Expedition Bjurälven 2019 report

Expedition Bjurälven would like to express sincere gratitude to the main sponsors in 2019: Ursuk, Apeks and xDeep.

Efficiency of our equipment is something we rely on. Using drysuits provided by Ursuk, Apeks regulators and sidemount harnesses from xDeep we could reach longer into the limestone rock of the Bjurälven valley than we could ever imagine. Outdoor clothing from Klättermusen made the Expedition safer and more enjoyable. Esri Sverige, Suntec, Äventyrsgruvan as well as the Swedish National Land Survey are also acknowledged for their support of the expedition.

The local authorities and population were backing us up 100% as usual, making the expedition possible. We would like to thank the people of Stora Blåsjön and authorities in Jämtland County, Ica Blåsjöfjäll, Restaurant Fjällripan and Ica Gäddede as well as Mikkes Skoteruthyrning for all their help.

Figure 1 Newly discovered cave "Köldhålet" ("Cold Hole"). Photo: Irena Stangierska

Compiled by Dmitri Gorski

Bo Lenander, a member of the current expedition crew, discovered the entrance to the Dolinsjögrottan in 1979. The first winter expedition to Bjurälven valley was launched in 2007, following several unsuccessful attempts to dive in the Dolinsjögrottan. Previous attempts were unsuccessful mainly due to very strong current that rips through the cave system summertime, measuring up to 20 knots.

In wintertime, the water is much calmer and hardly any current can be detected. Another factor in favor of conducting the expeditions wintertime is easier logistics. All the equipment can be transported to the cave entrance using snowmobiles, minimizing the risk of damaging the fragile vegetation in the national park where the cave is located.

In 2008, divers of the second Expedition Bjurälven could enter the cave and map some 50 meters of the passages beyond the entrance. Thanks to excellent cooperation with the authorities and continuing support of the local population, diving and exploration in Bjurälven continues every year. Twelve years since the first expedition, the official mapped length of the Dolinsjögrottan is 2 432 meters.

Dolinsjögrottan is Sweden`s longest water-filled cave and among the 80 longest underwater caves in the world. Köldhålet cave is on 2nd place with its 223 meters. Total mapped length of all nearby caves in the area, which we someday hope to connect, is 3 117 meters.

Members list 2019

Pirre Sandberg	Dmitri Gorski	Andreas Johansson	Mariusz Dziobek
Leif Sigvardsson	Marco Kupiainen	Oscar Svensson	Irena Stangierska
Micke Tilja	Bo Lenander	Robert Staven	Gunnel Fredriksson
Mats Fröjdenlund	David Thor	Ola Löfquist	Patrik Rylander
Stina Gabrielsson	Jonas Roos	Lasse Löfquist	Anders Thomasson
Stefan Barth	Amanda Lindberg	Ane Mengshoel	Mikkel Stokke
Trond Einar Solberg			

Figure 2 Expedition Bjurälven 2019 exploration team (Leif Sigvardsson and Stina Gabrielsson are not in the photo)

Goals and summary

The overall goals of Expedition Bjurälven are:

1. Explore, map and document caves in the Bjurälven valley
2. Promote the caves in the area and the local community of Stora Blåsjön
3. Contribute to scientific research through cooperation with universities

After Expedition Bjurälven 2018, the official length of the Dolinsjögrottan was 2432 meters. No exploration diving was conducted in Dolinsjögrottan in 2019. A total of 95 meters were mapped in Köldhålet and two new entrances were discovered in nearby dolines.

25 cave explorers participated in the expedition in 2019. This included 2 new divers and 2 guests. In addition, we were lucky to have with us three locals from Stora Blåsjön and a guest from Jorm for the whole week. The weather was shifting during the 2019 Expedition. Conditions were good and stable in the beginning of the expedition, but towards the end of the week heavy rain contributed to

sudden rise of the water level in the caves. Dolin lake flooded the base camp there and a lot of equipment ended up under water. This was discovered on the following morning, which triggered a rescue mission where all of the equipment was successfully recovered.

Documentation and media

High-quality photo material was collected this year. National Geographic photographer Irena Stangierska and her team joined Expedition Bjurälven 2019 to record the beauty of the Bjurälven in her pictures. The images will be used in our PR-work as well as by our sponsors.

Exploration and mapping

53 dives were performed during the expedition in 2019, see Figure 3. This was fewer compared to the year before. Only photo dives were performed in the Dolinsjögrottan and the focus was on exploration of the nearby caves. This contributed to a decrease in the number of dives. Dolinsjögrottan with its established base camp is easy to dive, while diving in the other caves nearby demand considerably more preparations and logistics.

Total dive time decreased compared to 2018 as well, and divers spent 52 man-hours in the cave during the expedition week, see Figure 4. This can be explained by the fact that Dolinsjögrottan demands long dives to reach the EOL, while the other caves in the area are still relatively short. Average dive time decreased considerably, see Figure 5.

