~ TECHNICAL REPORT ~
EXPLORATION, MAPPING AND SURVEY
~ AIKAB HEMICENOTE ~

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This self funded expedition would not have been possible without the dedication of the team members who committed their time and money to this work.

Chris

Don

Alessio

Steff

John

Uwe

We would like to express our gratitude to the Ministry of Environment & Tourism for approving our research and collecting permit.

Johan

We would also like to thank the staff of the Etosha National Park for their assistance,

and a special thank you to Shayne and all the hard working volunteers.

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1 Background and Rationale

1.1 Site location and description

Aikab, also known as T'Kai T'kab, Txai-txab, Xai-qab or Ai!gab, is a large water filled karst lake (cenote) situated in a surface depression (doline) on the southern boundary of the Etosha National Park (Figure 1). Unlike the better known Namibian cenotes of Otjikoto and Guinas which have open water surfaces, Aikab is characterised by a partial collapse of the roof, leaving the majority of the lake surface covered as a hemicenote. The water surface area of Aikab nevertheless exceeds that of Otjikoto and Guinas.

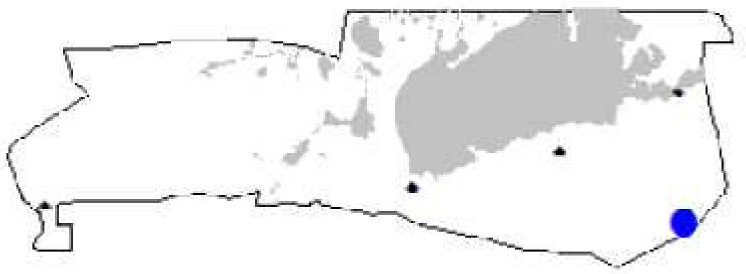


Figure 1. The approximate position of Aikab (blue dot) near the southern boundary of the Etosha National Park.

1.2 Exploration and Mapping

Aikab has been visited by several individuals and groups over the years, many of whom made some attempt at describing, mapping or surveying the doline and lake surface. The last known survey was done in 1989. At that time computer aided mapping was unheard of, and while the efforts of these pioneers need to be admired, the results resemble a rather crude sketch map when compared to what is possible with current methods and technology.

The subterranean part of the lake has never been explored or mapped. In 1992 a team of divers from South Africa visited Aikab to collect submerged stalactites for paleoenvironmental research purposes. Although they managed to dive to a depth of 40 metres, they did not have the time or equipment to explore and map the hidden depths. The extent of the subterranean chamber and the volume of water that it holds remain unknown.

1.2 Hydrogeology

Otjikoto, Guinas and Aikab are in line with, and relatively close to each other. The first two are only 20 km apart, while Guinas and Aikab are about 40 km apart. The hydrological links between Guinas and Otjikoto have been monitored and studied extensively, but their links with Aikab remain unknown. Furthermore, while major fluctuations in the Aikab water levels are evident as water lines on the walls of the cavern (above and below the water surface), the drivers of these changes and the relationship with local borehole water abstraction and rain fed recharge remain unknown.

1.4 Biodiversity

Although not extensively sampled, the terrestrial fauna and flora of the hemicenote has been investigated and described by various expeditions over the years. That these surveys were not exhaustive is borne out by the fact that during the 1992 expedition, Aikab yielded a unique species of terrestrial isopod restricted to Namibian caves – duly named *Namibianira aikabensis*. Since some sunlight enters the cave, particularly during the middle of the day, it is unlikely that Aikab contains stygobiotic species such as the cave dwelling catfish *Clarias cavernicola*, which is without sight or pigmentation and occurs only in the total darkness of the Aigamas cave near Otavi.

While previous surveys established some baseline biodiversity data for Aikab, the list is by no means complete. In particular, the invertebrate fauna from different depths and light penetration zones need to be surveyed in order to expand the baseline data for the upper levels, and establish a baseline for the deeper levels.

2 Aim of this study

The main aim of this expedition to Aikab is to explore and map the lake – above and below the surface.

The secondary aims are to:

- Extend the current invertebrate baseline.
- Investigate the hydrology of the lake.

3 Initial Work

The Namibian contingent of the multi-national science team visited Aikab on two occasions prior to the main expedition. These visits consisted of:

i. A quick reconnaissance in June 2013 with a surface swim and depth sounding in a few places in order to confirm the feasibility of the expedition.
ii. An exploratory dive trip in October, with the morning spent on rigging and getting equipment into the water, one dive in the afternoon and extracting equipment and de-rigging the following morning.

The finding from these two trips were:

- Confirmation of the basic plan and depths found by the original survey team of Irish and Marais (Figure 2).
- A significant drop in the water level from our previous visit. This was somewhat surprising since there is no direct water abstraction from Aikab.
- Artefacts on the floor at a depth of about 40 m (Figures 3 & 4).
- A series of linear dunes some distance from the debris cone (Figure 5).
- Presence of at least two types of aquatic invertebrates on the slopes of the debris cone (Figure 6).

