. 75 million years ago towards the end of the Cretaceous period, with the intrusion of carbonatite-rich magma into the Nama sediments then covering southern Namibia. Some distance below the surface the hot magma encountered groundwater, which was immediately flushed into steam. The resulting pressure caused the overlying rocks to bulge upwards and form a 400 m high and 10 km wide dome, into which more magma intruded, producing more steam. The overlying cover having thus thinned, superheated steam eventually blew out the centre of the dome in an immense explosion. Groundwater drained into the new crater, where it came into contact with more magma, leading to further explosions from deeper levels within the earth's crust; in the final stages of explosive activity material from 2 km deep was blasted out of the crater. Ejected rubble and ash built up a crater rim, but after the cessation of explosive volcanism, rain washed the fine material back into the crater, where a lake had formed. Layer upon layer of soft sediment were deposited on the lake floor, while a number of hot springs around the edge brought up fine-grained quartz to cement the fresh sediment.

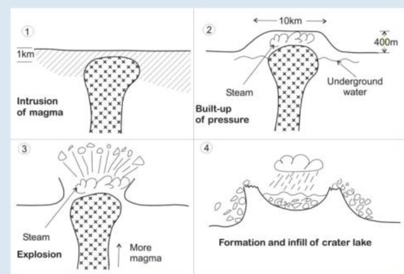
The process that created Brukkaros is called phreatomagmatism, caused by the interaction of magma and water. Although the explosive stage that laid the foundations probably lasted only a year or two, deposition and cementation of the lake bottom sediments took hundreds to thousands, before erosion removed the surrounding rocks during the following millions of years, leaving only the resistant crater lake sediments. Radiating outwards from Gross Brukkaros are more than hundred carbonatite dykes and pipes, making up the Brukkaros Volcanic Field, which is of the same age as the nearby Gibeon Kimberlite Province.



A rugg ed path leads down into 2 km wide bowl of Brukk aros , where fe w sounds penetrate to disturb the deep quiet

Re gional Geology

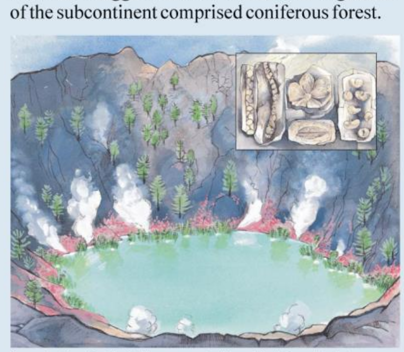
Brukkaros Mountain rests upon flat-lying red-dish-brown sandstones and shales of the Fish River Subgroup (upper Nama Group; ca. 530 million years), which were overlain by tillites and shales of the Dwyka Formation (Karoo Sequence; ca. 220 m.y.) during the Gondwana glacial period. During subsequent uplift of the southern African subcontinent most of the Dwyka beds were removed, but a few remnants which escaped erosion occur locally on the eastern and southwestern slopes of Brukkaros.



Simplified sketc h of the formation of Brukk aros

Brukk ar os Flor a

As Cretaceous sediments are extremely rare in Namibia, the lacustrine Brukkaros beds occupy a special position in the stratigraphic column. Dating has been possible with the aid of various plant fossils known as the "Brukkaros Flora". Among the fossil material recovered are pieces of wood, plant stems, seeds, leaves and an angiosperm flower with five main petals. While most of the plant life presumably clung to the lake shore, hardier specimens may have climbed the crater walls. The Brukkaros fossils together with other occurrences of the same age in South Africa and Botswana suggest that the Cretaceous vegetation of the subcontinent comprised coniferous forest.