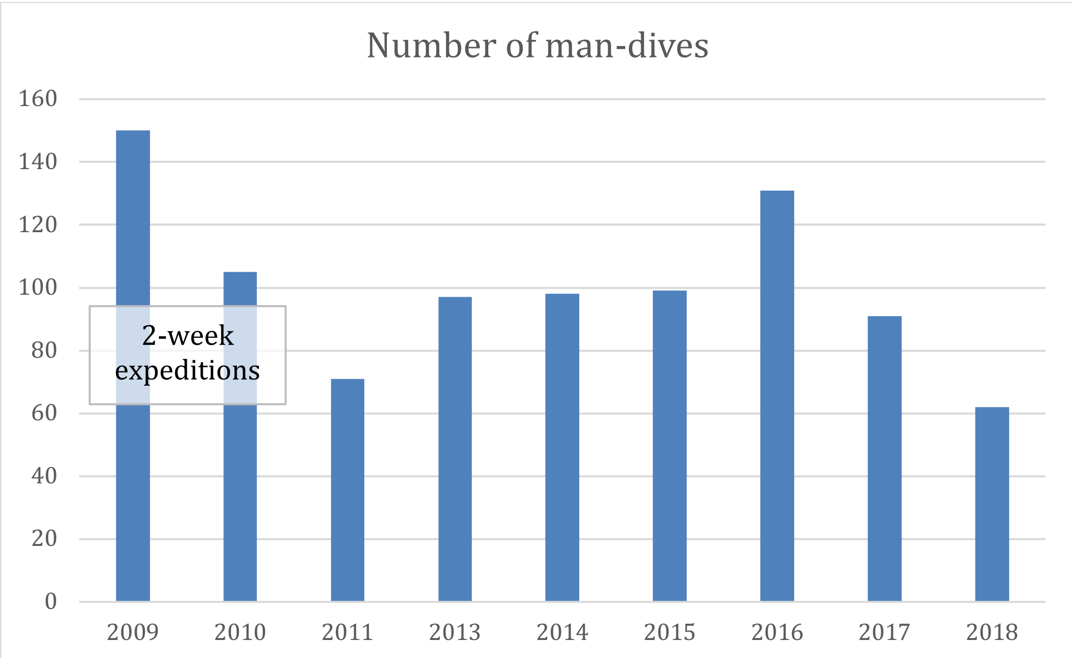

Figure 3 Dive statistics for Expedition Bjurälven

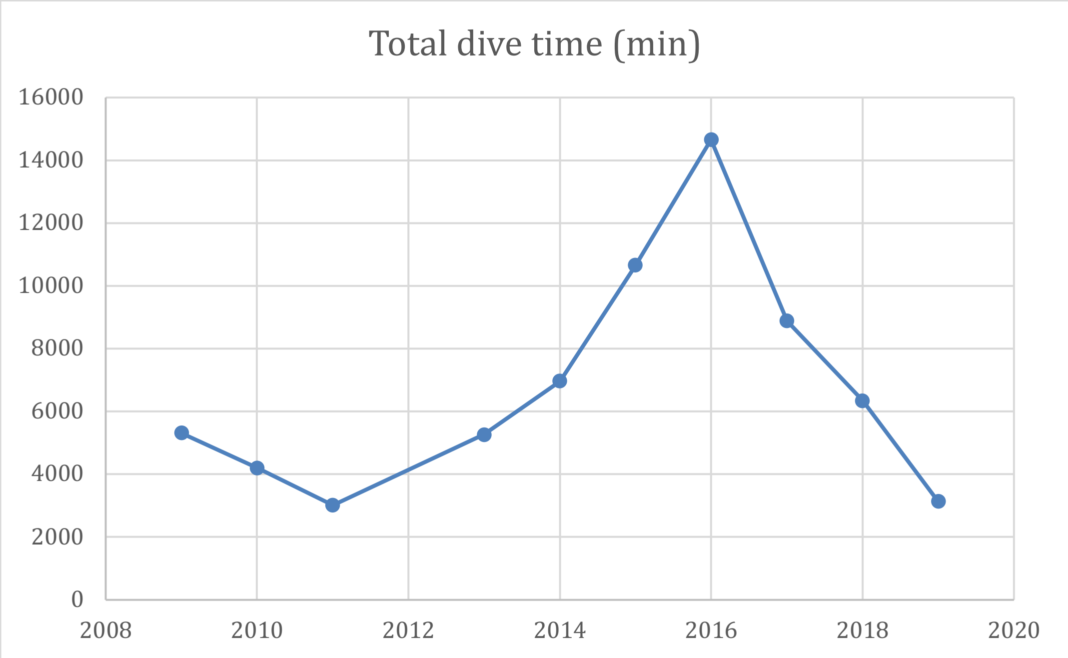

Figure 4 Total dive time during the expedition

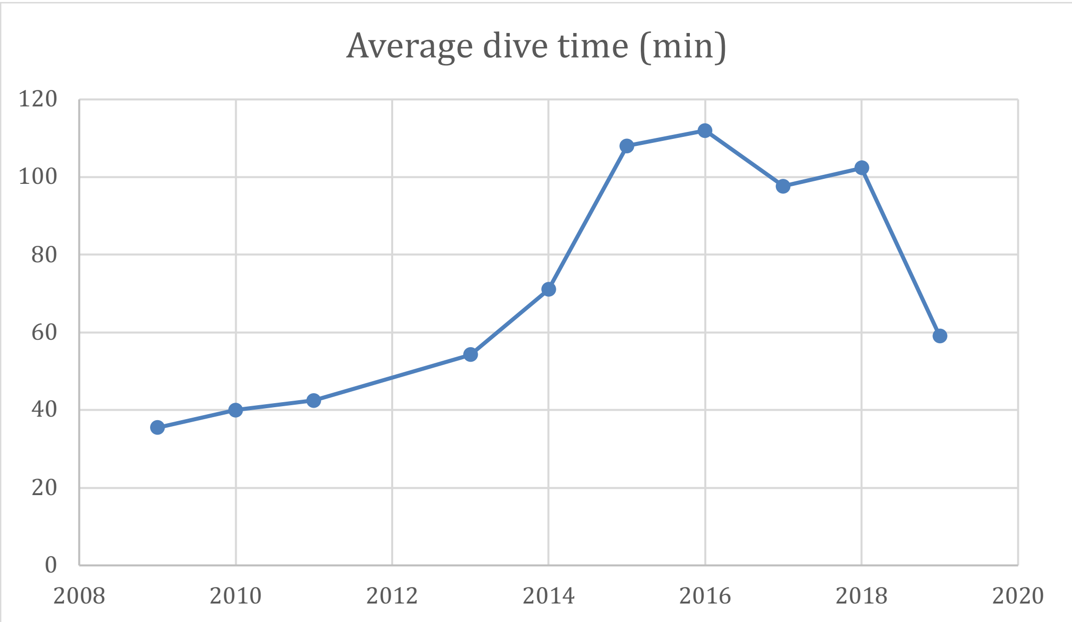

Figure 5 Average dive time per dive

95 meters of passages were mapped in Köldhålet in the direction of Dolinsjögrottan, see Figure 6. Leads in Köldhålet are most promising for the 2020-expedition. Another promising lead is the discovery of a divable passage in Festins cave, see Figure 7. All the caves in the Bjurälven valley can be seen in Figure 8.

	Mapped length [m]
Bjurälvsgrottan	300 (unchanged in 2019)
Dolinsjögrottan	2432 (unchanged in 2019)
Köldhålet	223
Spegelgrottan/Semigrottan/D3	162 (mapping data from 2019 lost)
Festins cave	65 (explored earlier)