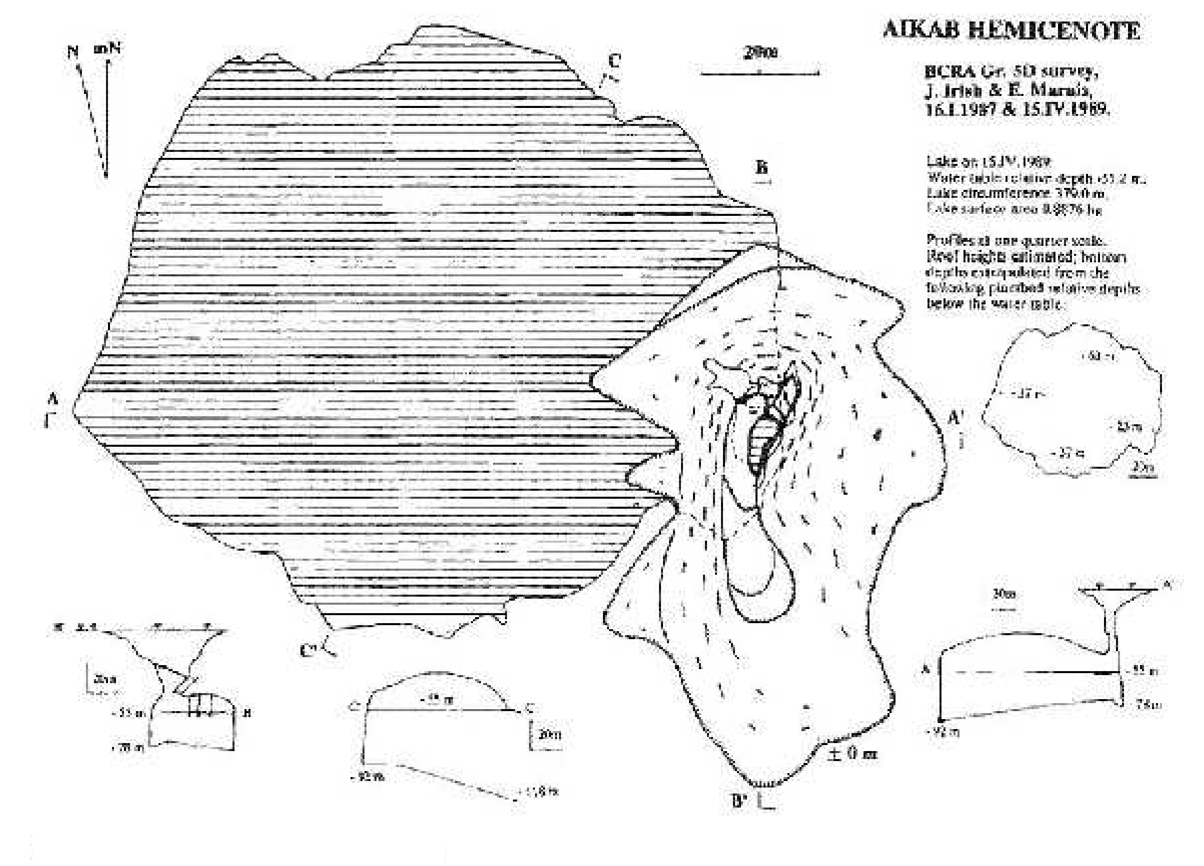


Figure 2. Aikab plan and profile as surveyed by Irish and Marais in 1987 and 1989.

Figure 3. Artefacts at the foot of the debris cone at a depth of about 35 metres below the surface.

Figure 4. Artefacts against the southern wall of the chamber at a depth of about 45 metres below the surface.

Figure 5. Johan above one of the dunes.

Figure 6. Aquatic invertebrates at a depth of about 30 m. The shrimp-like specimens are similar to a species that has only been found in Dragon's Breath cave lake. The leach-like specimens are unknown.

4 The Main Expedition

The main expedition, lead by Dr Johan le Roux and involving the full international team, took place in May 2014. The main focus of the expedition was:

- Extensive survey of the cave lake.
- Extensive biodiversity survey.

These two activities are described in detail below.

4.1 Cave lake survey

This survey was conducted by Dr Alessio Fileccia, following well established procedures that require the recording of the following parameters:

Figure 7. Alessio surveying the lake.

- Distance between consecutive points
- Azimuth of each leg (virtual segment connecting points/stations)
- Inclination (slope) of each leg.
- Distance from the station point to the walls, roof and the bottom parameters.

The lake perimeter was mapped from a series of measurements taken while following the cavern wall in two boats. The lake bottom was sounded along lines tightly fixed on opposite walls. Depth was measured every 10 m using a 100 m tape with 2 kg lead weight at the end. This simple technique allowed a fairly precise reconstruction of the bottom topography inside the lake surface perimeter. Measurements (from surface to roof) from the same points used to measure the bottom depth were taken to determine the height of the ceiling above water. These survey parameters were taken using a Disto 8 laser and a Cave Sniper. The latter instrument is equipped with an electronic compass and a tilt meter, and receives distance recordings via Bluetooth from the Disto 8 instrument. The three readings are stored and classified in the memory for later download. To add details to the survey, waypoints and tracks with a Garmin GPS were taken on surface. This allowed the mapping of the doline borders above the cave.

Data was initially processed manually on millimetre grid paper to check all figures before digital processing with the following software packages:

- Visual Topo for plotting legs and stations, and to get the closure error.
- Didger and Surfer for georeferencing, statistical calculations and contour lines.
- CorelDraw for titles, pictures, logos and final retouch.

The plans were referred to magnetic north with declination values taken from the 1:50000 maps, South west Africa 1977 edition.

4.2 Biodiversity survey

This survey was conducted by Dr John Irish and was comprised of three components:

i) Underwater faunal investigations.

ii) Above-water faunal investigations in the cave chamber.

iii) Floral investigations in the doline.

Underwater faunal investigations were carried out by the diving team. Besides incidental collecting and photography of invertebrates, baited traps on the bottom were used to collect representative samples of the aquatic fauna.

Figure 8. Steff collecting underwater faunal specimens.

Above-water faunal investigations comprised a thorough inspection of the lower cave chamber walls and lake surface.

In order to determine whether the sheltered doline acts as a climatic refugium for some plants, a botanical survey of the doline was done. Collected material is still undergoing study by a botanist but at least one plant has already been flagged as unusual for the area.

5 Results and Discussion

Results are presented and discussed under the same headings as for "Work Conducted", i.e. cave lake survey and biodiversity survey.