Reconstruction of the Brukk aros cr ater lak e, whic h formed today' s mountain; inset: fossils of Brukk aros flor a (drawings b y C. Mar ais)

Fr om the top of Brukk aros one has an uninter rupted view o ver the surrounding plain

Brukk ar os T rivia

During colonial times Brukkaros was the site of a German heliograph station, and later, in the mid-1920s, a solar research station operated by the National Geographic Society and the Smithsonian Institute was set up on the mountain. It was one of a number of high-altitude observatories around the world collecting solar radiation data to establish a correlation with Earth's weather. It consisted of a solar telescope at the mouth of a 10 m deep tunnel in the flank of the mountain, and a variety of measuring instruments further in. The ruins of the station, which was abandoned in 1931, can still be seen today.

planetearth
Source: Roadside Geology of Namibia, and others

Namibia's Geological Treasures

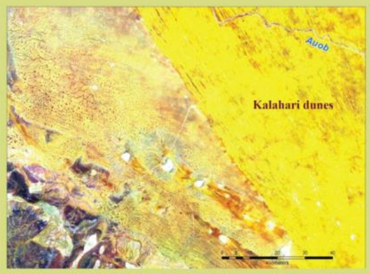
Thunderstorm brewing over the Kalahari

KALAHARI

Although the generally flat landscape of the Kalahari (meaning "great thirst" in the Tswana language), with its low partly overgrown reddish dunes, holds little attraction, the sheer extent of one of the World's largest bodies of sand, reaching from the northern Cape as far north as the Congo River and from Namibia eastwards into Zimbabwe, tends to stimulate the imagination and add glamour to an otherwise uninspiring journey. In the old days, before airplanes and internal combustion-engines, expeditions into this vast region covered by red sand required careful planning, as surface water is extremely rare for most of the year, and any precipitation almost immediately sinks into the ubiquitous sand or evaporates. Nevertheless, the Kalahari is not a true but a fossil desert, as parts of it receive over 250 mm of annual rainfall and are quite well vegetated; only in the southwest it is truly arid with under 175 mm of rain annually.

Springbok resting in front of Kalahari dune

Satellite image showing the dry valley (Omuramba) of the Eiseb, which is one of the Kalahari's drainages in eastern Namibia



The extent of the Kalahari dune field is clearly visible on satellite images

Kalahari - Past...

The Kalahari was once a much wetter place, when it was dominated by the ancient Lake Makgadikgadi. In its heyday, about 20 000 years ago, it was about 30 m deep and covered as much as 80000 km^2, before suffering a similar fate as "Lake Etosha". After the Zambezi River was diverted and the water was able to flow out of the basin, Lake Makgadikgadi began to decline. A drier climatic period caused an increase in evaporation and a decrease in the flow of the Chobe, Okavango and Cuando Rivers that continued to feed it. By about 10,000 years ago Lake Makgadikgadi was gradually filling up with sediment and debris from the Okavango and windblown sand. When the formation of the fan-shaped inland delta of the Okavango through tectonic processes further reduced the water flow into Lake Makgadikgadi, its days were numbered. Today all that remains of it are the Okavango Delta, the Nxai Pan, Lake Ngami, Lake Xau, the Mababe Depression and the Makgadikgadi Pans themselves.

... And Present

The Kalahari, which covers an overall area of more than 1.5 million km^2, is the most recent large-scale geological landform deposited on the southern African sub-continent. Overlying Karoo sediments and volcanics of Cretaceous age, its geomorphology is characterised by dunes, pans and dry "river valleys" (called *omurambas* in Namibia), by which the area is drained.

The Kalahari succession of variably consolidated sands, clays and gravels varies greatly in thickness, reaching up to 600 m in the north. Often the soft sediment is cemented by microcrystalline calcite into calcrete, which usually forms where evaporation is in excess of precipitation. Depending on a variety of climatic and environmental factors crucial in its formation, the texture and properties of calcrete (or dolocrete) vary considerably; some types have been used as low-cost building material or for road surfaces with satisfactory results.

How Old Is The Kalahari?

The age of the Kalahari is difficult to determine as fossils are very rare and the process of calcretisation tends to destroy pollen. Dates from fossil water, pan sediments and calcrete carbon isotope analysis indicate Quaternary ages, but it is thought that deposition of the earliest Kalahari sediments probably started in the Late Cretaceous.

As rocky outcrops are almosts scarcer than trees in the Kalahari and restricted to river cuttings and pans, most of the knowledge about the older sediments has been derived from water and a few exploration boreholes. However, the only area where a stratigraphy has been established that is laterally traceable for any distance, is the Owambo Basin of northern Namibia.