Table 1 Mapped length for the different caves in Bjurälven valley

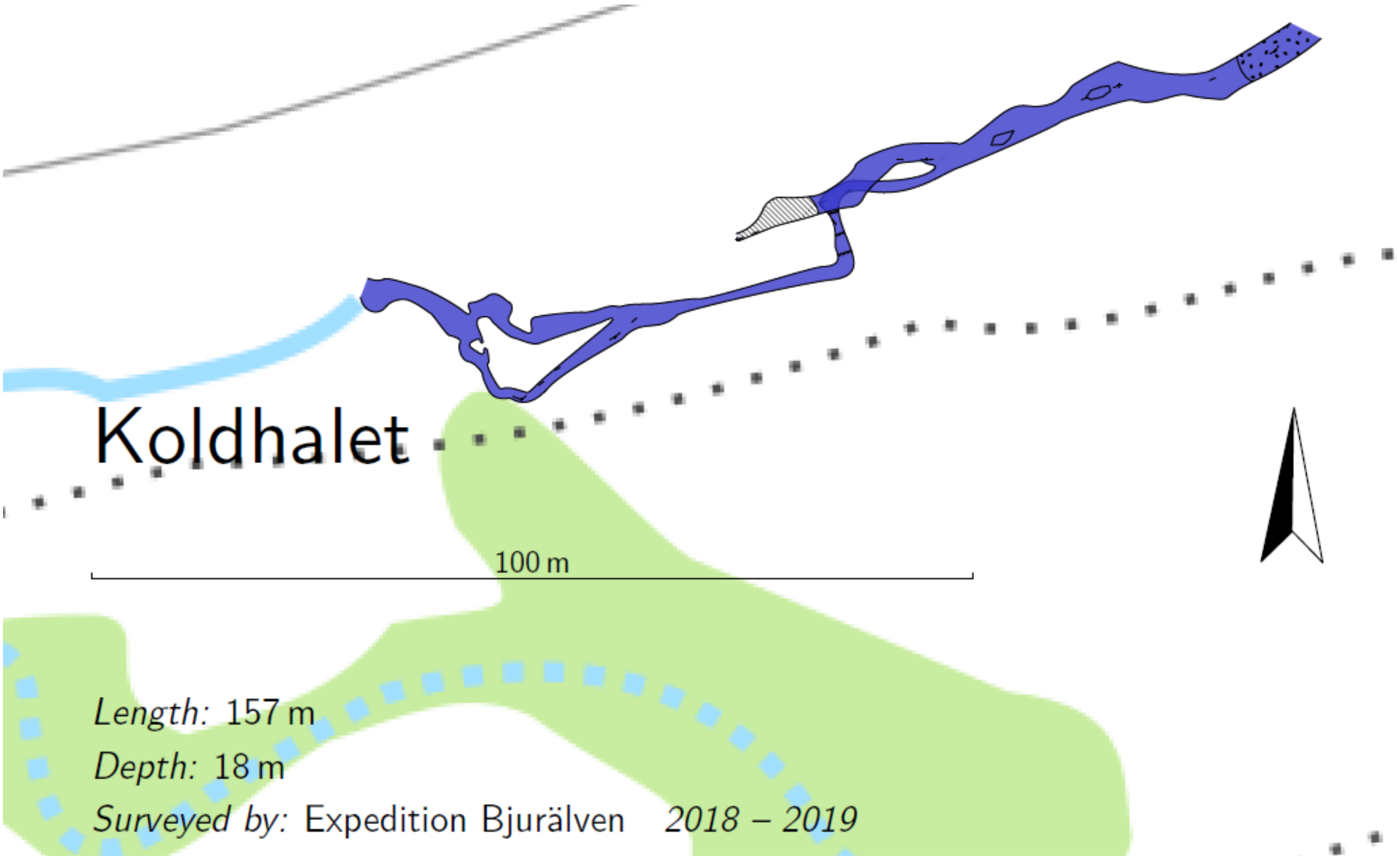

Figure 6 Köldhålet cave

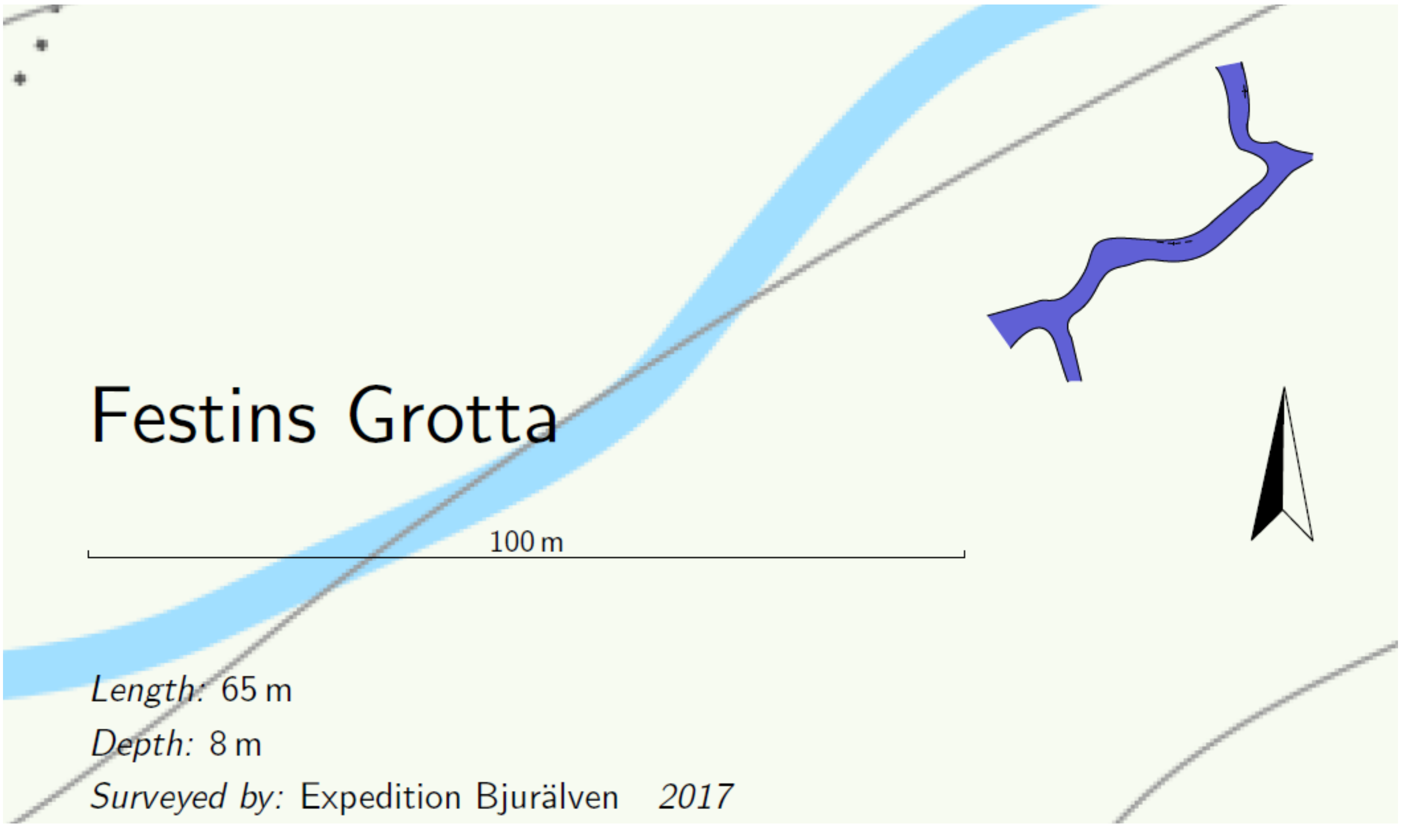

Figure 7 Festins cave

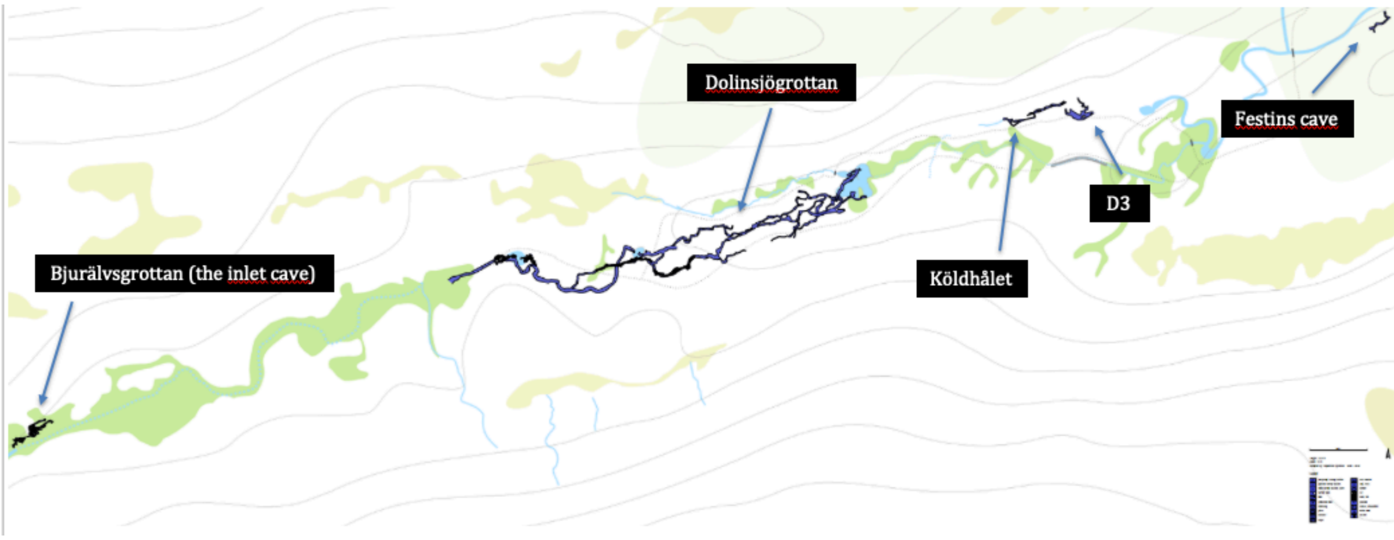

Figure 8 All the explored and mapped caves in Bjurälven valley

