Speleological Expedition Namibia 2023

Kaokoveld

Otavi

EUROPÆ SPELÆOLOGICA FŒDERATIO

korda's

ÖAW ÖSTERREICHISCHE AKADEMIE DER WISSENSCHAFTEN

universität innsbruck

VHO - Exploring Speleo Team

Summary

The Austrian caving club in Bad Mitterndorf (Verein für Höhlenkunde in Obersteier, VHO) in cooperation with the University of Innsbruck carried out a speleological expedition to Namibia from March 24th to April 12th 2023. The expedition was supported by the Austrian Academy of Sciences (ÖAW), the Fédération de Spéléologie Européenne (F.S.E. - Europe), and Integrated Rural Development and Nature Conservation (IRDNC - Namibia).

Expedition goals were twofold:

1. the exploration of the Kaokoveld caves located from the air in 2018. Reaching the entrances and accurate orientation (most entrances are via longer 4x4 drives and extensive ascents). Exploring and measuring the caves (floor plan, elevation, photo documentation, etc.)
2. speleogenetic and paleoclimate studies of the Namibian caves in Otavi including sampling in accordance with the permit issued by the National Commission on Research, Science and Technology of Namibia.

The group of 14 speleologists and geologists split into three teams. The first two teams carried out explorations within the Kaokoveld area while the third team focused on speleogenetic and paleoclimate studies in caves of the Otavi Mountains. Members of the teams came from six different nations (Table 1).

Table 1: Participating members

Participant	**Institution**	**Nationality**
Heidrun André	VHO, Verein für Höhlenkunde in Obersteier, Austria	Germany
Anna Brandmeier	VHO, Verein für Höhlenkunde in Obersteier, Austria	Germany
Jutta Brandmeier	VHO, Verein für Höhlenkunde in Obersteier, Austria	Germany
Yuri Dublyansky	University of Innsbruck, Austria	Russia
Peter Jeutter	VHO, Verein für Höhlenkunde in Obersteier, Austria, *co-leader*	Germany
Gabriella Koltai	University of Innsbruck, Austria	Hungary
Ralf Langer	VHO, Verein für Höhlenkunde in Obersteier, Austria	Germany
Leonie Leitgeb	University of Innsbruck, Austria	Austria
Tanguy Racine	University of Innsbruck, Austria	France
André Schoeman	VHO, associated Otavi caving group	Namibia
Kyle Schoeman	VHO, associated Otavi caving group	Namibia
Christoph Spötl	University of Innsbruck, Austria, *co-leader*	Austria
Andreas Wolf	VHO, Verein für Höhlenkunde in Obersteier, Austria	Germany
Christine Wolf		Germany

In the Kaokoveld area, the teams targeted caves located through an aerial reconnaissance mission carried out by plane in 2018. The area is rather difficult to access and a major part of the endeavor was scouting the best way to access the cave entrances. The majority of entrances (some very large) are located on remote terrain, whose access required time and material consuming off-road driving as well as exhausting hikes under the African sun.

In total 14 caves were explored and surveyed. The largest of them, Omuhako Cave, yielded a total length of 505 m and a depth of 54 m. To our knowledge Omuhako Cave is the largest cave known in Kaokoveld to date. Altogether, the teams surveyed cave lengths of more than 1400 m.

Out of the 26 potential caves initially spotted from the air, the teams could access, explore and survey eight. Several of them lived up to the expectation of their entrance dimensions, like Starling Shaft with its gaping 57 m entrance shaft, for a total depth of 68 m or Three Guardians Cave, a huge entrance leading directly into a 27 m shaft, high side passages and a total depth of 47 m. Two of the entrances recorded during the aerial survey were visited by drone but on balance of their less promising potential and remoteness, they were not pursued any further.

Only 12 out of the 26 entrances spotted could be located accurately enough to make an approach worthwhile. The use of a drone enabled more accurate positioning and allowed the discovery of an additional large entrance. For two rather promising but hard-to-access entrances the

exact location was confirmed by the drone. Their eventual exploration requires logistical planning for a three-day hike involving donkeys to ensure adequate water supply. These and some additional entrances in the north remain speleological targets.

Other un-surveyed caves were found during the course of the expedition; notably the Parrot Portal caves with a combined length of 180 m and large entrance portals.

The science team studied and sampled several caves in the Otavi Mountains, under permit RPIV011282022 issued by the National Commission on Research, Science and Technology of Namibia. The team confirmed the hypogene origin of these caves based on cave-morphological observations and performed detailed studies of the complex sediment fill which comprises several generations of clastic sediment infill, erosion phases and multiple speleothem generations. Samples for radiometric and paleomagnetic dating were obtained and temperature loggers were deployed to monitor the modern cave microclimate.

Cooperation between the international team and the Namibian members included training in caving techniques and cave surveying. Caves discovered in tribal rural areas may help to provide a future eco-touristic perspective for the formerly nomadic Ovahimba and Herero people.

It is planned to publish the results of the expedition in due course within the VHO publications as a special edition bilingual in German and English. This will include all cave surveys, the expedition diary, photos and a selection of the scientific results.

We would like to express our special thanks to ÖAW, F.S.E., University of Innsbruck, IRDNC, Korda's, Bergwacht Bayern (Oberau/Murnau), Mark Tringham, André Schoeman, Eckart Basson, Roger Collinson and Muhaamberua Virere.

In the Petrified Forest area of Omuhako cave — *Tanguy Racine*

Expedition leaders: Peter Jeutter, Christoph Spötl
Report edited by: Tanguy Racine
Front page: The way down to the main chamber of Omuhako cave — Tanguy Racine

The three teams and the support staff, names given left to right, back to front. *Top:* of Leonie Leitgeb, Christoph Spötl, Gabriella Koltai and Yuri Dublyansky (Team 1). *Centre* Anna Brandmeier, Tanguy Racine, Kanjumena Koruhama, Icoruhama Ic, Rabocicx, Jutta Brandmeier, Muhaamberua Virere, Kyle Schoemann, André Schoemann, Regina, Chicken Giraso, Romanus Ic, Peter Jeutter, Candy, Absalom (Team 2). *Right:* Andreas Wolf, Ralf Langer, Mukuambi Tjimuine, Christine Wolf, Heidrun André (Team 3).

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Expedition aims and objectives

Exploration of the Kaokoveld caves

Building on the 2018 aerial survey conducted by André Schoeman and Peter Jeutter, the expedition aimed at precisely locating and reaching the entrances. Most entrances can only be reached by gravel roads or tracks, necessitating a 4x4 drive. Most entrances also require a long approach on foot. The main expedition objectives were to explore and map the caves reached, producing high standard plans, elevation views, as well as extensive photo documentation.

Geological investigations

Another objective of the expedition was the identification of speleogenetic markers to complement existing models of cave formation in the Kaokoveld (Martini et al., 1999).

Selected geological investigations in the Otavi Mountains, e.g. speleogenetic and paleoclimate studies in Blowing Hole, Varianto Cave, and caves on Uisib farm started in April 2021.

Publication of the research results

A key deliverable from the expedition is the further documentation of known and documented caves (distribution / location map / updating the cave register Kaokoveld), including those mapped and researched by the teams around Eugene Marais and Mark Tringham. A second deliverable is a bilingual (German/English) VHO publication covering northern Namibia, complete with pictures and illustrated results. A publication that refers to web links for details in order to make it clear and to keep legible is also conceivable.

Speleothems and sedimentary fills in Uhlenhorsthöhle — *Christoph Spötl*

Introduction

Geography & Climate

Namibia is a country located in southwestern Africa, bordering Angola, Zambia, South Africa and Botswana, with a population of nearly 2.6 million. Its capital, Windhoek is located near the centre of the country. It is one of the least densely populated countries in the world. Perennially running rivers are confined the borders of the country, for instance the Orange and Kunene rivers at the South-African and Angolan borders, respectively. The Kaokoveld area is located in the northwestern corner of the country, in the Kunene region between the towns of Opuwo and Sesfontein (Figure 1). The Otavi mountainland is located between the towns of Otavi and Tsumeb, at the border between the Oshikoto and Otjozondjupa regions.