5.1 Cave lake survey results

5.1.1 Plan view and profiles

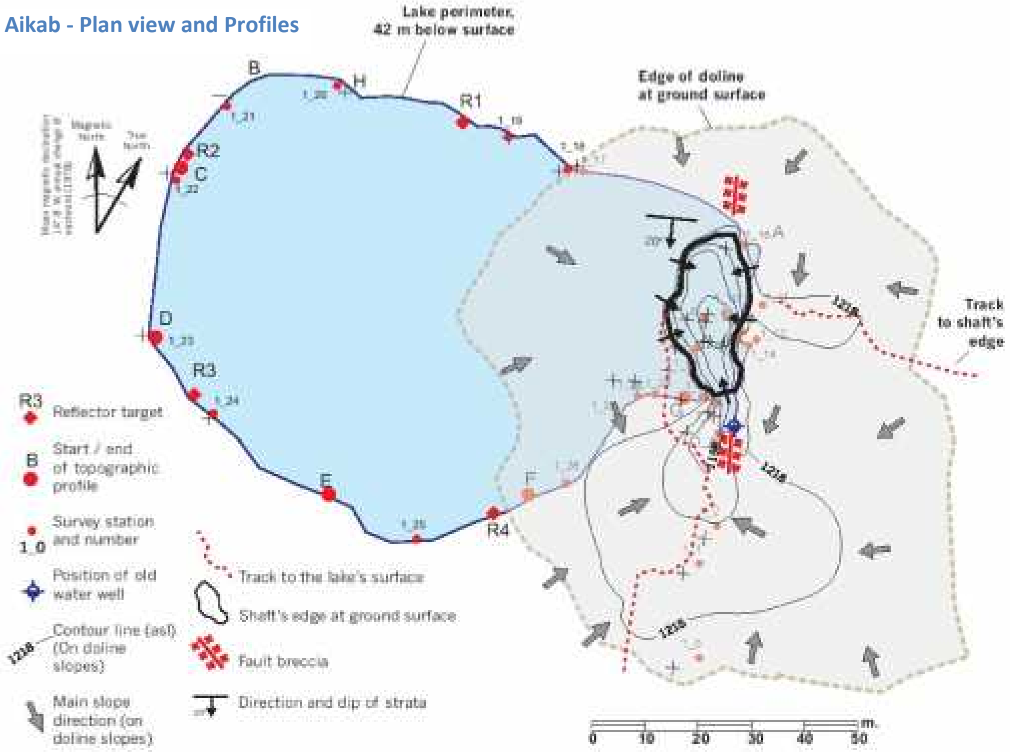
Refer to Figure 9 on the next page.

The approximate border of the doline (grey coloured) is superimposed on top of the lake perimeter, 45 m below. The ground surface inside the broken line surface shows the change in slope as depicted form the contour lines, from nearly horizontal to vertical near the edge of the shaft (thick black line). The water line can be reached from the south by entering a narrow canyon. A small side shaft (not visited) is located at station 1-8. The elevation view is an extended profile, meaning that the different legs are stretched and reprojected on a vertical plane.

The total depth of the shaft, from the surface down to the current water line, is between 42 and 45 m (approx.) depending on the highest point of measurement (flat ground surface or start of descent at the rock edge by SRT).

A well visible N-S vertical fault cuts the rock layers that are plunging 15° to 20° South.

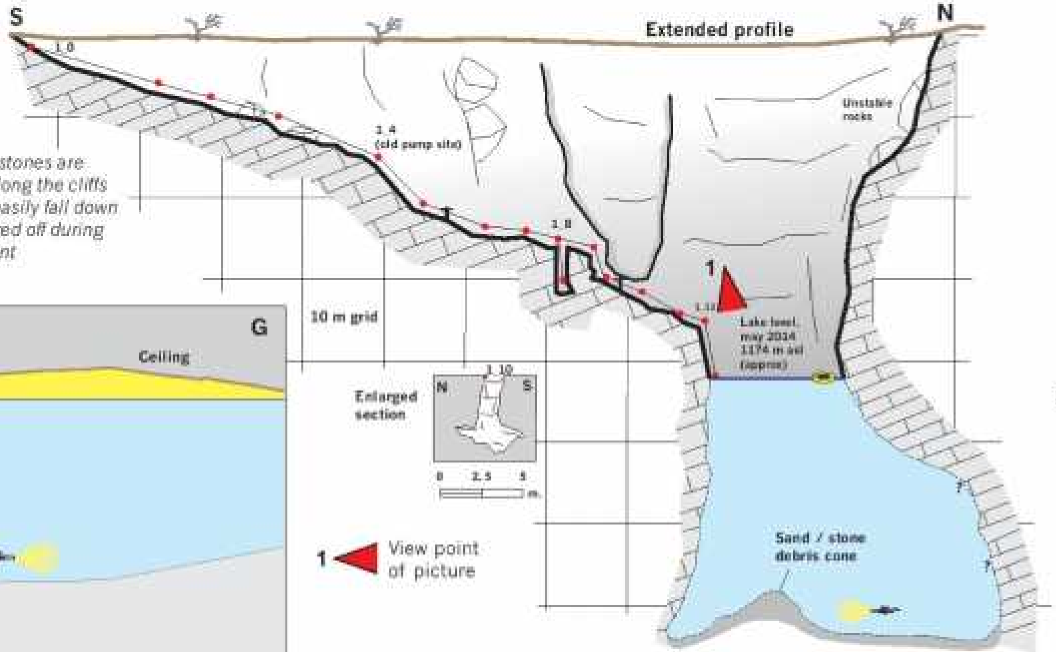
Figure 9. Aikab - Plan view and Profiles

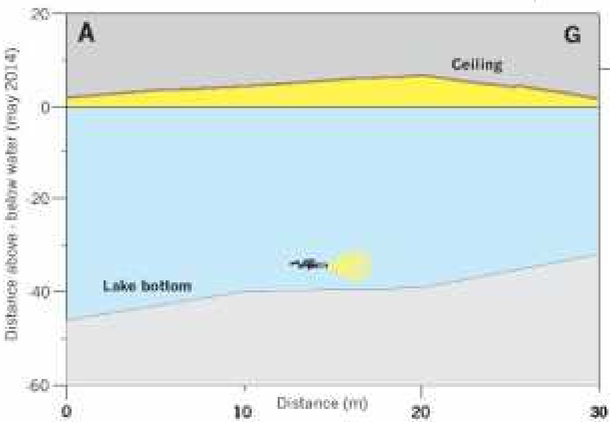



Surveying the lake


1: The floating platform at the base of the 42 m shaft

Unstable stones are present along the cliffs that can easily fall down when kicked off during the descent





Aikab expedition 2014

Plan view and profiles

Expedition members

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Expedition leader - underwater exploration

Chris Steenkamp (NAM)
Dive Coordinator - underwater exploration

Don Shirley (S.A.)
Deep underwater exploration

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Underwater exploration

Uwe Sieg (NAM)
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Alessio Fileccia (I)
Cave survey

Field Assistance
Mathew Walters (NAM)
Shayne Kötting (NAM)

Position: Etosha Nat. Park Namibia
Local name: Aikab underground lake
Entrance shaft elevation (asl): 1216 m
total depth: 147m from surface
max depth underwater: 105 m
(bottom not reached)
lake perimeter: 327 m
lake surface: 10140 sqm
volume chamber (a.w.): 87740 cum
minimum volume of water: 278170 cum
Date of survey: may 2014
Data aquisition: GPS Garmin, Disto8, Cave Sniper,
bottom soundings every 10 m, w. weight,
Data processing: Visual topo, Surfer suite, Corel Draw
Precision of survey: BCRA 5/C
Lithology: dolomitic lmst. 700 M.y.
Prepared by Alessio Fileccia july 2014

5.1.2 Lake bathymetry and profiles

Refer to Figures on the following pages.