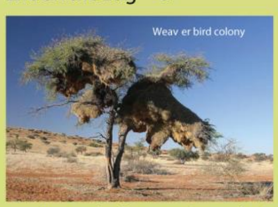
Pan formation presumably began at end of the Palaeogene, ca. 2 m.y. ago, while the Kalahari dune field is believed to date back to the last glacial period, i.e 16000 to 20000 years ago. In contrast to the Namib dunes, the 5 to 25 m high longitudinal and crescent dunes of the Kalahari are vegetated and therefore stabilized except for some minor reworking . Spaced 1 to 1.5 km apart, they have been derived from immediately underlying sands and calcretes or from wind-blown sand from adjoining pans and riverbeds.

Rusty orange is the main colour of the Kalahari

Kalahari sunset

Drill core of the Etosha Calcrete Formation; clasts of red clay floating in off-white to beige calcrete

Life on the Edge



Weaver bird colony

Vegetation in the Kalahari largely consists of drought-resistant grasses and acacia thornbush, and a few other adapted species (e.g. *Tsamma* melon). National parks have been established in Botswana and South Africa to protect the wildlife, which includes hyenas, lions, meerkats, giraffes, warthogs, jackals, antelope, and many species of birds and reptiles. The huge nests of weaver bird colonies are a frequent sight, and seasonal wetlands like the Makgadikgadi Pans of Botswana, are visited by tens of thousands of flamingos in the rainy season.

Due to the erratic rainfall, the Kalahari is sparsely populated. Sheep, ostriches, goats and cattle are raised on huge farms or communal land, while the San people, or Bushmen, have lived in the Kalahari for 20000 years as hunter-gatherers. They are the remnants of Southern Africa's original inhabitants, who occupied the whole sub-continent long before black and white settlers invaded their territories, as can be seen from the 'Bushman' rock art found in caves and rock shelters all over southern Africa.

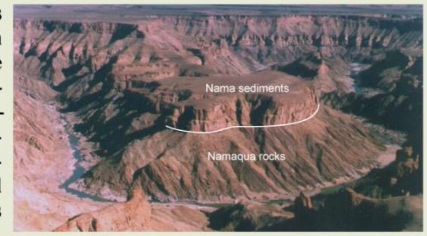
Meerkat

Source: Roadside Geology of Namibia, and others

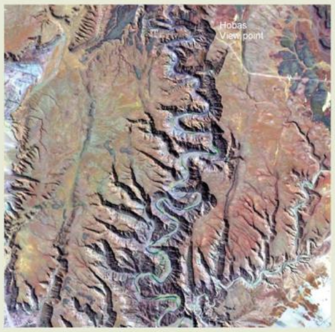
FISH RIVER CANYON

Layered Nama sediments topping the canyon walls

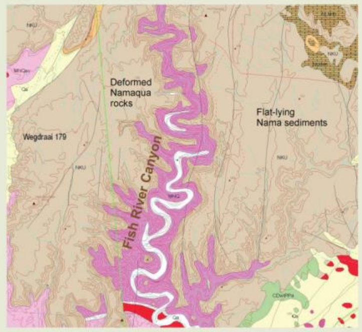
Situated some 80 km west of Grünau, the Fish River Canyon starts about 30 km upstream of Ai-Ais Hot Springs and winds its way more than 50 kilometres to the main view point on Farm Hobas. Altough a mere trickle during the dry season, the Fish River over millions of years has managed to cut a 160 to 550 m deep gorge through both the flat-lying Nama sediments of the Huns Plateau and the underlying deformed and metamorphosed gneisses of the Namaqua Complex, which can be easily distinguished in the canyon walls. Second in size and grandeur only to the Grand Canyon of the Colorado in Arizona (USA), it is a national monument, as well as one of the most popular tourist attractions in southern Namibia.