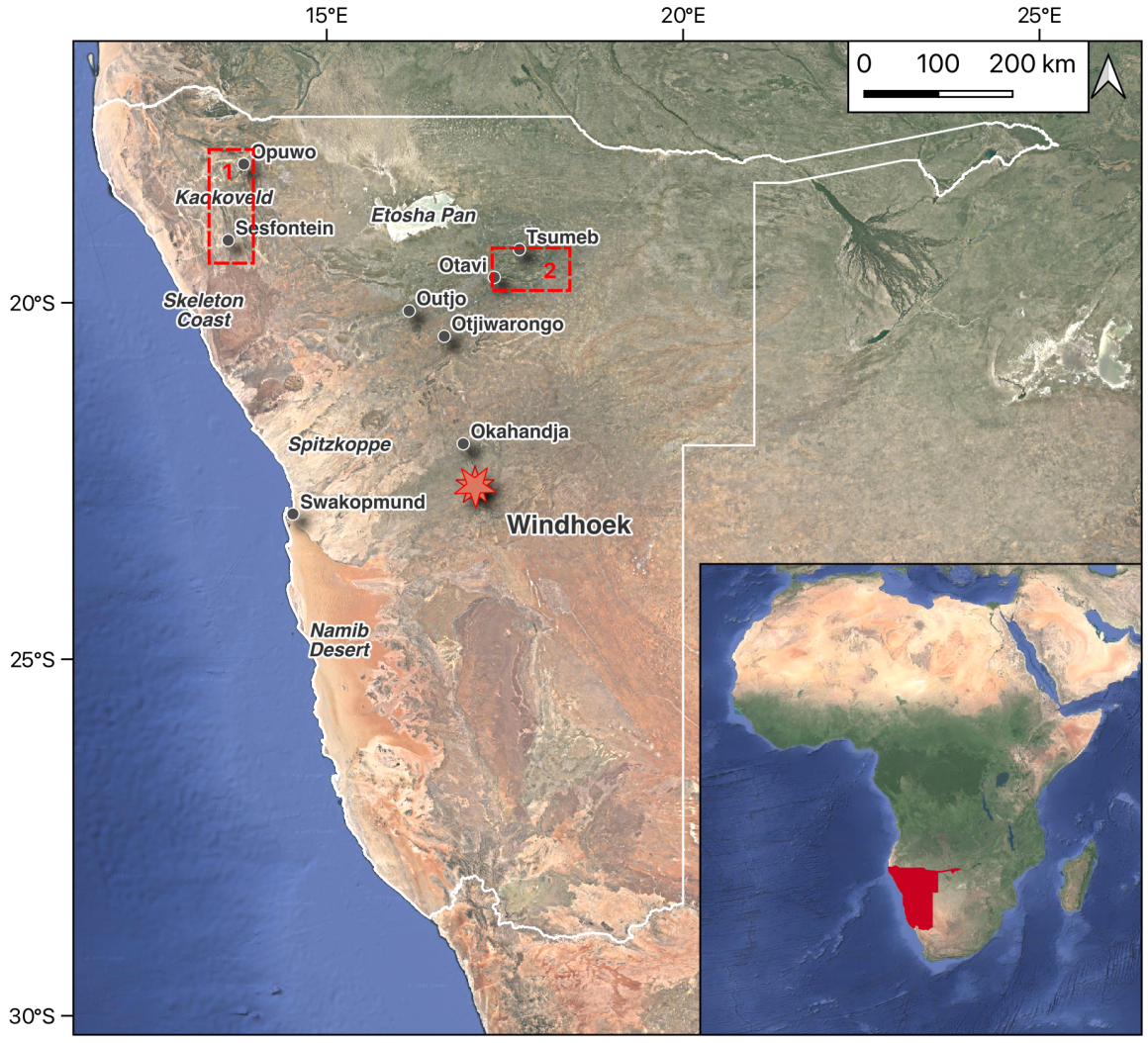


Figure 1: Map of Namibia with caving areas visited: 1) Kaokoveld and 2) Otavi Mountainland — © Google Satellite 2023

In the north of Namibia the climate spans from hot and arid to semi-arid from west to east. Precipitation amounts are modulated by the Benguela current flowing north off the western Namibia coast line. This ocean circulation pushes cold winds and high pressure systems in a northerly direction over the western part of the country, suppressing rainfall. On the contrary, expansions of the intertropical convergence zone (ITCZ) bring moisture from the equator poleward to the northeastern parts of the country. Thus the area east of Kakokoveld and north of the Otavi Mountainland experiences a rainfall season between October and April, with as much as 500 mm rain annually. On the lee side of these mountain ranges, rainfall totals decrease westward to about 10 mm annually. In the resulting desert areas, such as the Skeleton Coast or the Namib-Naukluft

desert, with droughts being common, the latest one in May 2019.

People of the Kunene region

Two main groups of people inhabit the area. The semi-nomadic and pastoralist Himba people (also known as Ovahimba) live in the Kunene region. They generally speak the Otjihimba language. They are for the most part subsistence farmers, raising sheep and goats and moving with their flocks to grassy areas. Despite their small population of 30 to 50 000, the Ovahimba feature prominently in Namibian travel brochures in the context of community-based tourism. It is for instance possible to visit "Himba living museums", where local communities perform traditional activities.

The Herero are a people culturally distinguishable from the Himba; they are generally more settled and speak the Otjiherero language. Cattle farming is highly valued in Herero culture, and the traditional headpiece for many Herero women is a horned hat called otjikaiva, worn as a homage to the cows which long sustained Herero people.

Left: Herero women with traditional patchwork dress and horned otjikaiva headdress. *Right:* Ovahimba in traditional goatskin garments, and women wearing their hair in ochre covered locks — *Heidrun André*

Geology

The geological makeup of the Kaokoveld and Otavi mountain land can be found on the 1812 Opuwo and 1912 Sesfontein sheets at a scale 1:250 000, by the Geological Survey of Namibia. In the northwestern part of the country are extensive outcrops of karstified carbonate rocks, forming an arc-shaped mountainous region known as the Otavi fold belt (Figure 2). This configuration is the result of two separate orogens: the Kaoko belt to the northwest, and the Damara belt to the southeast, which played a key role in the assembly of western Gondwana in the early Phanerozoic eon (Goscombe et al., 2005).

The Kaoko orogen is dated to about 580 to 570 Ma, as a result of the transpression of the Congo craton margin and the Ribeira-Dom Feliciano magmatic arc system, now outcropping in South America, which resulted in the closure of the so-called Adamastor ocean (Goscombe and Gray, 2007). The deformation associated with the Kaoko belt are dominantly N-S trending folds, and the orogen also gave rise to a wide barrovian-type metamorphic belt, as well as widespread magmatism. The Kaoko belt is divided in three coast-parallel zones, namely 1) the Orogen Core Unit, which experiences granulite metamorphic facies and partial melting, comprising granitoids dated to 550 Ma (Goscombe et al., 2005); 2) the Central Kaoko zone, a fold and thrust belt showing eastwardly decreasing barrovian-type metamorphic facies, thrust over the 3) the slightly metamorphosed Eastern Kaoko zone.

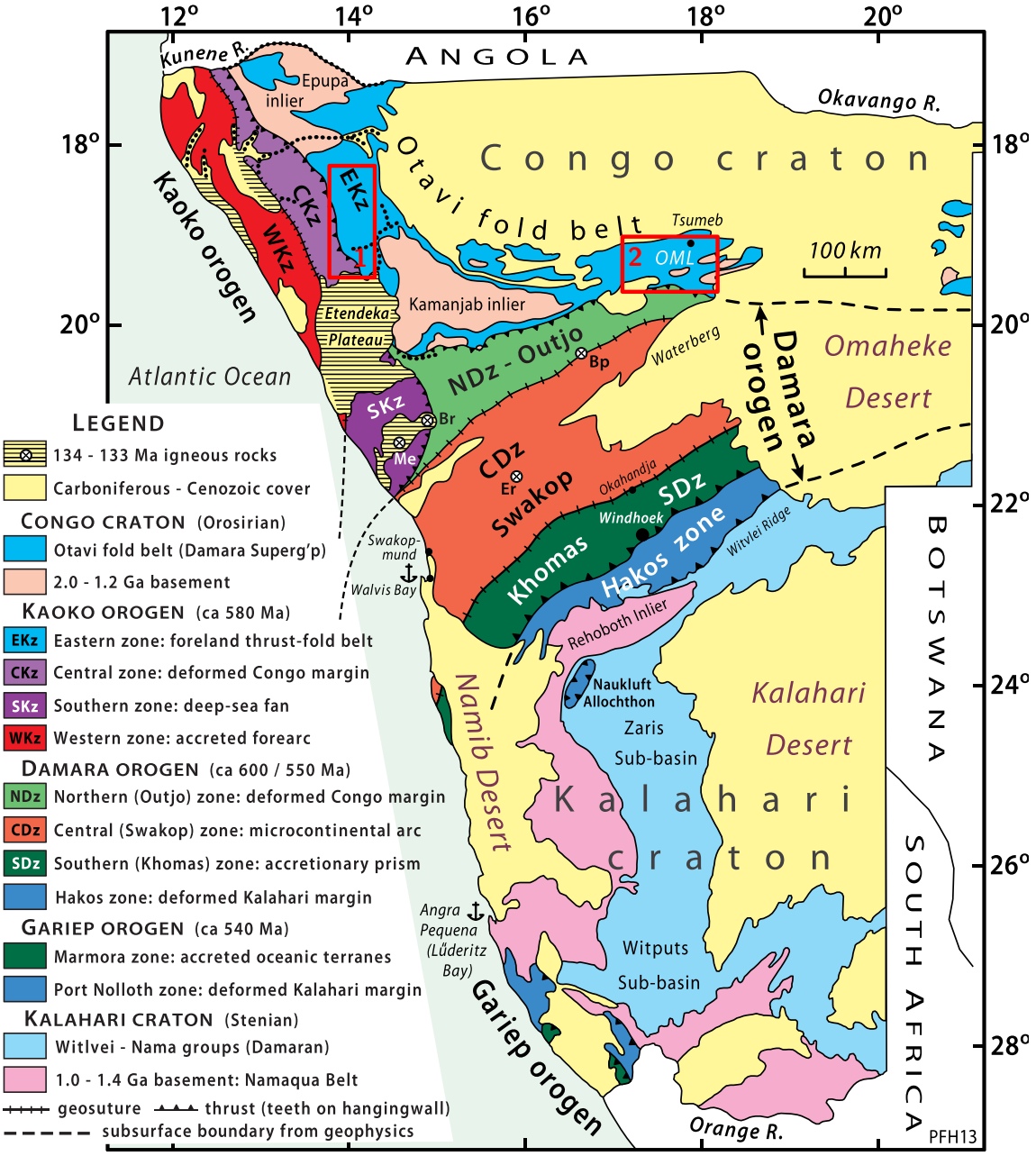


Figure 2: Bedrock geology of Namibia, modified from Hoffman et al. (2021b). Rectangles denote areas of speleological exploration during this expedition: 1) Kaokoveld and 2) Otavi Mountainland.

The Damara orogen is dated to about 570-550 Ma, post-dating the Kaoko orogen, is the result of the high angle collision between the southern Congo craton margin and the Kalahari craton, which resulted in the closure of the so-called Khomas ocean (Coward, 1981). It is manifested today by a series of E-W trending folds, easily seen within the Otavi Mountain Land (Goscombe et al., 2018).