The plan shows the lake perimeter and the bottom contours. Depth below the entrance shaft is -28 m on top of a steep debris cone. Numerous dives indicate that the roof opens underwater to distances that were explored only in a few places. There are no beaches along the borders and walls are almost vertical everywhere. The main structure underwater is a 10-15 m high east – west ridge - a debris cone that resulted from the collapse of the cave roof many years ago. The bottom deepens to the north and east to -60 m below point H of the profile. Don Shirley dived as deep as 105 m following the submerged roof without reaching the bottom.

Figure 10 Deep diver Don.

From the survey we can extrapolate some statistical data:

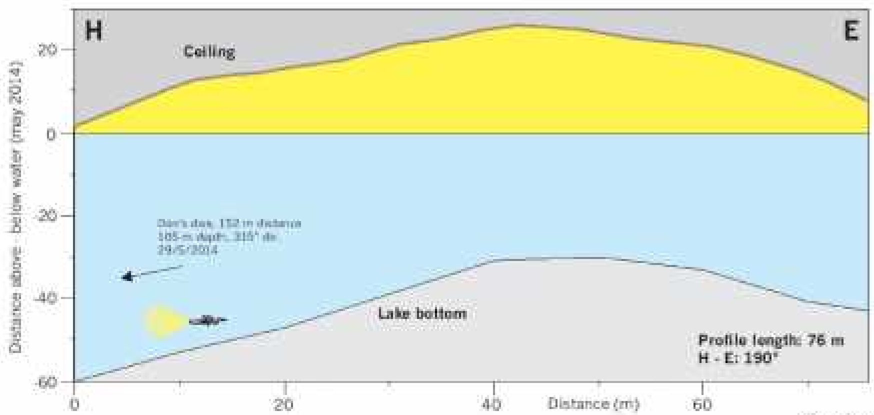
- Lake perimeter: 327 m
- Lake surface area: 10140 m2 (1 ha)
- Chamber volume: 87740 m3
- Minimum volume of water stored: 278170 m3

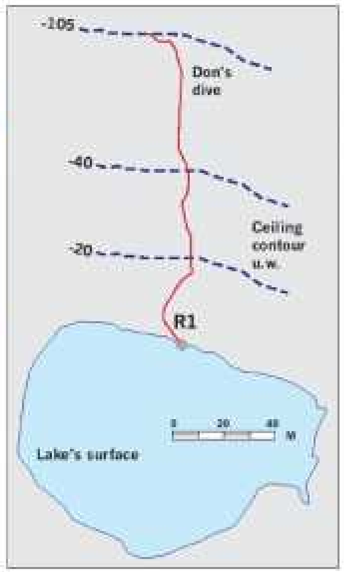
All figures above are subjected to change over time and according to natural recharge. The minimum volume of water is certainly underestimated - what is listed is probably less than one third of the actual volume. It must be remembered that the biggest part of the water volume is under the roof, plunging underwater. Horizontal marks above and under the water line (Figures 11 & 12) left from floating calcite, show that the level changed in the past from + 4 m to -15.4 m relative to the level recorded in May 2014.

Figure 11. Calcite lines on the cavern walls above the May 2014 water level.

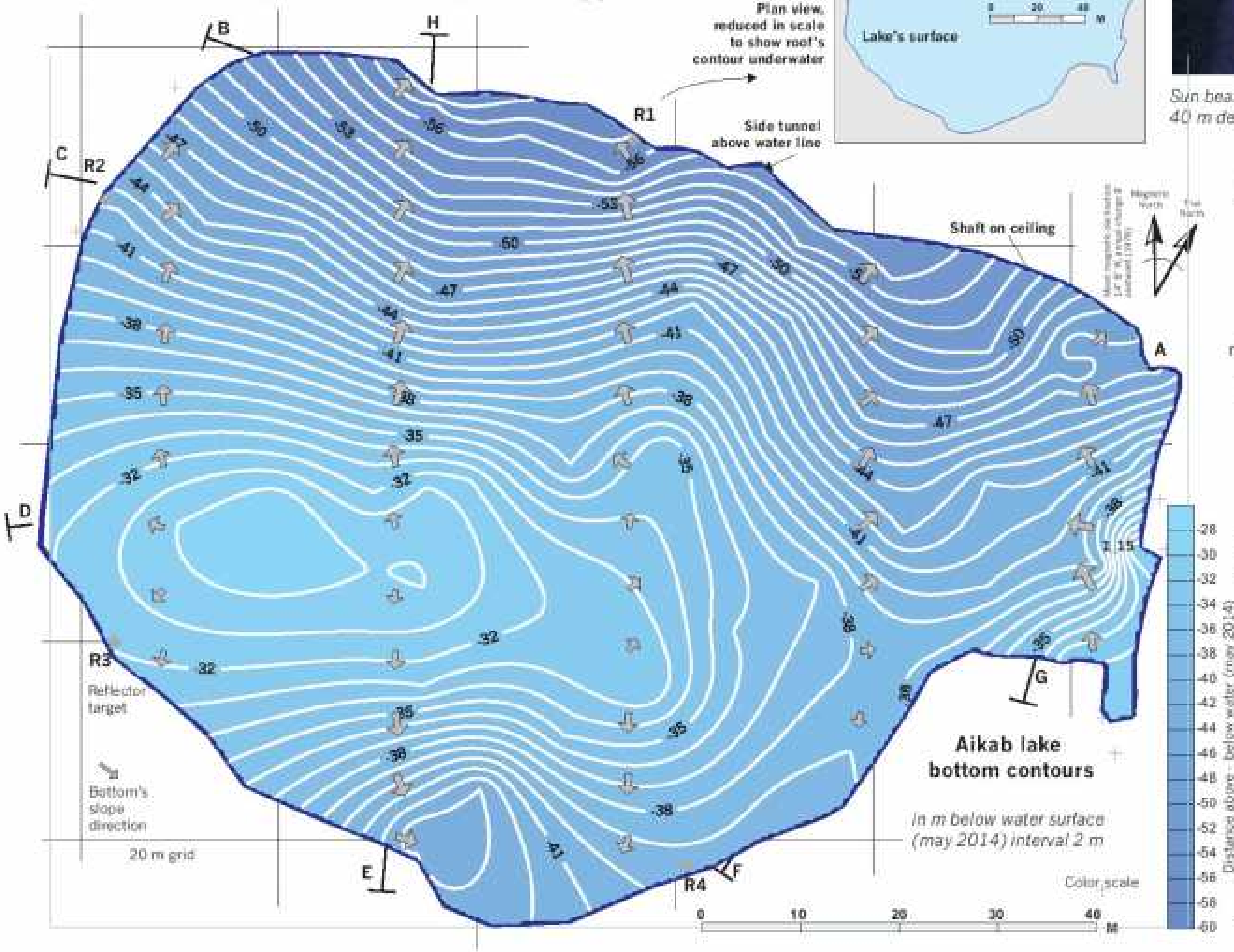
Figure 12. Calcite lines on the cavern walls below the May 2014 water level.