View from main lookout point



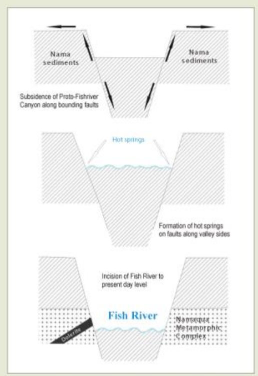
Satellite image of the Fish River Canyon: the different rock types forming the canyon walls are clearly visible in this view (compare geological map)



Geological map of the Fish River Canyon: while the rocks of the Namaqua Complex underlie the entire Huns Plateau, they are exposed only where the Fish River cuts down through them

Geological History

The Namaqua Complex originated as layers of sediments and volcanic rocks deposited more than 1800 million years ago in a shallow sea. After deposition they were buried to a depth exceeding 20 km by the slow accumulation of more sediment. During this process they were intruded by granitic magma and transformed under high pressures and temperatures to gneiss, amphibolite, schist and granulite (ca. 1200 m. y. ago). Some 770 m. y. ago these metamorphic rocks were invaded by doleritic magma which formed prominent dark dykes that can be seen in the canyon walls. Another 300 m. y. later the Namaqua rocks once more became exposed on the Earth´s surface through erosion of the overlying strata to form the floor of another shallow sea in which the sandstone, shale and limestone of the Nama Group were laid down. As no major phase of deformation or metamorphism followed their deposition, these rocks today are still nearly horizontal and have preserved their original sedimentary structures - thus forming a sharp contrast to the underlying massive Namaqua metamorphic rocks.



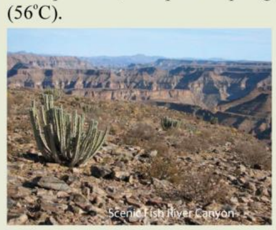
Simplified sketch of canyon development

Ca. 350 m.y. before present erosion had removed most of the Nama rocks and the initial river valley had formed as a wide depression. During the Dwyka glaciation it was deepened by south flowing glaciers, and eventually filled up by glacial sediments, sandstone and shale of the Karoo Sequence. Today's canyon began to form during post-Karoo uplift of the new-formed African continent. During this period the glacial deposits were nearly completely eroded; the rocks exposed today in and around the Fish River Canyon belong to the Namaqua Metamorphic Complex, with only the lower portion of the Nama Group (sandstone and black limestone) preserved in the vicinity of the Canyon.

Hot Springs

Ai-Ais Hot Springs Spa offers both indoor and outdoor pools, which are supposedly beneficial to sufferes from rheumatism

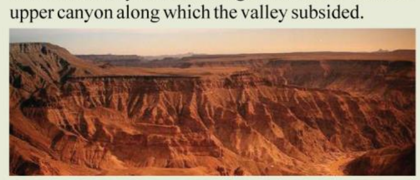
Along the fault zones forming the canyon sides groundwater rises to the surface to create a number of hot springs. The two best known are Ai-Ais (60°C) and, a little upstream, Sulphur Spring (56°C).



Scenic Fish River Canyon

Story of a River

The Fish River rises between Rehoboth and Maltahöhe. For the first 450 km of its course (overall length approximately 650 km) its gradient is comparatively low and it flows within a broad valley. Only ca. 50 km south of Seeheim, downstream of the confluence with the Löwen River, the gradient increases, causing the Fish River to incise more strongly into the underlying rocks. Initially it must have flown slowly over a flat land surface where it could meander freely as shown by its numerous bends, but continental uplift after the break-up of Gondwanaland ca. 130 m.y. ago resulted in the deep incision of the river into this surface to its present day level. At first, it cut through the horizontal layers of the Nama sediments, but later reached the underlying gneisses, amphibolites and migmatites of the Namaqua Complex. The same uplift created disturbances in the earth´s crust as evidenced by the bordering faults in the northern upper canyon along which the valley subsided.



Sunset over the canyon

While the upper canyon (8 km wide, 160 to 190 m deep) thus is a tectonic trough, the southern lower canyon (5 km wide, 460 to 550 m deep) was simply incised into the Nama and Namaqua rocks. From the first waterfall north of the northernmost viewpoint, to a point opposite the Chudaub trigonometrical beacon, the canyon is 56 km long; the Fish River hiking trail follows the river course for 85km from the main view point near Hobas to Ai-Ais Hot Springs.