The clastic and carbonate rocks of the Damara supergroup outcropping east and north of the Kaoko and Damara belts, respectively, were deposited at the southwestern margins of the Congo craton (Foster et al., 2008). Deposition began with deep rift clastics of the Nosib group (Figure 3). Following these is the Otavi group, comprised of a 1.5-3.5 km thick, shallow-water facies carbonate platform (Miller, 2008). The group begins with rift-margin carbonates (the rocks of Abenab and Tsumeb sub-groups) and ends with molasse type clastic deposits of the Mulden group (Figure 3).

The sedimentary record of the Otavi group is interrupted by two striking diamictite formations

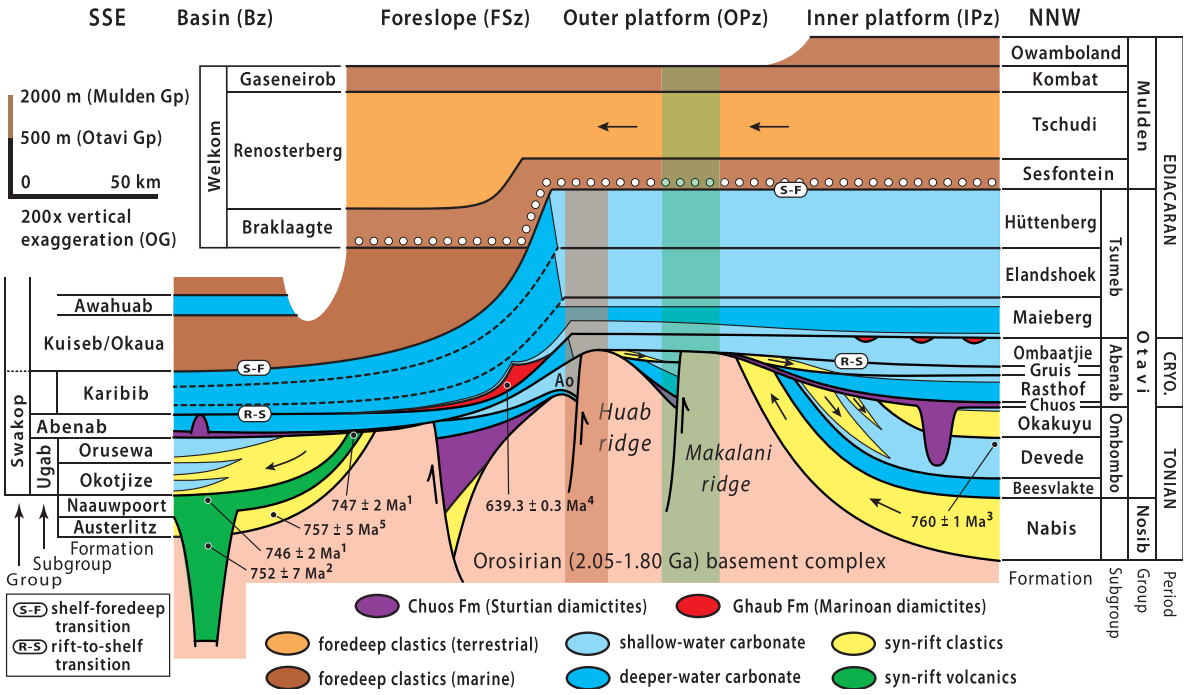


Figure 3: Composite stratigraphic reconstruction across the Otavi fold belt, modified from Hoffman et al. (2021b).

— rocks containing an extreme range of grain sizes, with large boulders floating in a much finer clay matrix — of glaciogenic origin. The Chuos and Ghaub formations testify to two catastrophic episodes of Earth history which occurred at the end of the Neoproterozoic, namely the Sturtian and Marinoan glaciations, respectively (Hoffman et al., 1998). Paleomagnetic evidence shows that the Congo craton lay at low latitudes (30°S) at the time, and the deposition of these suggestive an extensive ice sheet cover over much of the Earth, so much so that the corresponding geological period is termed Cryogenian (720-635 Ma). At the time, ice sheets may have covered the entirety of the Earth's surface (the Snowball-Earth hypothesis). At the low latitudes, the abrupt deglaciation was accompanied first by the deposition of so-called cap carbonates (Williams, 1979), and later by the deposition of shallow water facies platform carbonates.

In the Kaoko belt, the post-Marinoan glaciation cap carbonate sequence is represented by the single deposition sequence comprising the Maierberg formation (Hoffman et al., 1998). The deposition of this formation occurred as ocean-atmosphere interactions and carbon cycling began anew in the wake of the deglaciation, with a combined effect of increased silicate weathering and enhanced atmospheric CO_2 drawdown in the oceans, leading to the deposition in massive carbonate deposits. During the late Proterozoic period, before the advent of hard-shelled organisms, the characteristic reef-building organisms were cyanobacteria, forming organo-sedimentary structures called stromatolites. The latter are laminated growth structures (finely laminated, pillar shapes, cusps, etc.) arise as a result of sediment trapping and binding by organic mats.

The thicker platform carbonates of the Elandsoek and Hüttenberg formations are parasequences containing 1-m scale sedimentary cycles (Hoffman et al., 2021a). The collective thickness of these units varies between 0.75 km in the Kaoko belt and 2.5 km in the Otavi Mountain Land. The Elandsoek and Hüttenberg formations mostly comprise a succession of grainstones and mostly silicified "ribbonites", a facies of laterally linked stromatolites (4). These stromatolitic horizons are easily distinguished in the field, due to their buff colour in contrast to the surrounding light grey limestone.

Many caves explored during the expedition, especially the ones located on the westernmost ridges of the Kaoko belt are developed within the platform carbonate formations of either the Elandshoek or the Hüttenberg formations (Fig. 3).

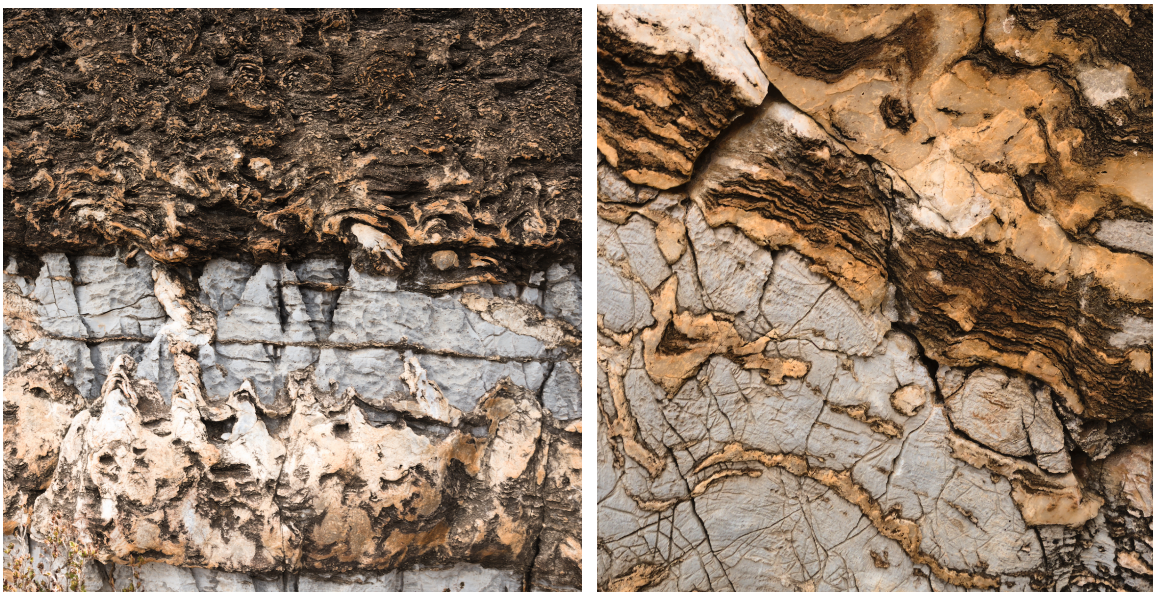


Figure 4: Preferentially silicified, laterally linked stromatoid pillar structures in the Hüttenberg formation, near Otjikondavirongo (buff colour), separated by calci-mudstone (grey) (Wright, 1992). — *Tanguy Racine*

Previous cave exploration in Kaokoland

SWAKNO (Suid Wes Afrika Karst Navorsing organisasie), a Windhoek based scientific oriented caving association pioneered the cave explorations in the Kunene region and the Kaokoveld. The group was led by Eugene Marais, other members were Jaques Martini and John Irish. Using aerial photographs and a stereoscope they identified their targets before the advent of Google Earth.

Back in 1990, they explored for the first time some of the prospects of Kaokoveld, with the Orumana and Parakietgat sinkholes being the major findings. SWAKNO led further cave expeditions over Namibia in the following years, but the next visit to Kaokoland took place in 1994. The group explored various significant sinkholes: Columbarium, Arboretum and Hermitage caves, finding the striking Temple of Doom cave, significant for its hypogene solutional morphology and baryte deposits, as well as descending the 130 m deep Wow Gdoom pothole. The latter is one of the deepest caves in the country and the deepest in Kaokoveld.

Two expeditions were carried out in Kaokoveld 2015 and 2018 by members of the Gloucester Speleological Club, led by Mark Tringham, in cooperation with the IRDNC. Since a couple of significant Namibian caves up to 5 km long – namely, Dragon's breath and Arnheim caves – were already known from equivalent cave-bearing formations in other parts of the country, it was thought that the Kaokoveld might yield another such cave system with extensive horizontal development. Over the course of those two expeditions, the team used satellite imagery, documented 1.1 km of new cave passages in 23 caves. The two most significant findings with respect to length are Ondimba ja Omungongo (358 m) and Oktjakateta (138 m).