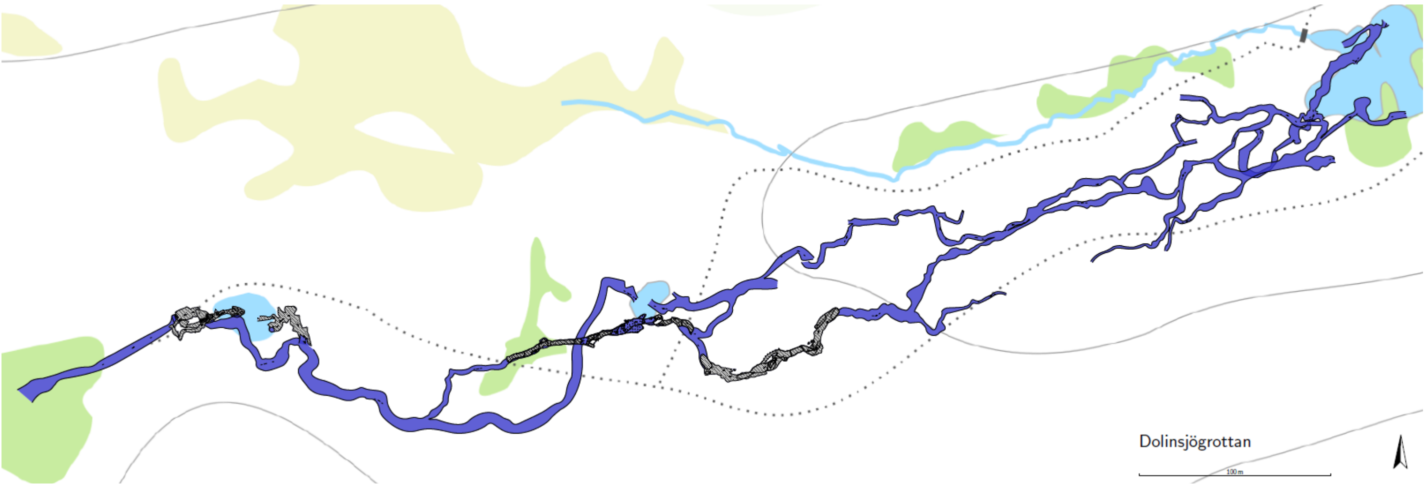

Figure 9 Dolinsjögrottan, the longest underwater cave in Bjurälven valley (consists of 5 sumps up to date)

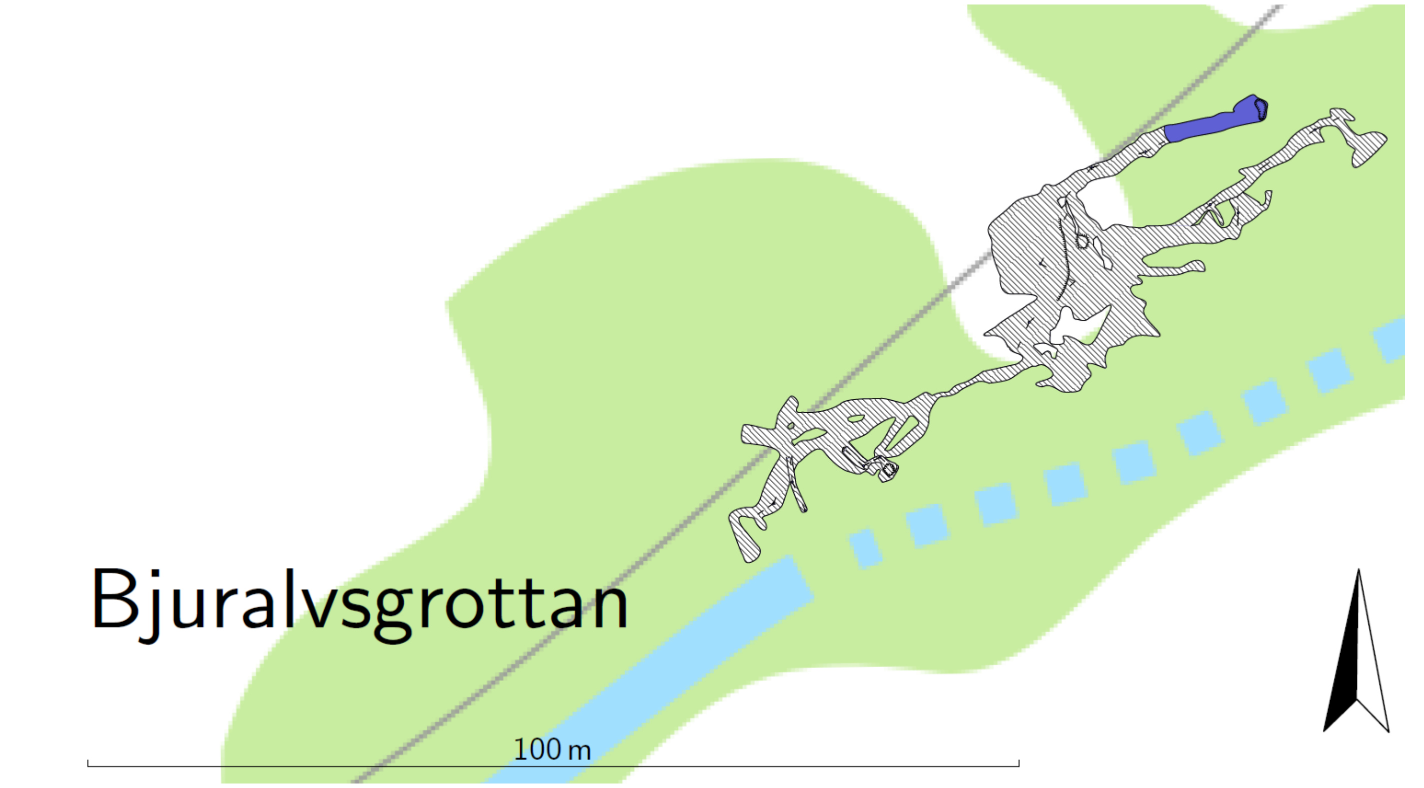

Figure 10 Bjurälvsgrottan, the inlet cave (mostly dry)