Figure 13. Aikab - Bathymetry and Profiles





Sun beams can easily light down to the bottom at 40 m depth, through the crystalline water



Aikab expedition 2014

Lake bottom bathymetry and profiles

Expedition members

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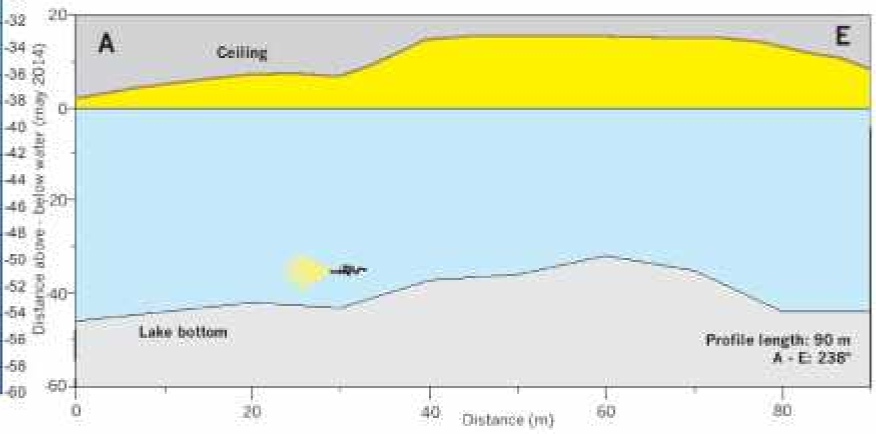
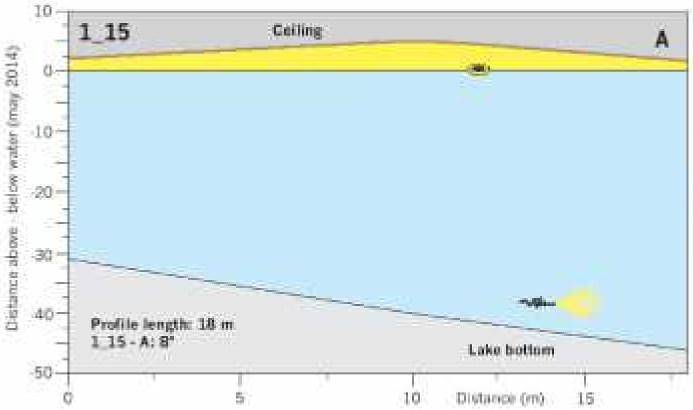
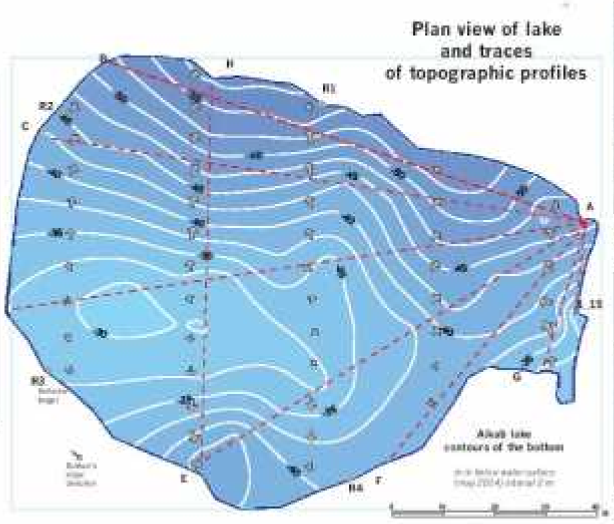


Figure 14. Aikab - Bathymetry and Profiles continued.





Debris cone at 28 m underwater, below the entrance shaft. Bones of animals fallen from the top are visible.

Two divers are collecting fauna specimens on the debris cone.

Aikab expedition 2014

Lake bottom bathymetry and profiles

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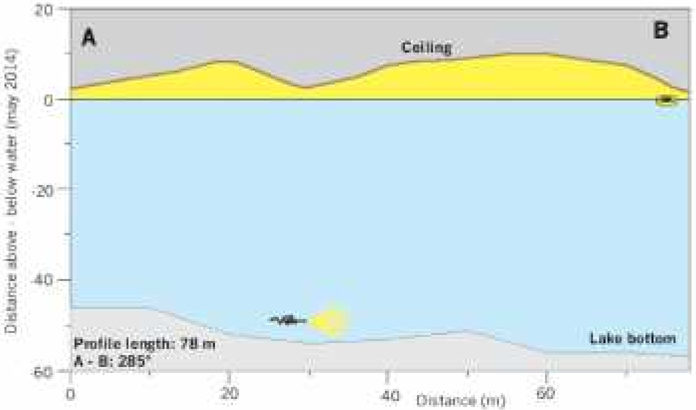