Local support

We would like to express our gratitude for the local support provided by IRDNC support staff during this expedition and extend particular thanks to Mr. Virere Muhaamberua for organising the recruitment of guides and porters, on which the success of the exploration rested.

IRDNC support for the first camp in the Otijkondavirongo village. *Top to bottom, left to right:* Muhaamberua Virere, Regina, Chicken Giraso, Kanjumena Koruhama, Rabocicx, Absalom, Romanus Ic, Icoruhama Ic, Candy, Ipaheua Muhenje, Uanata Muhenje, Uririraye Tjiimbi, Baba Mbunguha, Mukuambi Tjimuine and Robert Tjuku

General access notes

Access to localities in the Kaokoveld area requires adequate four-wheel drive vehicles. Northwest of Kamanjab, road surfaces are exclusively gravel or dirt (C or D roads). Unmarked trails known to the local inhabitants are often driveable, while some roads marked as D-level on online mapping services are poorly maintained in places, and sometimes impassable. Local knowledge is thus key.

The crux on which rested the success of this expedition was access to the Omuhiva valley and the westernmost carbonate ridge in which many entrances had been spotted during the 2018 aerial survey. Locations along this mountain range were first believed to be accessible from both the southwest (Otjikondavirongo) and the northeast (Ongango). During this expedition, it was found that the northeastern access route is the only one currently open.

The campsite at Otjikondavirongo is located a ten-minute-drive upstream of the village school. The site is found immediately after a river crossing. The camp benefits from a seasonal stream but there is neither electricity nor phone signal. The campsite in Omuhiva valley was set up a short distance northward from a bend in the D-3705 road from Ongango. There is neither running water nor electricity and the closest shop is located in Ongango, a 25-minute drive away.

Setting up the camp at Otjikondavirongo — *Tanguy Racine*

Main findings

In the section below, a description of the most significant findings of the Namibia 2023 expedition is provided. Maps of the most significant finds are provided in text. Visits by the science team to known caves of the Uisib area also yielded important new observations on the speleogenesis and multi-stage sedimentation history within those caves.

Table 2: Caves found and surveyed during the Namibia 2023 expedition

Cave name	Length *(new)* (m)	Depth (m)	Altitude (m asl)
Omuhako Cave	505 *(505)*	54	1452
Cave of the Three Guardians	145 *(145)*	47	1483
Gecko Canyon Motel	13 *(13)*	1	918
Jeweller's Chamber	41 *(41)*	19	1037
Dwarfbeak Cave	17 *(17)*	8	1406
The Pigeonhole	15 *(15)*	10	1415
Starling Shaft	135 *(135)*	68	1459
Orutura Cave	23 *(23)*	2	1480
Blowing Hole (Nosib/Atoom)	415 *(130)*	62	1465
Porcupine Cave	85 *(85)*	8	1397
Leopard Cave	26 *(26)*	6	1434
Himba Village Cave	65 *(65)*	13	1405
Parrot Portal caves 1+2	150 *(150)*	40	938
Khoekhoe-kai//om Cave	80 *(80)*	25	1519
Total	*1430*		

The decorated chamber at the bottom of Starling Shaft — *Tanguy Racine*

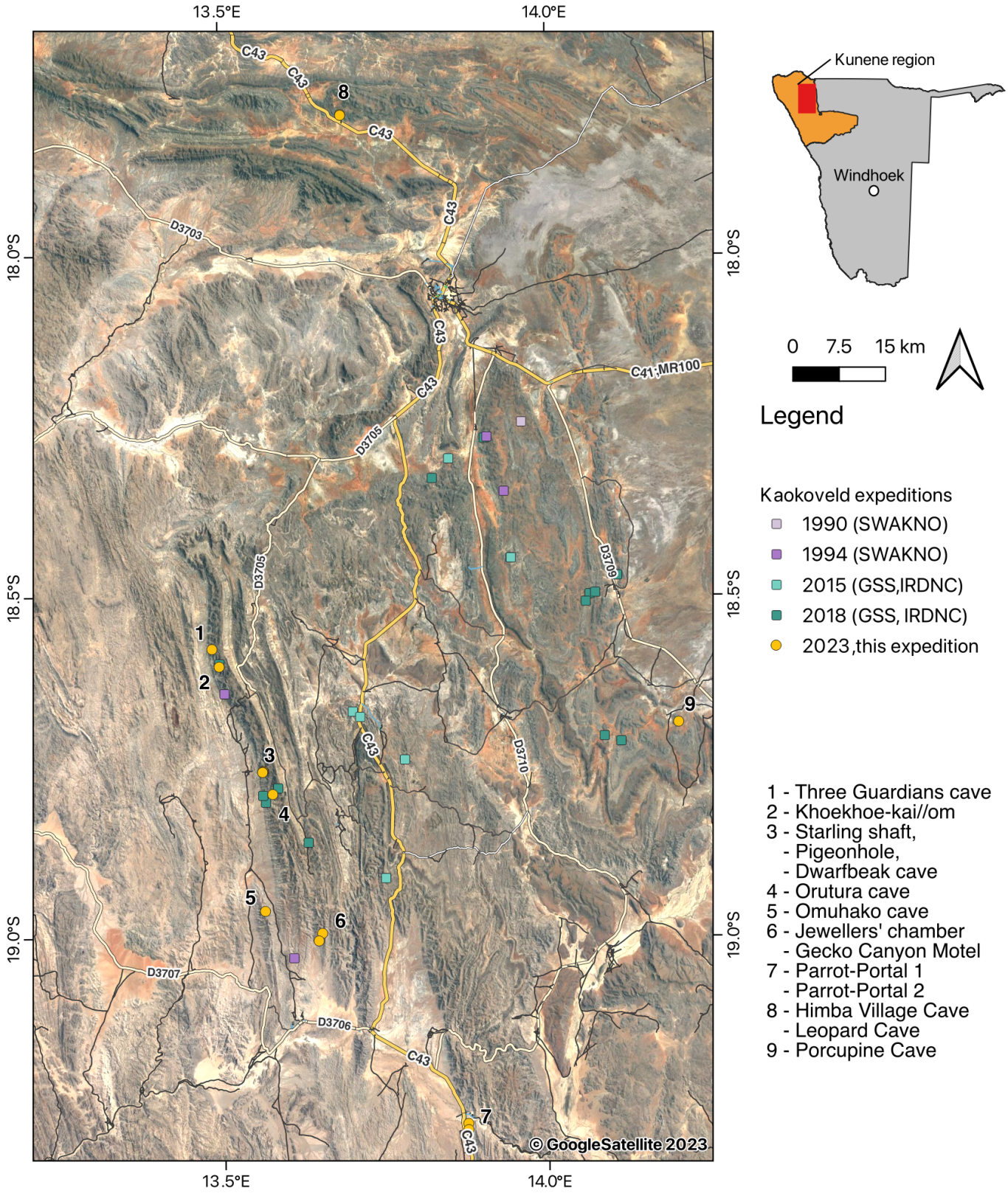


Figure 5: Location of the caves investigated in the Kaoko mountain belt.

Otjikondavirongo area

In the context of this report, the Otjikondavirongo area refers to the westernmost ridge of the Kaoko Belt Eastern Zone. This range is oriented N-S and represents the westernmost outcrop of the Northern Platform carbonates, bounded by the major Sesfontein fault (Figure 2). Several caves were explored in the area within a 2 km radius of Otjikondavirongo village (e.g. Starling Shaft), others up to 5-6 km north (Khoekhoe-kai//om cave, Three Guardians cave). The most significant finding was Omuhako cave, almost 15 km south of the village.