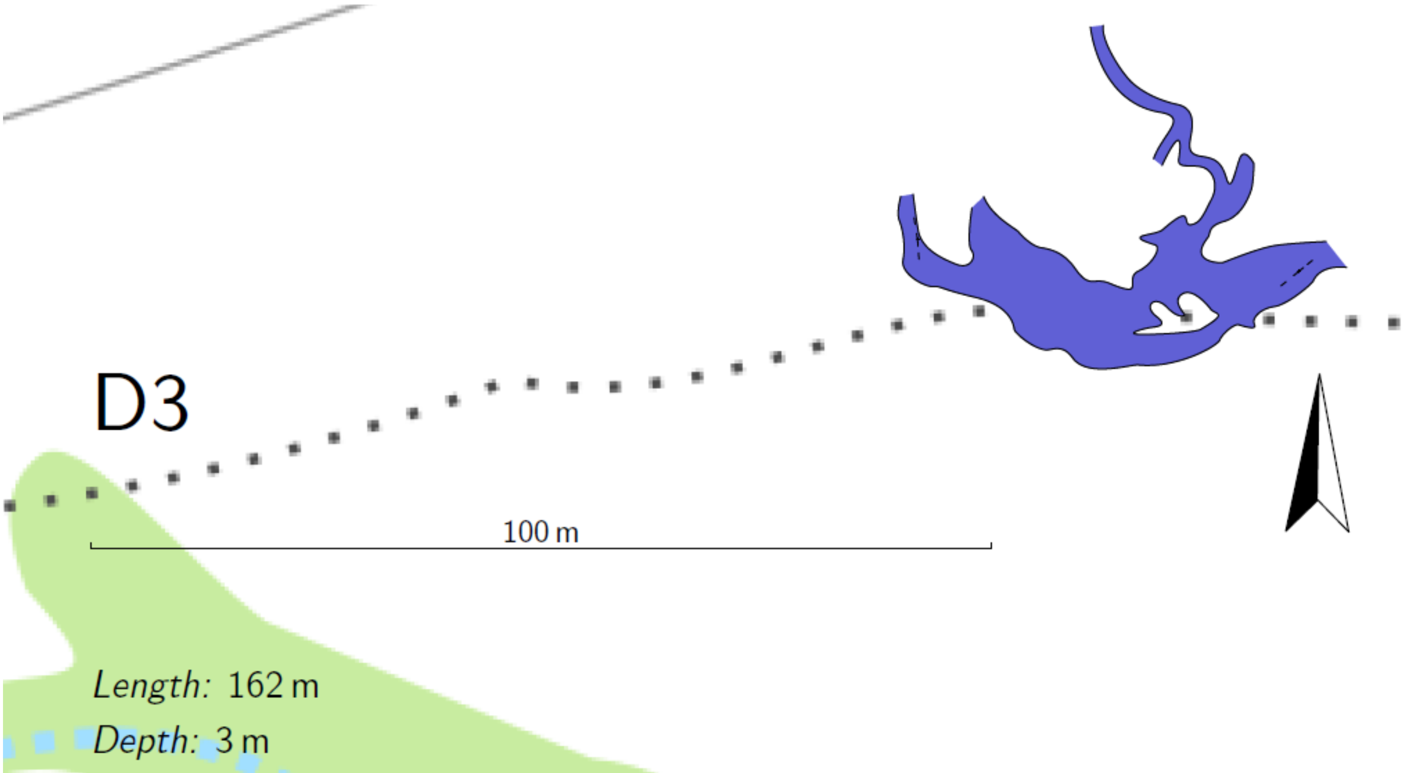

Figure 11 D3 cave

Radiolocation

By Bo Lenander, SM5CJW

During the last eight expeditions we have used VLF electromagnetic devices both for radio-location and communication. These devices have been used both for location of divers in the cave from the surface and for simple encoded messages.

As the dives in the cold water are getting longer it is important both for safety of the divers and comfort for the personal on surface to know where in the cave the divers are during their several hours long dives. In case of an accident the time to get help is a critical matter. Loss of air must of course be solved immediately, and the victim cannot get help from the surface.

But all other types of accidents can be supported from outside the cave. **When?** and **where?** are two questions that can be answered quickly using wireless diver location equipment. It is also possible to send simple encoded messages through the rock. After eleven years of exploration of the Dolinsjö cave we still have only one narrow entrance to the more than two kilometres of passages we have mapped so far.

Finding alternative entrances is of high interest but the marble rock in the cave is covered by thick layers of sand and gravel that remain from the end of the ice age. Only in a few places the rock can be seen from the surface. But there are many alluvial dolines in the sandy Bjurälven area, some of them are really big (up to 50 m diameter), indicating possible cave passages under them.

The terrain in the area is very hilly and it is not easy to walk around on the surface when it is in addition covered with up to three meters of snow. During winter time blow holes in the snow can be found indicating air-filled passages underground. But when the tunnels are filled with water there will be no such phenomena visible on the surface. Most of the dolines are plugged with sand, clay, ice and snow at the bottom.

To get a hint about where a digging project can be initiated it is important to know the relation in position between the surface formations and the cave with high precision. Here the radio-location can be used. The transmitter is a small device carried by the diver. It is equipped with a magnetic antenna in form of a ferrite rod with a winding. The ferrite rod must have vertical orientation, giving a vertical magnetic pulsating field of the working frequency (here about 32 kHz). On the surface the magnetic field is vertical straight above the transmitting antenna (ground zero) and will be leaning outwards from that ground zero more the longer the horizontal distance to the ground zero is. When the field is leaning 49.5 degrees the horizontal distance to ground zero times two is the vertical distance or depth to the antenna in the cave.

When searching for the ground zero it is easy to be confused – at a horizontal distance of more than 1.5 times the depth there is a weak vertical return magnetic field and there it is very hard to get information about the direction to the ground zero. It is therefore important to bring as good maps as possible along with the radio-location receiver. It can be very time consuming to run around in deep snow on surface. When taking positions of fix points in the cave it is important to know when the transmitter is correctly aligned on the fix point.

To give the status swim or fix, indicating if the beacon is in transit or on the fix point location, different Morse coded signals can be sent from the cave. It is very cold down there and the time to take the position must be kept to a minimum. When the radio-location (ground zero and depth) is ready a signal can be sent from the surface down to the divers in the cave (a green light is flashing on the transmitter) and then the divers switch over to swim. Then they go for the next fix point and can be followed by the person on surface. Nine fix points in Svenonius cave, Köldhålet cave, D3 cave and Semi cave were localized in 2019 using a 32 kHz locator.