Grand Canyon, Arizona, USA

Fish River Canyon, Namibia

Located at the southern end of the Fish River Canyon the recently refurbished Ai-Ais Hot Springs Spa (re-opened in August 2009) is a veritable oasis in the middle of a grandiose mountain scenery teeming with wildlife and birdlife, which is part of the Ai-Ais/Richtersveld Transfrontier Park. The sulphate- and fluoride-rich hot spring, which is supposed to have natural curative properties, was discovered in 1850 by a Nama shepherd searching for his lost sheep (Ai-Ais meaning "burning water" in the local Nama language).

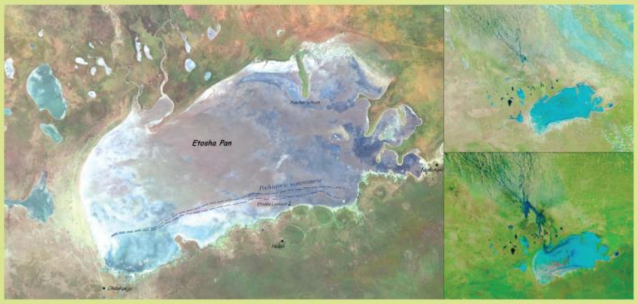
planetearth Earth sciences for society

Source: Roadside Geology of Namibia, and others

E T O S H A P A N

Part of the Etosha National Park, which in 2007 celebrated its 100th anniversary, the Etosha Pan covers an impressive 4760 km^2, with a maximum N-S extent of 80 km and an E-W extent of 120 km. Although the Etosha Park is most famous for its diverse wildlife, which includes almost the entire spectrum of African big game, the pan itself, with its eerie atmosphere of desolation, attracts a great number of visitors, too. Most of the time a dry, almost completely flat, salt pan of glistening white, after strong rains it still reminds of its former glory, when the area was covered by a lake that, if it existed today, would be the third largest in the world.

Zebras r oaming Etosha Pan



Satellite imag es of the Etosha Pan during the dry season (left) and during the e xceptional r ainfalls of 2008 (right); the dashed line on the left picture indicates the ancient w ater course tha t once fed "Lak e Etosha"

Etosha T oday

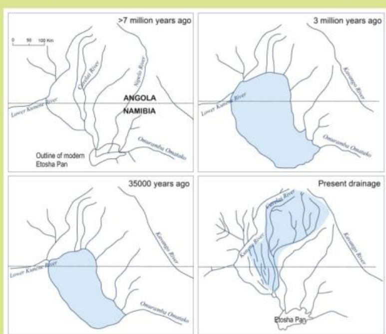
Lying at an altitude of some 1100 m above sea level Etosha Pan is surrounded by extensive grass and thornbush savannahs, with an average annual rainfall of 300 mm. Some 22000 km^2 (including the pan) of this northern Namibian plain were set aside as a National Park in 1907, making Etosha the sixth largest National Park in the world.

The Etosha Pan forms the lowest point of the Owambo Basin, a large intracontinental sedimentary basin, floored by mesoproterozoic rocks of the Congo Craton, and containing some 8000 m of sedimentary rocks. The immediate bedrock of the pan consists of silts and sands of the Andoni Formation and Etosha limestone, which belong to the Cenozoic Kalahari Group. Only the very uppermost part of the lithological profile of Etosha Pan is subject to alteration by recent flood waters, and exhibits a mineral assemblage characteristic of a saline-alkaline environments (e.g. East African salt lakes), including analcime, K-feldspar, sepiolite, saponite, calcite, dolomite, strontianite and various salts. Although shades of off-white are the predominant "colours", large parts of the pan surface display a distinct green-gray hue, which is caused by the micaceous mineral glauconite.