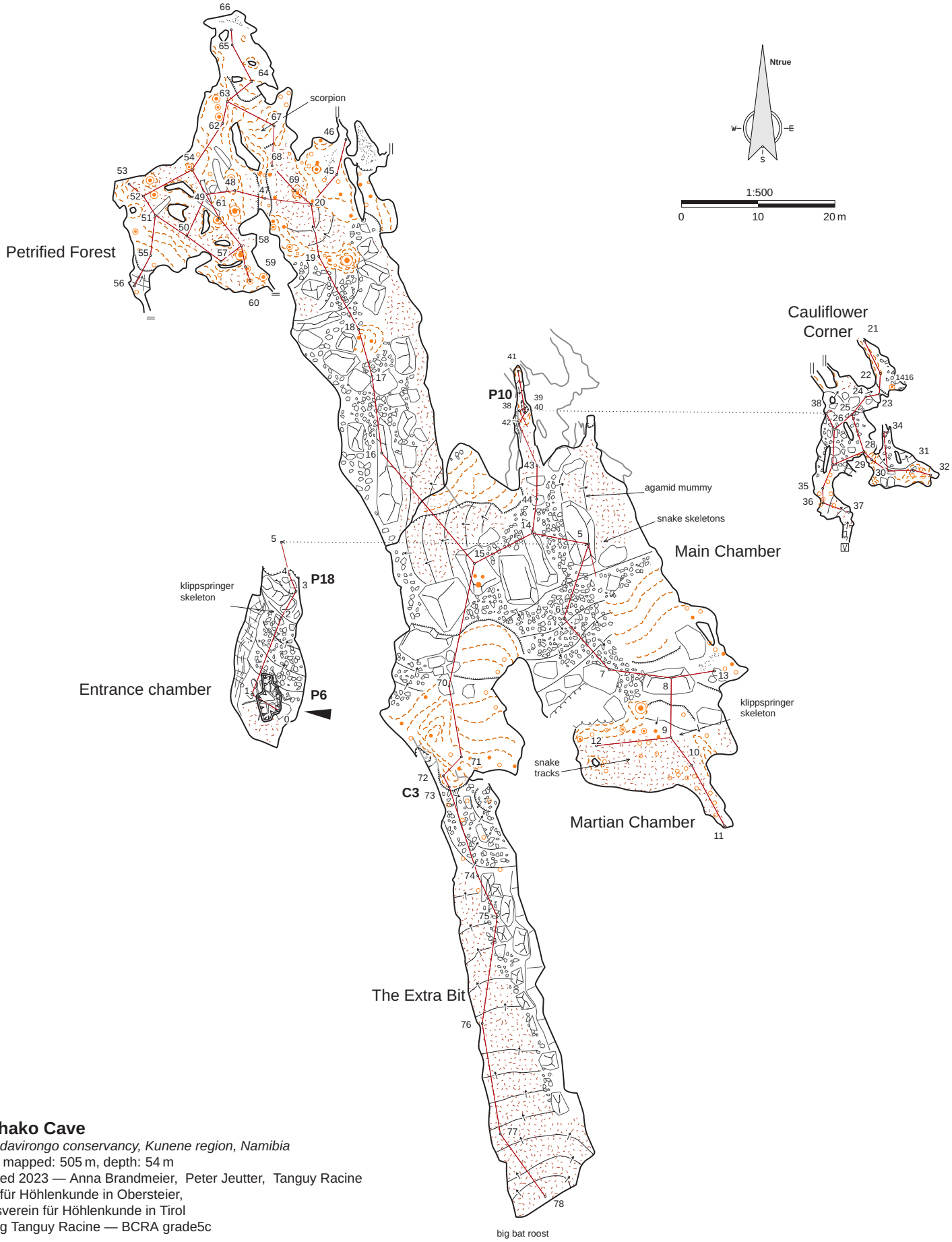
Omuhako Cave

Omuhako cave can be accessed from a drivable, but apparently little used track linking Sesfontein to Otjikondavirongo (Figure 5). It is possible to park due east of the cave entrance, and hike in an almost direct line to the cave. The entrance is located on the eastern slope of the N-S trending mountain, near its summit, at an altitude of 1469 m.

The cave opens with a 3 m diameter entrance into a bell-shaped chamber, out of which grows its eponymous tree, a tick-tree (Sterculia africana). The chamber floor falls off the north, where a 20 m a pitch gives access to a well decorated, large sunlit chamber. The 20 m pit lands on a steep debris slope, on the SE side of the chamber. The passage, heavily decorated with cauliflower calcite, ends at a depth of 50 m at an alcove with a flat, strikingly red dust floor.

Back at the main chamber, a way on, descending directly opposite of the pitch landing reveals a constricted pitch head. The small pit drops over flowstone ledges into a complex series of interconnected chambers with many striking cupola morphologies. This series reaches a depth of 53 m below the cave entrance. The northwestern end of the main chamber continues as a wide passage (10 m tall, 10 m wide) for 60 m towards the north, reaching a section sporting stunning flowstone and cauliflower calcite formations. The passage ends at a depth of 54 m, in a series of increasingly smaller inter-connected, decorated chambers. The southwestern end of the main chamber is dominated by a massive flowstone formation some 15 m tall. On its far side, a 4 m downclimb gains a south trending 70 m long gallery. The ceiling is decorated with some corroded stalagmites, while the floor is a gently ascending dune of guano, with a bat roost at the end. In total, 505 m were surveyed in Omuhako cave over two days of exploration.

Martian chamber at the bottom of Omuhako cave — *Tanguy Racine*



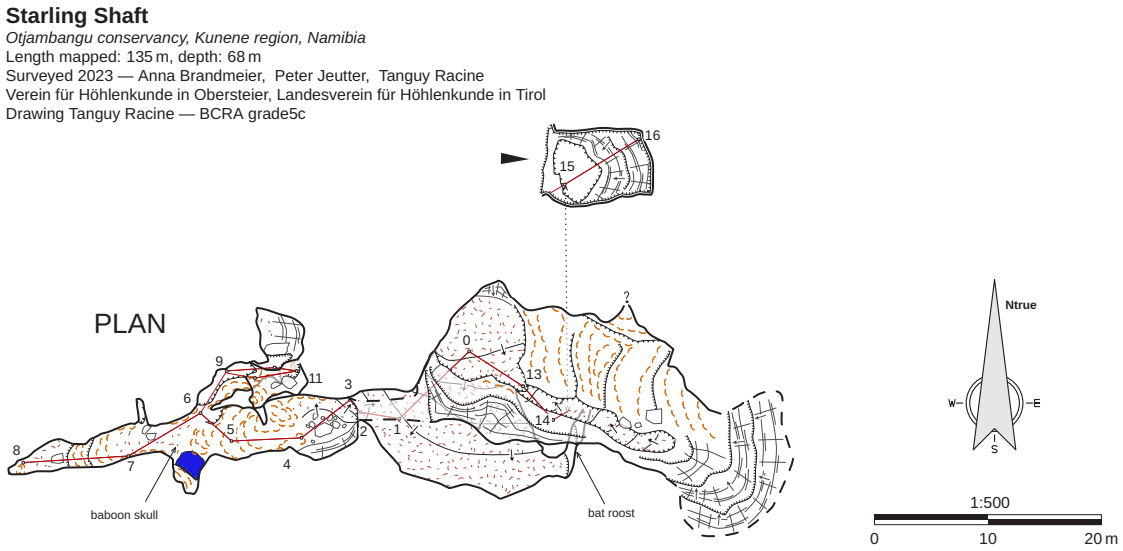
Omuhako Cave
Otjikondavirongo conservancy, Kunene region, Namibia
Length mapped: 505 m, depth: 54 m
Surveyed 2023 — Anna Brandmeier, Peter Jeutter, Tanguy Racine
Verein für Höhlenkunde in Obersteier,
Landesverein für Höhlenkunde in Tirol
Drawing Tanguy Racine — BCRA grade5c

Omuhako cave survey (scaled)

Starling Shaft

Although initially spotted on the 2018 aerial survey, this cave was found by members of the IRDNC looking for potential cave entrances near the Otjikondavirongo campsite (Figure 5). Parking the car east of the village, a short 1.3 km hike up in an easterly direction leads almost to the summit of a nearby hill, along which some prominent west-dipping dolomite beds make recognisable landmarks. Starling shaft can be found along the most prominent of those.

Starling shaft opens with an impressive 55 m deep, sunlit entrance shaft. A pair of anchors at the western rim of the shaft gives a 30 m freehang to a wide ledge, followed by a series of rebelays to reach the floor. Midway through the descent, the chamber dimensions increase dramatically, with a large dome-shaped chamber with a steep floor joining in from the east. The northern wall of the shaft is covered in thick flowstone deposits reaching all the way to the cave floor. The continuation is found on the western side of the debris cone at the shaft bottom. A short shuffle under a low-ceiling enters a parallel shaft, where light filters in from above. On the far (western) side, a free-climb down a thick, corroded flowstone deposit yields another chamber, with a small pool of standing water. Climbing down further to the west eventually reaches a dead end, the deepest point of the cave at a depth of 68 m. At the side of the flowstone, it is possible to climb down and reach a small chamber and short climb, forming a loop.



Plan view of Starling Shaft (scaled)

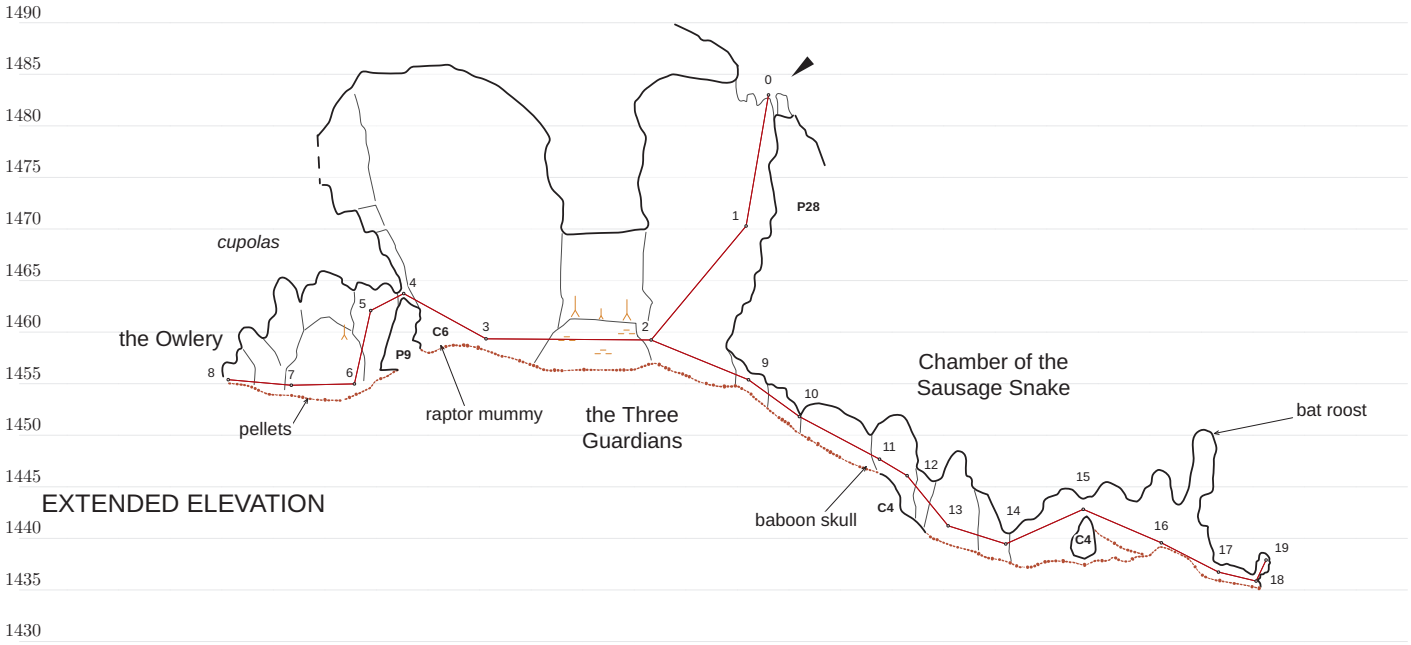
The entrance pitch of Starling Shaft — *Tanguy Racine*