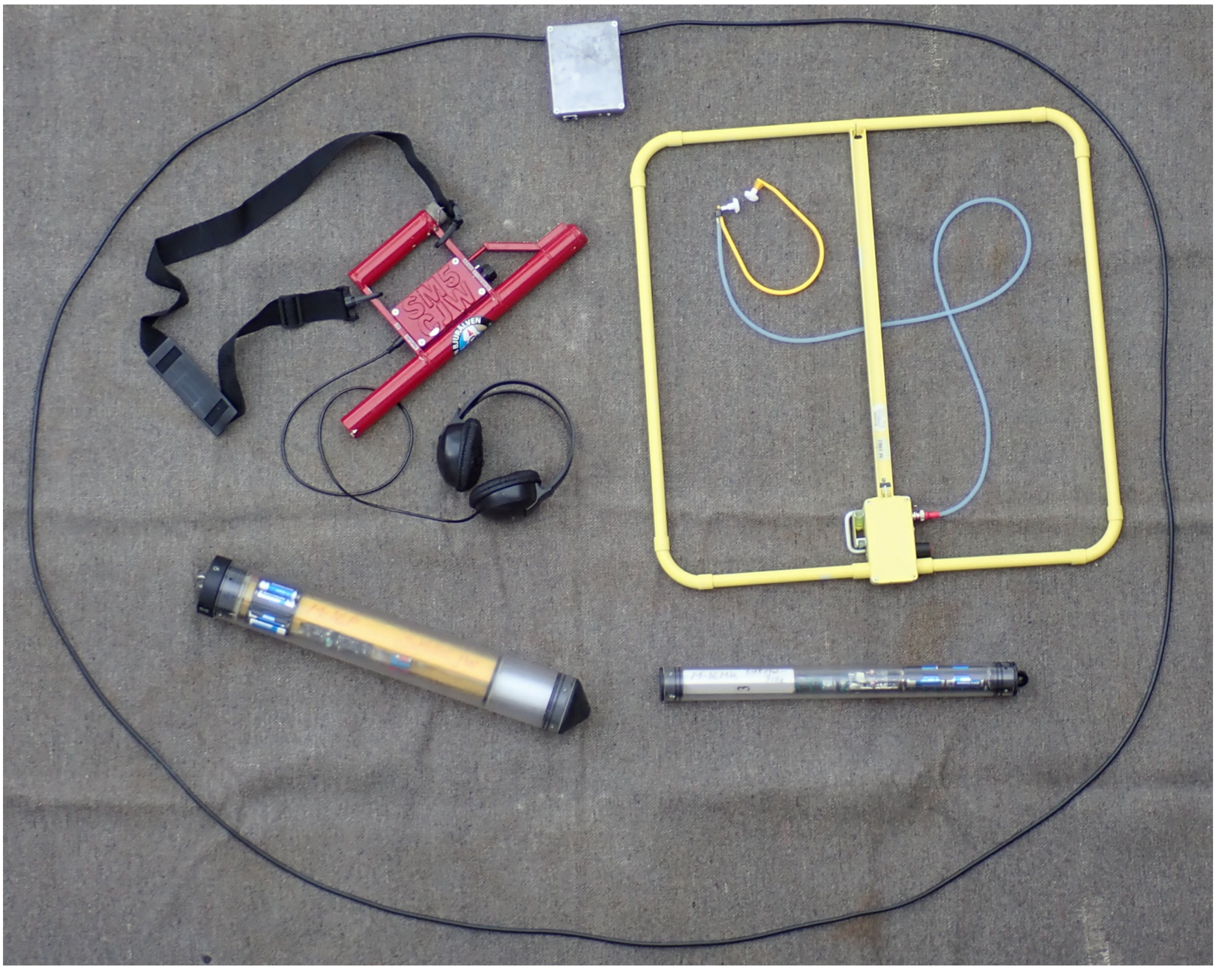

Figure 12 Direction finding receivers M-16R (red) and M-19R2 (yellow), Command Transmitter (with big cable antenna), M-16CT (yellow tube) and Marker M-16MK.

The equipment was developed and built by Bo Lenander (SM5CJW). The pinger and marker as well as the transmitter in the DF receiver M-16R has been tested in an EMC-lab to verify that they do not give a dangerous magnetic flux density (B). The command transmitter is used together with DF receiver M-19R2 to light the bright green LEDs in the pinger as a message to the diver that the fix point has been measured. The big antenna loop is only electrically closed and in resonance during transmission, to not disturb the DF reception.

VHF-communication on the surface

The whole expedition area from Bjurälven valley to the parking lot at Leipikvattnet (a distance of around 4 km) had good VHF signal coverage in 2019. Following equipment was utilized to achieve this:

- GP-antenna mounted on a 7m high mast and located in the Dolinsjö base camp
- Handheld Icom hunting radio walkie-talkies (5W and 155 MHz)

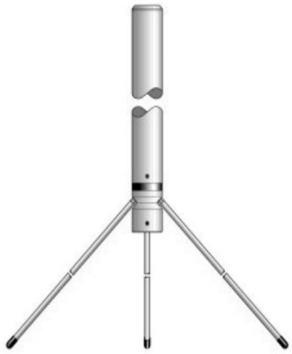

Figure 13 Icom IC-F51V radio (5W, 155 MHz, IP67) and the GP antenna for the base station.

VHF-communication between the surface and the cave

Using standard durable radio stations with high frequency for cave communication is a big advantage since the antennas are small (10-30 cm). The short wavelength is also suitable for tight spaces.

The otherwise standard method of ensuring signal propagation through water is to use very low frequency (30-100 kHz). But the antennas, required for these frequencies are much larger compared to a 155 MHz antenna. So, if 155 MHz works – use it! On the other hand, the higher frequencies are much less efficient when it comes to precision of radiolocation, where the best result is obtained using some 10-s of kHz.

The fact that it was possible to establish a connection over the distance of 1600-m using 155 MHz in Bjurälven can probably be explained by reflections from the steep sides of the valley. This would not have been possible in plain terrain, where only the vertical communication would be of any use from the cave.

WSPR

Weak Signal Propagation Reporter (WSPR) is a world-wide activity to study the propagation of radio waves as a function of position on earth, operating frequency, time of day, antenna, transmitting power and position in the sun spot cycle. World-wide are computer controlled receivers reporting signals heard from computer controlled weak radio transmitters to ”the cloud”, an Internet area of all collected data.

A WSPR transmitter can be of matchbox size and connected to a simple wire antenna. The transmitter has been programmed to send a call sign (here **SM5CJW**), position on earth (here Maidenhead coordinate **JP74**) and power output to the antenna (here **0.2W**). The WSPR beacon was set to automatically transmit 110 seconds six times per hour at the chosen frequency (here 14, 10 or 7 MHz).

The Bjurälven area is not very often on the air and our WSPR activity helps the world community to study the propagation of radio waves, especially in those days of very few sunspots. Radio waves in the shortwave bands are also very much influenced by aurora (caused by particles from the sun and how they interact with the magnetic field of Earth and molecules in the high atmospheric layers.

We can observe it as the ”Northern Light” or ”Aurora Borealis”). WSPR has nothing to do with cave diving but as we are there at this time of year we can help the WSPR studies without any extra effort. Our little WSPRlite transmitter with its 12 m vertical wire antenna was heard as far as in Guangzou, China. Totally we got many thousands of listening reports during the week, most of them from Europe.