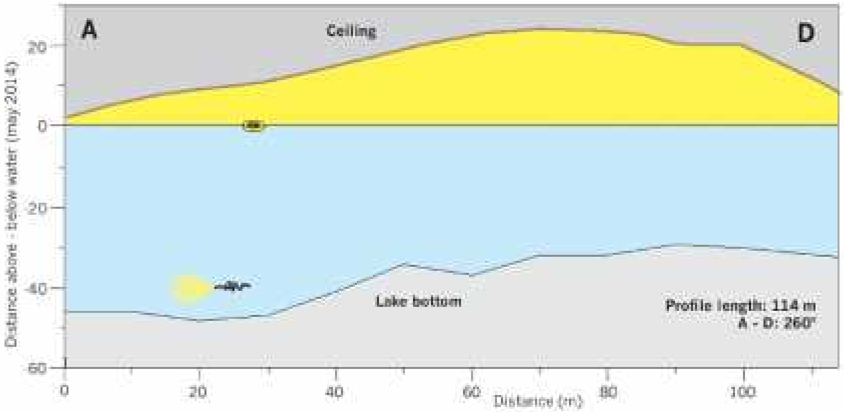

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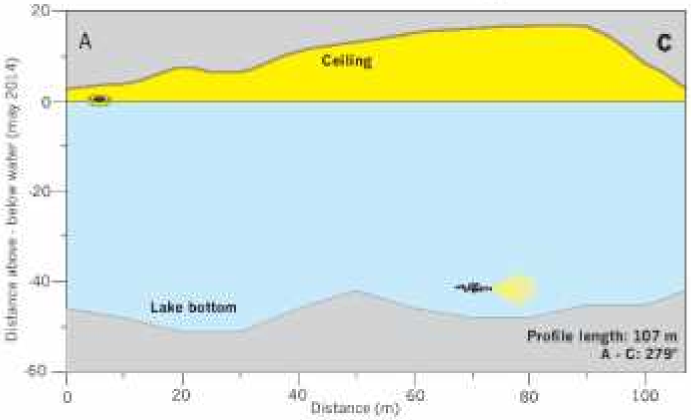


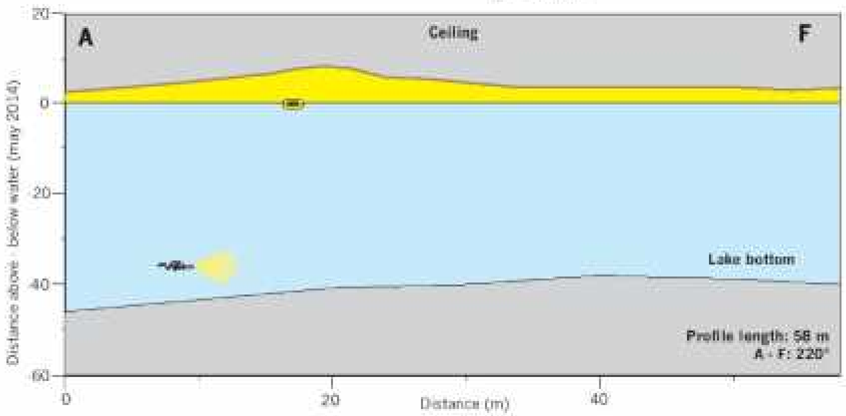


Figure 15. Aikab - Topographic profile, W-E.

This figure shows a more complete section of the lake and the entrance shaft. The roof separating the cave ceiling from the surface is only 20-25 m thick.