Extended elevation of Starling Shaft (scaled)

Three Guardians Cave

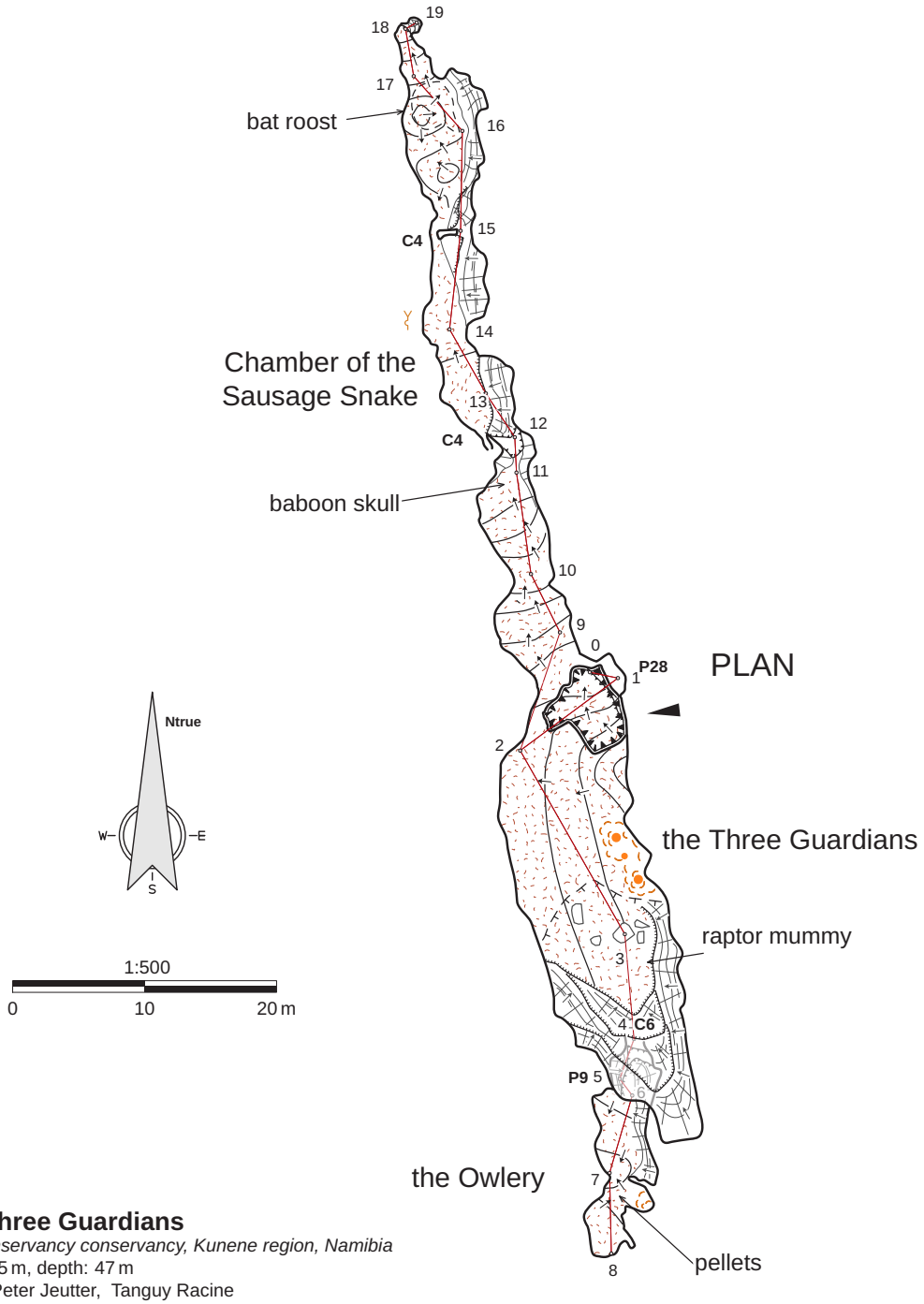
The cave was first spotted by aerial survey. From the camp in Omuhiva valley (in the Obujokanguindi conservancy, Figure 5), a 2.2 km walk westward over the mountain range and steeply along a mountain ridge reaches a series of steeply dipping dolomite beds forming a break in slope, along which the 5 m diameter cave opening can be found.

The cave begins with a 27 m deep open pit, landing on a guano and debris floor, in a sunlit chamber 10 m wide and 30 m long. Three ancient flowstone deposits, found along the eastern wall in the twilight zone, give the cave its name. Along the southern end, the cave ceiling rises to a height of 30 m in a dome shaped chamber. A short 4 m off the floor of the southern wall leads into a 1 m diameter hole, beyond which is a series of smaller chambers (the Owlery), floored by debris, guano and owl pellets. The walls are imprinted with cupola morphology. An ancient and broken flowstone deposit exhibits a 1 m section of layered calcite. A lone, half metre tall stalagmite decorates one of the cupolas on the western wall.



Extended elevation of Three Guardians cave (scaled)

Back in the entrance chamber, at the foot of the entrance shaft, the floor drops away to the north, in a series of guano and debris-filled dome-like chambers which also serve as obvious bat roosts. Bones and animal remains are abundant, including a striking mummified snake, hanging precariously from a spike of cauliflower calcite. A short climb up leads to the terminal chamber, another bat roost, at a depth of 47 m.



Cave of the Three Guardians
Obujokanguindi conservancy conservancy, Kunene region, Namibia
Length mapped: 145 m, depth: 47 m
Surveyed 2023 — Peter Jeutter, Tanguy Racine
Verein für Höhlenkunde in Obersteier, Landesverein für Höhlenkunde in Tirol
Drawing Tanguy Racine — BCRA grade5c

Plan view of Three Guardians cave (scaled)

The entrance chamber and eponymous flowstones of the Three Guardians cave — *Tanguy Racine*

Wooden construction at the far end of Khoekhoe-kai//om cave — *Andreas Wolf*

Khoekhoe-kai//om cave

The entrance to this cave was spotted during the 2018 aerial survey. Similar to the Three Guardians Cave, it is located on the western slopes of the limestone/dolomite range separating the Omuhiva and Otjikondavirongo valleys (Figure 5). The name is derived from the Bushman language and translates to ”large chamber where Bushmen sleep”. The cave comprises a short climb down into a chamber of large dimensions and after a short bend to the right, the end of the passage is reached. In this twilight zone are some intriguing wooden stakes, clearly placed by prior visitors to the cave.

Sesfontein area

During the middle stage of the expedition, as teams 2 and 3 met up in Sesfontein, there was a push to explore the caves neighbouring this town. Some entrances had been spotted along the walls of nearby canyons, but they could not be accessed during day trips.

Parrot portal caves

These caves are located on the C43 road, between Kamanjab and Warmquelle and they are visible on the uplands east of the road (Figure 5). Three significant entrances could be spotted, the lower two were surveyed and are described below.

The lower portal requires a short climb to access. Beyond the 10 m tall entrance portal, the cave ends quickly (sunlight can still be seen from the innermost point). Cauliflower calcite formations coat the walls, while the floor is mostly littered with bat guano and bird excreta.

The upper portal divides into two branches from the cave's entrance portal. The lower, left-hand branch continues for a few tens of metres before ending at a choke. The right-hand branch can be accessed by a short climb, secured by a rope. There, on gains a large descending passage, followed by a short ascent to a small chamber. The cave is decorated by many brittle, corroded calcite pillars. The cave floor is littered with guano, small bones and owl pellets.

The uppermost portal requires more involved climbing and was not accessed during this expedition.

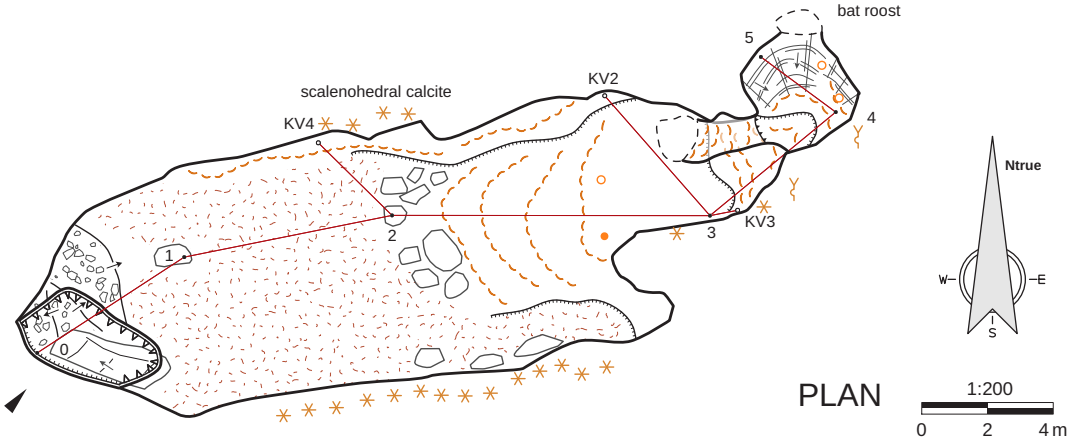
The upper entrance portal of the Parrot caves, with a view on the C43 road. — *Heidrun André*

Jewellers' Chamber

Jeweller's chamber was first spotted by aerial survey. It was then explored by driving north of Sesfontein some 10 km along dirt and gravel trails (Figure 5). A 4 km hike along a dry riverbed, heading northeast, ends at the confluence of two valleys. The cave entrance, marked by a large tree, is located about 10 m above this confluence.