Satellite positioning, LiDAR-data, drone mapping and internet connection

By Mats Fröjdenlund

GNSS

Starting in 2011 we have been performing electromagnetic direction finding of the cave divers and surveying of fixed points in the cave system. From 2014 these fixed points have been marked out in the cave using stainless steel trays (markers) labelled FP01 (Fix Point 01), FP02, and so on.

Using the electromagnetic direction-finding equipment, we have been able to obtain relatively accurate points on the ground surface directly above the fixed points. Also, the depth from the surface (or the snow surface) down to the fixed point has been obtained. To make a 3D and georeferenced cave map the ground surface elevation, the depth of the cave and its X and Y coordinates are required.

For this purpose, the National Land Survey/SWEPOS (https://swepos.lantmateriet.se) during the expedition in 2013, 2014 and 2015 kindly lend us both GNSS equipment (Global Navigation System Satellite = GPS, GALILEO and GLONASS) and communication equipment with connection to the SWEPOS correction services. It is possible to get a position in the reference system SWEREF 99 with uncertainty in the centimetre level. Our problem has been that the expedition site is out of reach for mobile Internet communication.

Figure 14 Leica CS15 field computer.

In 2019 our equipment consisted of a Leica Viva GS15 rover on a 2.0-meter-high carbon fibre pole and a Leica CS10 field computer, kindly provided by Lantmäteriet, see Figure 14. Our GNSS equipment was used to measure the points, located using the tracking device, invented by Bo Lenander. The measurement information from the field computer was transferred to a XML file with X, Y and Z values.

We also included the depth value and time for the measurement. To visualize the points on the aerial photo or the terrain model we were using the GIS software ArcGIS Pro® from Esri, see Figure 15. Thirteen new points were measured with the GNSS in 2019 and this included the new findings in Doline number 5 (D5). The RINEX post process, provided by the Lantmäteriet was very successful and 12 of the 13 points had an accuracy better than one centimetre.

LiDAR-data and drones.

2017 we managed to get the new LiDAR data from the Swedish National Land Survey (kindly sponsored by Esri Sweden). This means that we now can measure the depth of all dolines (sinkholes) using GIS and build a 3D surface model over the terrain and incorporate the 3D map over the caves in the same model.

A DJI Mavic 2 Pro drone was used for the first time to collect orthophotos from the areas of Dolinsjön and The Eight Dolines. The photos were processed in photogrammetry software Drone2Map for ArcGIS® and the output was 2D orthomosaic, elevation data such as DSM and DTM and 3D data. The result was amazing, and we will continue to collect data from drones, see Figure 16.

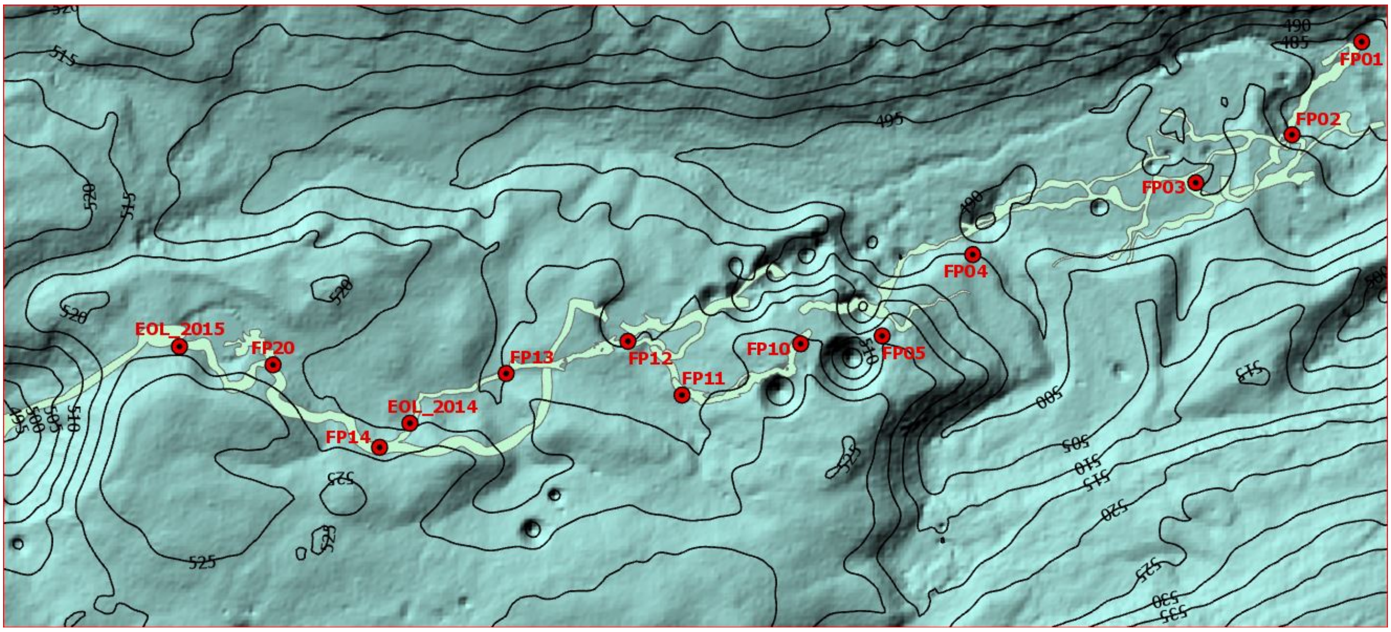

Figure 15 Fix points in Dolinsjögrottan.