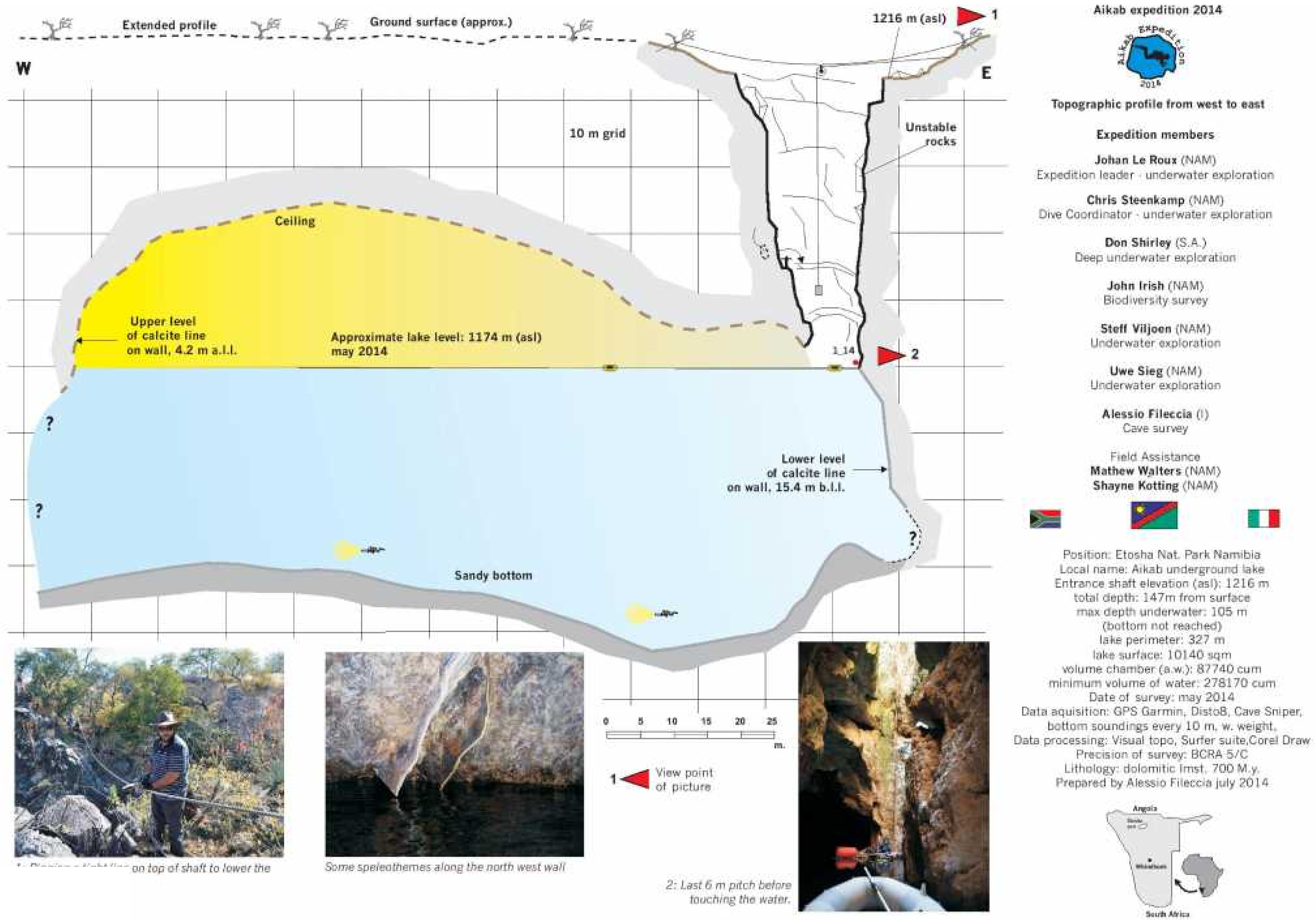
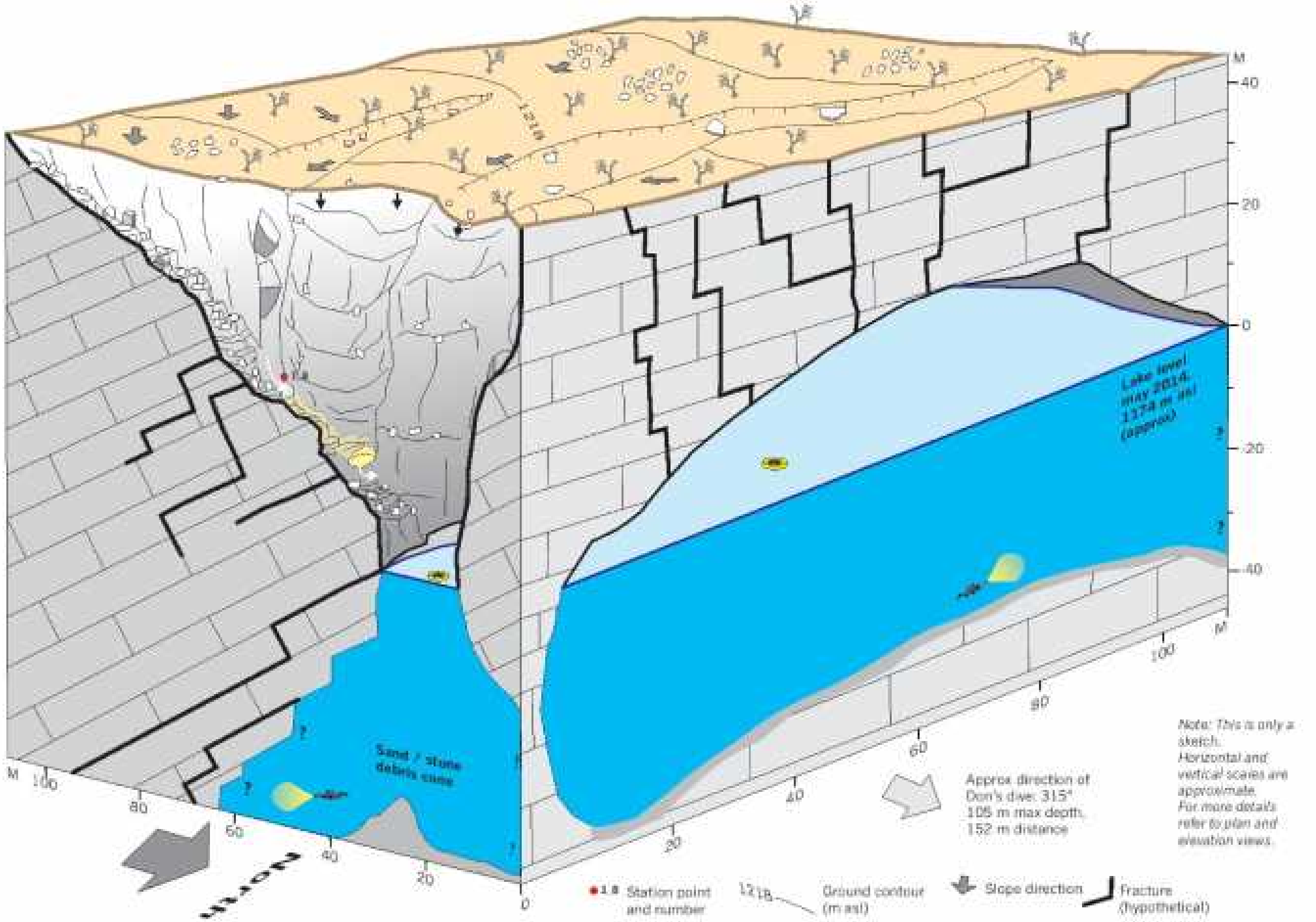


Figure 16. Aikab - Block diagram

This sketch is a 3-dimensional representation aimed at illustrating how the lake and entrance shaft are related. It must not be used for exact measurements.



Aikab expedition 2014

Shaft and lake block diagram

Expedition members

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Johan, Alessio, Chris, Don, Steff, Uwe, John, Shayne, Mathew

5.2 Hydrogeology

Aikab lies in the Cuvelai – Etosha basin, an area characterized by low precipitation with only temporary runoff and a radial drainage towards the center of the pan. Rainfall decreases from 600 mm/yr in the north east to 300 mm/yr in the west, while potential evaporation is in the order of 2700 – 3000 mm/yr. Groundwater flows are also towards the center of the pan, which constitutes the local base level for the system. The south-eastern recharge area is located in the Otavi mountains.

The probable location of this recharge area was confirmed by the discovery of about 10 lacustrine (lake) springs spread over an area of approximately 25m^2 at a water depth of between 70 and 100 metres (Photos 5, 6 & 7). The springs are about 1m in diameter and about 1m deep.

Figure 17. Lacustrine springs at a depth of 70+ meters - oblique view.

Figure 18. Lacustrine spring – oblique view close-up.

Figure 19. Lacustrine spring – vertical view close-up.

These structures are quite common on the bottom of European Alpine lakes. When a lake is located at the foot of a limestone mountain it is normally fed by runoff and underflow through karst fissures. The tunnels, variable in size, can discharge large amounts of water coming from higher piezometric levels, with pressure in the order of 10-20 bars or more. This hydraulic head can easily overcome that of the lake water and displace the sediment at the bottom creating a permanent passage such as those shown in figures 17-19. Moreover, the water supply can continue for long periods (e.g. even during dry season) due to the slow underground movement of water through the fissures.