A 5 m downclimb from a fallen boulder gives access to the cave chamber. The chamber is 6 to 7 m wide on average, 30 m long and its ceiling rises to 15 m above the floor at its highest point. The side walls are covered by at least two generations of secondary deposits. The first, exposed along the lower parts of the chamber, is a patchy covering of partly dissolved scalenohedral calcite crystals ranging from 5-10 cm in size. The second are massive flowstone deposits directly overlying the dissolution surface of the calcite crystals. At the far side of the ancient, massive flowstone deposit which can be climbed to reach the far side of the chamber, into a chimney of diminishing dimensions where bats roost, 20 m above the chamber's deepest point.

Jeweller's Chamber
Sesfontein conservancy, Kunene region, Namibia
Length mapped: 41 m, depth: 19 m
Surveyed 2023 — Anna Brandmeier, Tanguy Racine
Verein für Höhlenkunde in Obersteier, Landesverein für Höhlenkunde in Tirol
Drawing Tanguy Racine — BCRA grade5c



Plan and extended elevation of Jewellers cave (scaled)

Caves of the Otavi Mountainland

The goal of the visits to the caves in Uisib, in the Otavi mountainland was to conduct speleogenetic observations as well as a sampling campaign, under permit RPIV011282022 issued by the National Commission on Research, Science and Technology of Namibia. The team selected a few sites, which had already been explored and mapped to conduct this research. In addition, the team also walked the surface to characterise the karst landscape, noting morphologies of interest and sampling environmental water samples from nearby karst dolines (e.g. Guinas Lake), in order to better understand the karst system. A visit to Blowing Hole to retrieve data loggers also yielded some new discoveries.

Märchenhöhle

Märchenhöhle (Fairytale cave) was discovered and surveyed by SWAKNO in 1991 (Irish et al., 1991). It is located on the Uisib Farm (Figure 6) and can be accessed by driving on the dirt road from the entrance to the farm towards south. Turning right at an obscure intersection, the road continues into a forest. At the end of the road, a bench marks the parking space. From there on a track to the left (leading south at first) goes all the way up to Märchenhöhle. On that track, several other caves can be found as well, e.g. Uhlmannhöhle and Uhlenhorsthöhle. A big Marula tree helps with finding the entrance, which is located a little to the left (south) of the tree.

The cave starts with a wide-open pit equipped with a fixed ladder (Figure 7). At the bottom of the ladder, a 10 m high chamber with a sloping boulder floor is reached. At the lower end are two passages, the one of the right being rather short. To the left, the main passage continues, leading to two consecutive fixed ladders down to another, smaller, chamber. To the right is the “Märchenhalle”, a chamber decorated with a lot of straight stalactites and stalagmites.

The cave is characterised by a profusion of ornate speleothems found in several parts of the main passage. The stalagmites exhibit an intriguing texture, with a lot of little popcorn-like features. Some of them are slender and candle-shaped, measuring a little more than one metre long.

Within the cave are abundant reddish sediment accumulations, a feature that can be seen in the other caves of Uisib Farm as well.

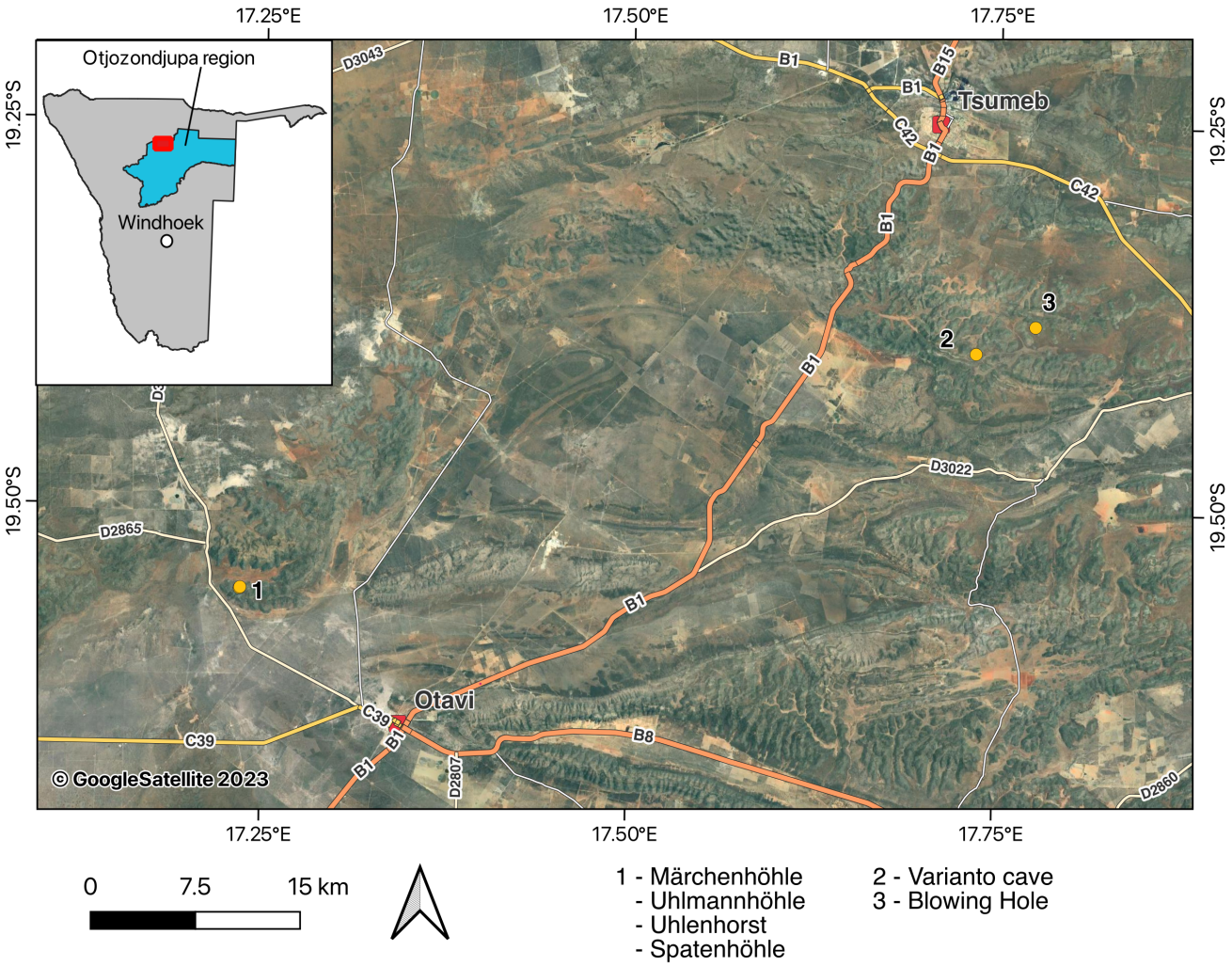


Figure 6: Location of the caves investigated in the Otavi mountainland. Note that although Varianto höhle was one objective of the trip, it was not visited during the expedition.

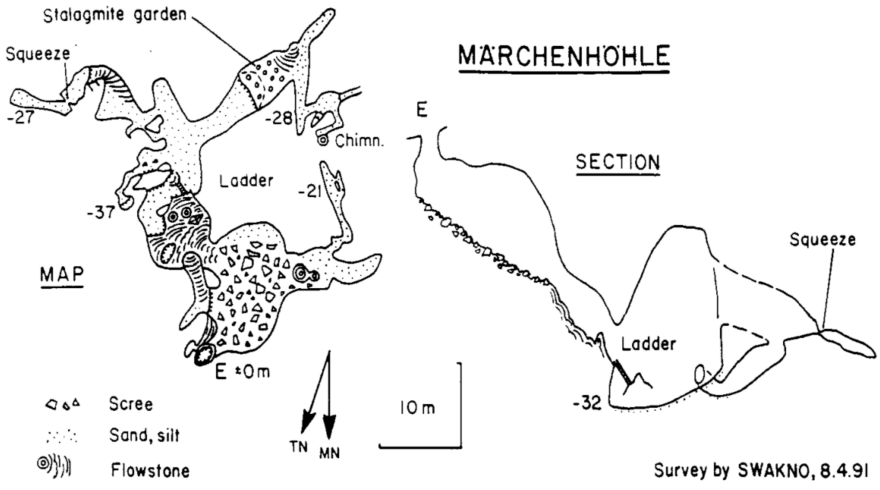


Figure 7: Map of Märchenhöhle reproduced from Irish et al. (1991)

Left, entrance to Märchenhöhle, Right, entrance to Uhlenhorsthöhle. — *André and Kyle Schoeman*

Uhlenhorsthöhle

Uhlenhorsthöhle lies on the same path as Märchenhöhle. After passing Uhlmannhöhle, a short but steep walk upwards leads to the entrance (Figure 6). The entrance portal, about 10 minutes walking time below Märchenhöhle, is very big and can hardly be missed.

The entrance is an open pit equipped with a fixed ladder. After going down, the cave continues to the west where it enters a big hall, where daylight can still be seen. To the left (south) the cave continues to an old flowstone pool and another drop, where SRT is needed. This part was left out in the 2022 and 2023 expedition but was mapped on a previous trip to the cave. A little stream previously observed in the main chamber, was dry during the 2023 expedition. Reddish sediment accumulations in this cave are noteworthy, because no such sediment could be found on the surface today, testifying to their ancient origin. Furthermore, some undercut flowstones and sediment pockets are preserved on the ceiling and walls, indicating that the red sediment was deposited prior to flowstone deposition. Most of cave sedimentary fill was then flushed out.