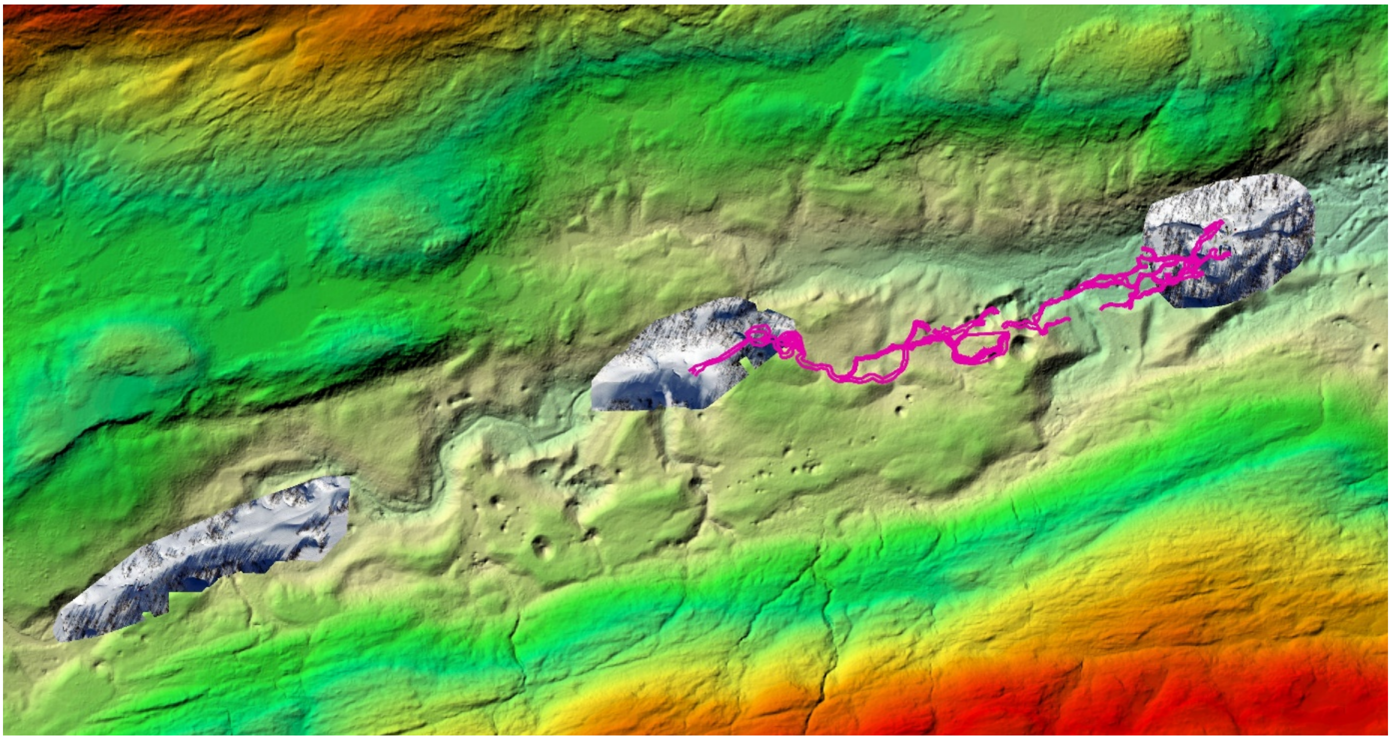
Figure 16 Map, showing LiDAR-data, orthophoto collected from drones and cave map.

Internet connection

The terrain, valley with high mountains around, makes it impossible to get in contact with the Internet through 3G or 4G even with directional antenna. Next year we will try to find a suitable site for receiving 3G and then relay the data with Wi-Fi technique to our base camp.

Expedition safety

By Stina Gabrielsson and Andreas Johansson

During a project with the size and complexity of Expedition Bjurälven there are always many risks to consider and we find it important to carefully analyze the expedition from a safety point of view, from the car trip up to Stora Blåsjön to hygiene during the meals. The main focus is on preventing accidents and injuries, but also to have plans in case an accident does happen.

Risks analysis

There are four main activities where the risk of injury or accident is high: diving, transports by car, transports by snow mobile and dry caving. Long exposures to extremely cold water during diving, alternated with dry caving, are the special features of the diving during Expedition Bjurälven. The fact that a rescue mission has to be mounted in multiple dry and wet passages makes it a tough challenge.

Diving Safety

We rely heavily on our equipment during the diving in Bjurälven. Especially our breathing apparatus, the regulators, which supply the diver with gas. A common problem in cold waters is regulator freezing, which causes free-flow and a very rapid loss of breathing gas. During the earlier years of the expedition there was a problem with freezing if the first stages of the regulators, which can cause the opposite, a complete stop of breathing gas. This phenomenon was established to originate from moisture in the breathing gas, which at very low temperature can form ice plugs in the breathing hoses.

The problem was solved through extra filters to dry the air filled into the diving tanks. The second most important piece of equipment is the dry suit and the warm undergarment every diver wear during a dive. A puncture of a suit or a glove will cause rapid heat loss as the cold water enters the suit. This poses a considerable threat in the conditions the expedition operates in. Decompression sickness, the risk most often associated with diving, is not a big safety problem in Bjurälven due to the relatively shallow passages and little amount of nitrogen that is absorbed by the body during a dive

Active risk management

Because the Expedition takes place in such a hostile environment we put a lot of emphasis on active risk management and prevention. The top priority is for the team to have sufficient level of training and knowledge about sub-arctic cave diving. A safe dive is a planned dive and for every dive a specific plan is set up. The dive manager, who keeps records of the plans, must approve the dive plan. In 2017 a simple stick map of the cave on a white board was created.

The map has markers for every team member to move in accordance with the persons activities during the day. This system, combined with radio-location we employ, is a great aid for the dive manager to keep track of the team members and the ongoing projects. In case of an emergency of any kind in the cave it is important to have plenty of breathing gas.

Every year several safety tanks are placed in the cave to aid in such an emergency. Another hazard is the entry and exit if the water. During the expedition we have a purpose-built platform for the hole in the ice to ensure safe and easy access to the cave. In 2016 we had the possibility to have communication between the cave (the first dry chamber) and the base camp using Heyphone (borrowed from Norwegian Caving Federation) for the first time.

The testing continued in 2017 and proved one again to provide a reliable way of communication. As the explored length of the cave grows, and so do the length of each dive, the opportunity for two-way communication increase the safety level significantly.

Rescue plans

The base camp holds a warm tent where hot beverages and food can be supplied. There are first-aid kits with equipment to deal with minor injuries as well as moderate trauma. We have a watertight emergency canister placed in the first dry passage. This canister contains dry clothing, spares, heating devises and painkillers. Using this, an injured diver might be able to improve his chances of safely getting to the surface without outside assistance.

In the case of exploration on multiple sites in the valley of Bjurälven we will arrange some kind of advanced base camp. In this smaller camp(s) there must be sufficient equipment to deal with the specific emergencies for the activities that are planned in the area. In 2018 we had a camp located at the entry point to Bjurälvsgrottan to support the exploration. The camp had a tent with hot food/beverages, a hypothermia stretcher and a first aid kit for minor injuries.

Specific problems encountered 2019

One diver had problems with a leaking glove, it was a small hole and the diver could exit the cave in a safe manner. There was also a situation when a diver accidentally put a position finder in "SOS-mode". The dive leader in the camp was notified and safety diver was sent in to find the diver. The situation was explained, and the position finder was set to a correct mode. The dive was then finished according to plan. We had one situation with separation of dive buddies. This was due to misunderstanding plus a section in the cave with poor visibility. The first diver to surface could immediately go back and find the buddy within ten minutes

This year we had three accidents involving snowmobiles. This was during the first couple of days when we had snowfall every day and the track became harder to navigate. No injuries to persons or damage to snowmobiles occurred.

A ropeway was built to manage the transport of equipment to and from the dive site of Köldhålet. We had one incident when a dive tank became loose when it was quite close to the top of the ropeway. The tank skidded all the way down to the dive site. There was no injury on person or property.

Free flow of regulators has previously been a recurring problem. This year there was only one incident with a frozen second stage. The dive was finished in a safe manner.

During the setup of the base camp we had several minor skin cuts and abrasions, all treated with tape, with no further treatment necessary.

At the end of the week there was an unusually heavy rain. Combined with strong winds and overall mild weather the effect on the water flow in the cave system was devastating. The base camp in Dolinsjön was flooded whereas the camp at Köldhålet was better situated. One and a half day was spent on recovering gear from the camp and the caves. Some parts of the snowmobile tracks had to be rerouted, for example over the lakes. All equipment could be rescued and no damage occurred.