Figure 20. Chris at a decompression stop after photographing the lacustrine springs.

In semiarid regions with longer tectonic stability this phenomenon is less frequent because it requires the contribution of many different geologic features (bedding, fault direction, tectonic stability, morphology of karst conduits, climatic conditions etc.).

A low (not passable) horizontal opening directly above the lake floor is located south of the springs. Rounded stones in front of this passage as well as under the overhang seem to indicate the action of a current

These findings, combined with the fact that the lake level rose by 0.5 m between the end of May and the end of July (without any rain), support our theory that the primary recharge area for Aikab is located at an elevation of 1300+ m.a.s.l. in the Otavi mountains, and that the recent recharge was supplied entirely by underflow of karst water (Figure 21).

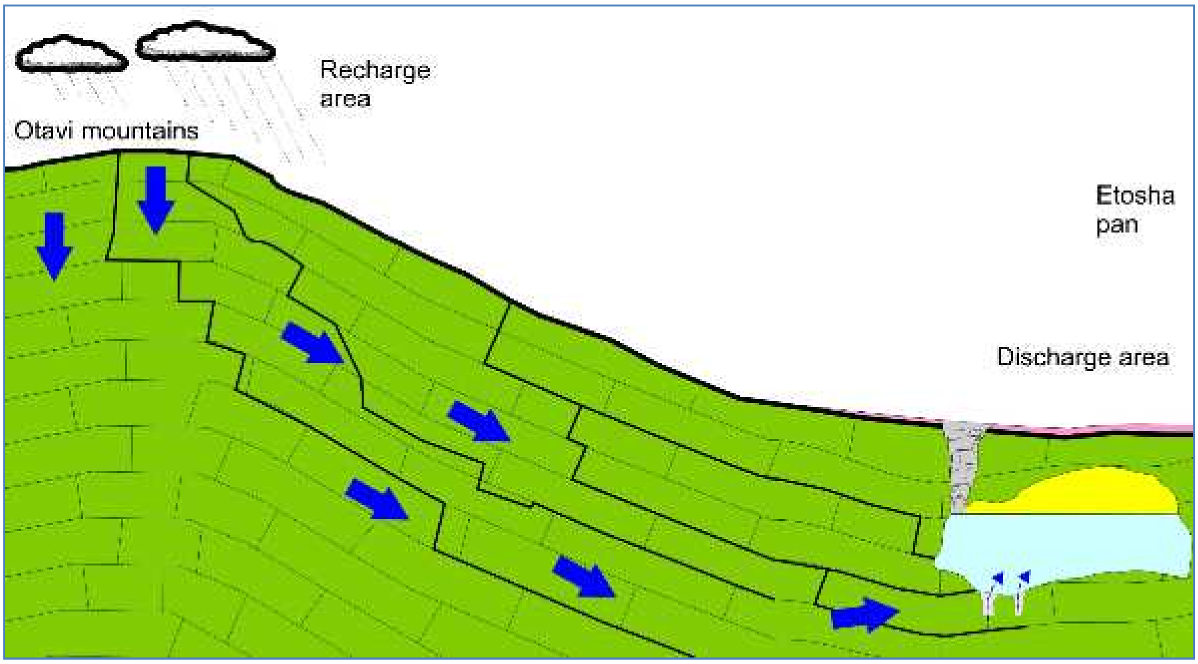

Figure 21. Schematic illustration of karst water recharge from the Otavi mountains into Aikab.

5.3 Biodiversity survey results

5.3.1. Underwater faunal investigations

Collected material are still undergoing study, but at least one species each of aquatic Annelida (segmented worms), Trematoda (flatworms), Isopoda and Ostracoda (both crustaceans) are present.

Figure 22. Aquatic worms from a baited trap.

Figure 23. Aquatic worm collected by divers.

None of the recorded taxa are "common or garden variety" invertebrates. The isopod is almost certainly the one previously described from Aikab, and for which Aikab remains the only place in the world it is known to occur. Both the aquatic worms belong to groups that are virtually unknown anywhere in Namibia, so there is a possibility that they will turn out to be new species as well. The other taxa belong to groups that are more commonly encountered, but not usually in such an extreme habitat, so they may or may not turn out to be undescribed species.

5.3.2. Above-water faunal investigations in the cave chamber

Besides the bats that roost in the chamber, other life forms that were encountered included Nycteribiidae (bat parasites), Veliidae (lake surface scavenger bugs) and a variety of spiders. This material is similarly still undergoing further study.

Figure 24. Bat parasite collected in the cave chamber.

5.3.3. Floral investigations in the doline

We are in contact with taxonomic experts on the faunal groups concerned to provide definitive identifications for the collected taxa, which will enable us to advise MET on the continued management of the cave.

6 Future Research

6.1 Hydrology

A water level data logger has been installed in Aikab (Figures 9 & 10) as part of the Hydrology Division of the Ministry of Agriculture, Water and Forestry's national groundwater monitoring network. There are similar loggers in Otjikoto and Guinas. The closest existing instruments to Aikab are on the farm Abie, approximately 5 km away, where loggers are installed in 3 boreholes. Daily readings have shown a depth to water level of 40 to 50 m and a rise of 2 to 3 m from the end of 2012 to 2013.

Figure 25. Two engineers from the Ministry of Agriculture, Water and Forestry (left) installing a water level data logger with the assistance of Willem Kubeb and Johan le Roux.

If funding allows, we would like to install flow loggers in the lacustrine springs. Long term readings of these two sets of instruments (water level sensor and flow meters) will be compared with data from the other loggers in the area as well as rainfall records. Analysis of these data will allow a better understanding of interconnectedness between the various subterranean water bodies, as well as potential recharge, groundwater flow rates and aquifer vulnerability.

Figure 26. Johan checking the subsurface installation depth of the water level data logger.

6.2 Exploration and mapping

The lake surface and lake bottom has now been definitively mapped. We would like to extend this dataset by mapping the roof contours below the water line, combined with sonar soundings of the bottom. This will allow a more accurate calculation of the chamber volume and associated water storage capacity.