Sediment samples and detailed stratigraphic logs of the sedimentary sections will provide some additional insight on the age, the depositional history and origin of these intriguing cave deposits.

Uhlmannhöhle

The entrance is somewhat obscured by boulders; however, the fixed ladder can be seen when walking the path up to Uhlenhorst- or Märchenhöhle (Figure 6).

The fixed ladder allows access to the entrance chamber, which, together with the following main chamber has high ceiling, and a floor covered by the same reddish sediment. In the middle of the ceiling hangs a thin yet very long stalactite. It looks like it could fall off by merely looking at it too hard.

Within the main chamber there are several walls with large exposures of layered red sediments. The grain sizes vary across and within layer boundaries, and horizontal and cross bedding can be seen. Small fragments of shells and organic matter were found in some of the layers. To the north, a passage continues that leads to an active flowstone with a beautiful white colour.

Kyle and André Schoeman — *Peter Jeutter*

Blowing Hole

During the 1995 VHO expedition to Namibia, Nosib Farmer Liebenberg mentioned a small hole with strongly blowing steam for which he gave a relatively accurate location. However, many days were spent looking for this entrance without it being found.

Twenty years later a farm worker from the Varianto /Atoom farms had a rest near the entrance (it was nearly completely closed at the time) and saw birds flying there no doubt to drink water from steam condensing under the roof of the tiny entrance hole. In 2016, Piet Basson, the Varianto farmer, showed this object to Peter Jeutter and Jutta Brandmeier. In the morning the cave was blowing out strongly: we measured 9km/h.

The entrance was opened up and a first investigation led into the steamy passage to a depth of 20 m, stopping at a vertical shaft. Immediately after the entrance, the cave opens up into a series of chambers with clear hypogene morphologies, developed in an impressive breccia. This part was surveyed and later in 2016, Peter Jeutter and Franz Schmidt came back to survey the cave over two trips, to a depth of 60 m and almost 300 m in length.

The first data loggers were installed but the monitoring attempt failed because the loggers did not survive the heat and humidity until they were collected by Robin and Peter Jeutter in 2017. In 2018, new loggers were installed by Marcel and Peter Jeutter. They were collected in 2019. The data shows that the cave air is clearly affected by daily temperature/pressure changes outside. The cave is intermittently breathinig: blowing air out as well as sucking in.

Top left: Panorama of undulose hypogene morphologies in one of the branches of Blowing Hole.
Top right: Mega-breccia in Blowing Hole side passage — *Christoph Spötl*

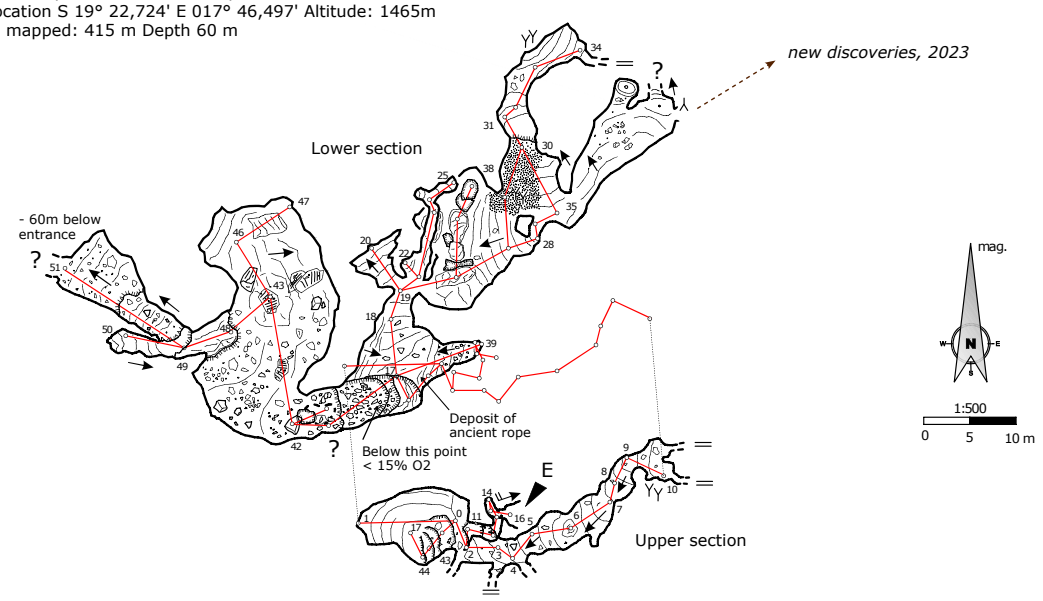
In 2021 Anna Brandmeier, Leonie Leitgeb, Christoph Spötl and Peter Jeutter visited the cave for speleogenetic and climate studies. Samples were taken and new loggers installed. During this trip, a new passage was discovered.

During the 2023 Kaokoveld/Otavi Expedition Anna Brandmeier, Tanguy Racine and Peter Jeutter started off visiting Blowing Hole with the aim to survey the passage discovered in 2021 and to collect the data loggers installed by Christoph Spötl and Leonie Leitgeb. Surveying the new passage turned out to lead to new extensions, a total of 130 metres were surveyed, leaving some question marks on the map. The new parts are some the most beautifully decorated parts of the cave (so far).

The cave has a high CO2 concentration and low oxygen levels. At the mid-level, at 35-40 m depth, where the new passages were documented, the Oxygen is around 18% (instead of 21%). It was an intense six-hour cave trip.

It is worth noting that we were not the first people in Blowing Hole. Tracks, an old and decayed piece of hemp rope, as well as some destroyed flowstones are proof that somebody visited the cave probably more than 100 years ago during colonial periods, presumably seeking for a possible water supply. The beautiful and continuing newly discovered parts were clearly unvisited before.

Blowing Hole
Farm Nosib, Otavi-Mountains, Namibia
GPS Location S 19° 22,724' E 017° 46,497' Altitude: 1465m
Length mapped: 415 m Depth 60 m



Surveyed 2016 &2022 by J. Brandmeier, F. Schmidt, P. Jeutter
Verein für Höhlenkunde in Obersteier - Drawing P. Jeutter, BCRA Grade 5c

Blowing Hole 2022 survey

Conclusions

Speleogenesis

Despite the extensive exposure of carbonate rocks in the eastern part of the Kaoko Belt (Figure 2), surface karst is little developed to absent, as a result of the aridity. Subsurface karst expressions under the form of large chambers (the Orumana sinkhole or Omuhako main chamber for instance) are present, however, testifying to locally intense dissolution. The currently accepted speleogenetic model for these cavities was put forward by Martini et al. (1999), after several years exploring the region (Martini and Marais, 2002; Martini et al., 1990). It was at the time that the hypogenic origin of many of the caves found in the region was recognised. The speleogenetic rests on several key observations:

- absence of surface karst morphologies at mega-scale, i.e., no dolines, no blind valleys, dendritic valley networks,
- absence of relationship between the surface drainage and cave entrance location (for instance, the Orumana sinkhole)
- presence of key morphologic indicators within the caves, upwards terminating alcoves, niches, cupolas, e.g. at Temple of Doom cave.
- presence of low salinity and low temperature calcite spar, and baryte in one cave (Temple of Doom)

The speleological findings of the 2015, 2018 and 2023 cave expeditions to Namibia are in accord this model. The Omungongo cave for instance was described as having a complex 3-dimensional maze of dry passages of phreatic origin, upwards terminating passages and successions of dome-like chambers. Similar morphologies were described from the Mundumithe cave, including ceiling half-tubes near that cave entrance. In almost all other instances, there appears to be a total lack of relation between the cave entrance location and local topography or drainage.

At the cave system scale, phreatic mazes were observed in two parts of Omuhako cave in the north and west, at depths between 45 and 50 m. Upwards terminating chimneys or cupola-like morphologies were found in the cave of the Three Guardians, for instance in the Owlery and in the deeper sections. No evidence of vadose flow was recorded in the Kaokoveld caves.

Entrances to the caves often result from the collapse of large underground chambers. In the piedmont of the Otavi mountains are several cenotes (for instance Guinas Lake) which formed by the collapse of subaqueous chambers (Martini, 1991). This is also the case in three of the caves explored in the Kaokoveld. At Omuhako cave, Starling Shaft and the cave of the Three Guardians, the cave entrance geometry is a vertical pit formed by the collapse of a chamber roof, ranging from 6 to 60 m in depth.

Only in a limited area were markers of the epigenetic speleogenesis could be observed, and those are absent in most of the Kaokoveld area, whereas they are developed in the Otavi Mountainland: immature rifts, pitted surfaces and sporadic karren fields. Such surface morphologies were also seen in the karst area north of Opuwo investigated by Team 3.

Outlook

In the Kaokoveld there remain several cave entrances known to the local people which were not yet investigated. The general cave morphologies suggest that small entrances lead to bigger caverns with collapse features. Horizontal cave development is not well developped, and is usually limited to small sections of phreatic mazes on the outskirts of larger chambers. Although there is potential in theory for > 400 m deep caves because of the steeply dipping carbonate strata, breakdown features and guano deposits usually close up the cave passages before they reach a great depth. The deepest cave in the area remains the Wow Gdoom pot at a depth of 130 m.

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Finances

Item	*Amount*
Flights	13 664.64€
Cars	6690.00€
Petrol	2102.62€
Food	1620.81€
Specific technical material*	650.86€
Accomodation	3795.04€
IRNDC local support	402.89€
Other	314.80€
Total expedition cost	**29 241.67 €**

* technical equipment (rope access) was mostly sponsored by the VHO and members of the team as well as the University of Innsbruck. These costs are not mentioned above. In Addition Korda's has sponsored 200m of rope.