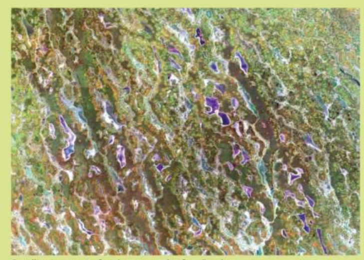
Geological History

Mudcrac ks char acterize the fine-grained pan sediment

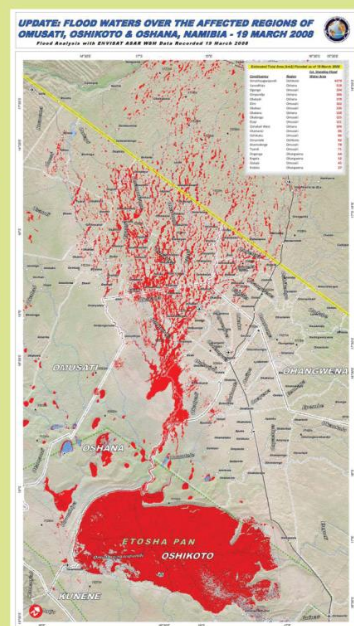
The development of Etosha Pan involves the formation of a palaeo-lake, followed by erosion. The palaeo-lake was formed through a drainage system including the upper Kunene and Okavango Rivers in the Late Miocene, some 5 to 7 million years ago. At the time of its maximum extent (ca. 3 million years ago) it covered an area of 55000 km^2. Only when a westward flowing river captured the headwaters of the Kunene River at the end of the Pliocene, was "Lake Etosha" cut off and began to die. As the lake shrank through continued evaporation under increasingly dry climatic conditions, the Cuvelai System with oshanas (small seasonal rivers) developed in its place. Pleistocene stromatolites, formed by carbonate precipitation through the activity of microorganisms, indicate the prevalence of a lacustrine environment supersaturated with carbonates at this time, as is typical for an evaporating inland body of water. When the lake had vanished, a pan formed which is supplied only seasonally with water through rainfall and flood events. Erosion set in, with fluvio-lacustrine processes in the rainy season and aeolian deflation processes during the dry season, which formed the prominent dunes to the northwest of the pan.



Sketc h of the rise and fall of "Lake Etosha"



Satellite imag e of oshanas north of Etosha



Map showing satellite-detected flood wa ters (red) in the Etosha area during the 2008 rainy season (also see sa tellite images a bove)

Game and Wa ter - Etosha' s assets

A number of springs occur along the southern margin of Etosha Pan, which provide water for the 114 mammal species, 340 bird species, 110 reptile species, 16 amphibian species and, surprisingly, one species of fish, found in the Park. During the long dry season, when other resources have dried up, it is upon these permanent waterholes the game congregates, thus making them favourable viewpoints for an impressive parade, especially during the hours of dawn and dusk. The source of the life-sustaining water are the Neoproterozoic dolomites of the Otavi Mountainland to the south of the Etosha pan. Karst structures in these mountains (e.g. Otjikoto Lake) provide ample mobility for groundwater, and where the carbonate rocks are in contact with the clay-rich and impermeable sediments of the younger Kalahari Group, it comes to the surface to form springs.

Goas water hole

Landscape of contrasts

Source: Roadside Geology of Namibia, and others

VINGERKLIP & MUKOROB

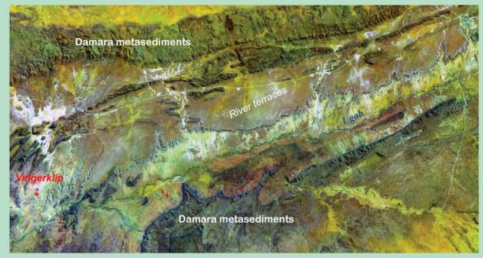
Namibia's Geological Treasures

After the collapse of the famous "Finger of God" (otherwise known as Mukorob) in 1988, Vingerklip, which is situated some 80 km southwest of Outjo and 45 km west of Khorixas, has become the best-known erosional rock formation in Namibia, ranking high amongst its geological attractions. With its prominent spout resembling a water kettle or coffee pot rather than a finger, it is part of the Tertiary main terrace of the Ugab River, whose remnants are dotted about the present-day Ugab Valley. From the vantage point of Vingerklip one has a magnificent view of the valley and the eroded terrace stretching away into the distance, which, because of its resemblance to a well-known Arizona landscape, has been accorded the soubriquet of "Monument Valley of Namibia".

Vingerklip and the Ugab Terraces

From its source in eastern Damaraland, the Ugab River follows an almost straight southwesterly course to the coast, having incised a broad valley into the Early Tertiary land surface. Due to a steep gradient in its upper reaches, it has cut down through older terraces during periodical floods; between Outjo and Vingerklip three terrace levels are exposed.

Standing 160 m above the present-day river, the main terrace rests on an Eocene surface and consists of more than 100 m of sand and sandy, calcrete-cemented conglomerate, capped by calcareous sandstone. Late Tertiary 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 has been found to contain Middle Stone Age tools.



Satellite image of the Ugab terraces between Outjo and Vingerklip

A carbonate matrix gives the Ugab terrace conglomerate its weather-resistance. Even so, cavities are clearly visible at the base of Vingerklip, which eventually will lead to its collapse.

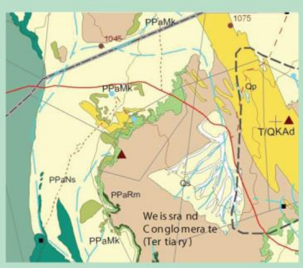
Vingerklip is a 30 m-high erosional remnant of the main terrace, which is best preserved on the northern side of the valley. Boulders in the conglomerate have been derived from Damara schists, marbles and quartzites, as well as from pre-Damara gneisses of the Huab Metamorphic Complex outcropping in the Ugab catchment area. The intercalation of conglomerate and sandstone give an indication of the changing depositional conditions in the river during the last 40 Ma.

The comparative resistance to erosion, which marks the Ugab terraces and has facilitated their survival to this day, is due to the carbonate matrix of the capping, which derives from the ridges of Otavi dolomite (Damara Sequence) to the north. Accordingly, the less indurated valley fill on the southern side of the Ugab River has succumbed more easily, leaving little to be seen. Distinct cavities at the broad base of Vingerklip, however, prove that erosion is doing its slow but persistent work even here, and that it is only a matter of time before the "Rock Finger" will be no more.

Even better than the satellite image the geological map shows the extent of the main Ugab River Terrace

Panoramic view of the main Ugab terrace and Namibia's "Monument Valley".

Satellite image of the area around Mukorob



Geological map showing distribution of Karoo sediments (greenish colours) and Kalahari dunes (orange)

Mukorob and Weissrand Escarpment

Mukorob, the Nama word for "Finger of God", used to be a prominent landmark in southern Namibia, near the village of Asab, which - although it no longer exists - is still listed as a National Monument. The rock pinnacle consisted of an upper, top-heavy sandstone pillar some 12 m in height and weighing ca. 450 tons, which rested on a thin neck of soft mudstone, 3 m long and only 1.5 m wide. The neck was supported on a broader mudstone base, and the whole structure towered about 34 m above the surrounding plain. Today, only the pedestal and part of the neck remain in their original position, while the debris of the collapsed head and most of the neck are scattered about the base.

The sandstones and mudstones of the Mukorob belong to the Permian Prince Albert Formation of the Karoo Sequence (270 million years); the Mukorob Member, also forms the prominent cliffs of the Weissrand Escarpment to the east of which Mukorob was part before it became isolated. Following the continental break-up of Gondwanaland, rapid erosion produced the Weissrand Escarpment a few million years ago.

Time and erosional processes chiseled Mukorob into the shape thousands of visitors knew prior to 8 December 1988, when its collpase was reported. With the soft mudstone neck eaten away at a greater rate than the sandstone head, the neck eventually became too thin to support the head. Slaking of the mudstones during the rainy season acted its part and further weakened the precarious structure; a fracture plane inclined at 45° to the northeast formed, down which the "Finger of God" slid to its destruction. Theory has it that the final straw may have been provided by the shock waves of an earthquake some 7500 km away, but even without that Mukorob would have been doomed.

The remnants of Mukorob as they can be seen today; inset: before the crash Mukorob was a spectacular sight, fully deservant of its National Monument status

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Source: Roadside Geology of Namibia, and others