Expedition Bjurälven 2018 report

Expedition Bjurälven would like to express sincere gratitude to the main sponsors in 2018: 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, Reel Diving, Leica Geosystems, 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 Partly water-filled passage between sumps 1 and 2 (Marble Passage)

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. Eleven years since the first expedition, the official mapped length of the Dolinsjögrottan is 2432 meters. Dolinsjögrottan is Sweden`s longest water-filled cave and among the 80 longest underwater caves in the world. Total mapped length of all nearby caves in the area, which we someday hope to connect, is 3087 meters.

Members list 2018

Pirre Sandberg	Dmitri Gorski	Andreas Johansson	Marcin Pawełczyk
Kristian Lyberg	Marco Kupiainen	Oscar Svensson	Irena Stangierska
Micke Tilja	Bo Lenander	Robert Staven	Mariusz Dziobek
Mats Fröjdenlund	David Thor	Ola Löfquist	Gunnel Fredriksson
Stina Gabrielsson	Jonas Roos	Øyvind Hegle	Anders Jansson
Stefan Barth	Amanda Lindberg	Ane Mengshoel	Patrik Rylander
Johan Utas	Leif Sigvardsson	Marcin Wojturski	Lasse Löfquist

Figure 2 Expedition Bjurälven 2018 exploration team (Johan Utas and Leif Sigvardsson 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 is 2432 meters. 187 meters of passages were mapped in Dolinsjögrottan and a conclusion was made that the collapse at the end of the line (EOL) is probably not possible to pass. A significant effort was also devoted to attempt diving in Bjurälvsgrottan, the upstream cave where all the water disappears into the ground to appear in Dolin lake and the other caves downstream. A number of dives there revealed what seems to be an impassable restriction, although further exploration of Bjurälvsgrottan will be evaluated for the expedition in 2019. A total of 655 meters were mapped in Bjurälvsgrottan and other nearby new caves in the same area, both upstream and downstream the Dolinsjögrottan. The focus of the expedition has thus changed from mainly exploring the Dolinsjögrottan system to exploring nearby caves and attempting to connect them to the Dolinsjögrottan.

25 cave explorers participated in the expedition in 2018, making it the largest expedition so far. This included 1 new diver and 3 guests. In addition, we were lucky to have with us three locals from Stora Blåsjön for the whole week. The weather was rather pleasant during the 2018 Expedition except for the extreme cold. Conditions were good and stable, but the temperature could be as low as minus 32 degrees Celsius morning time. After sunrise, this often changed to minus 5-10 degrees, perfect temperature range for the expedition. In strong contrast to the last year, where high water levels made several dry passages half-filled with water, this year the water level was very low. Some of the tunnels, that previously contained water, were now dry. This made it more difficult to transport gear between the sumps of the cave.

Documentation and media

Substantial amount of high-quality photo material was collected this year. National Geographic photographer Irena Stangierska and her team joined Expedition Bjurälven 2018 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

62 dives were performed during the expedition in 2018, see Figure 3. This was fewer compared to the year before. Less focus on the Dolinsjögrottan and more focus on exploration of the nearby caves 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 2017 as well, and divers spent 106 hours in the cave (including the dry sections between the sumps) 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 increased somewhat, see Figure 5.

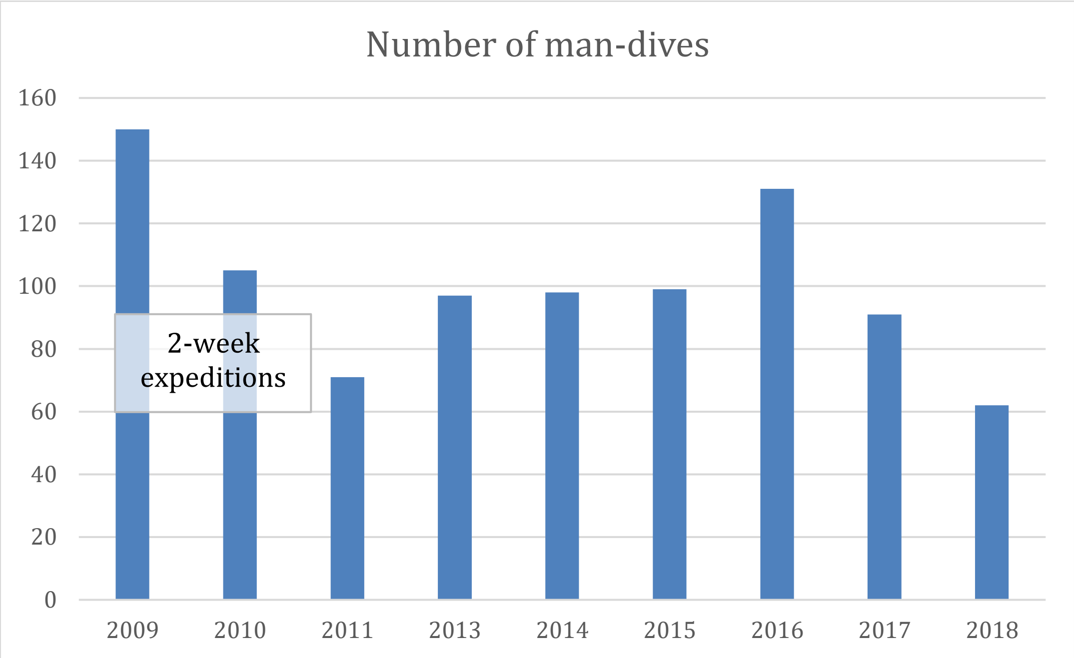

Figure 3 Dive statistics for Expedition Bjurälven

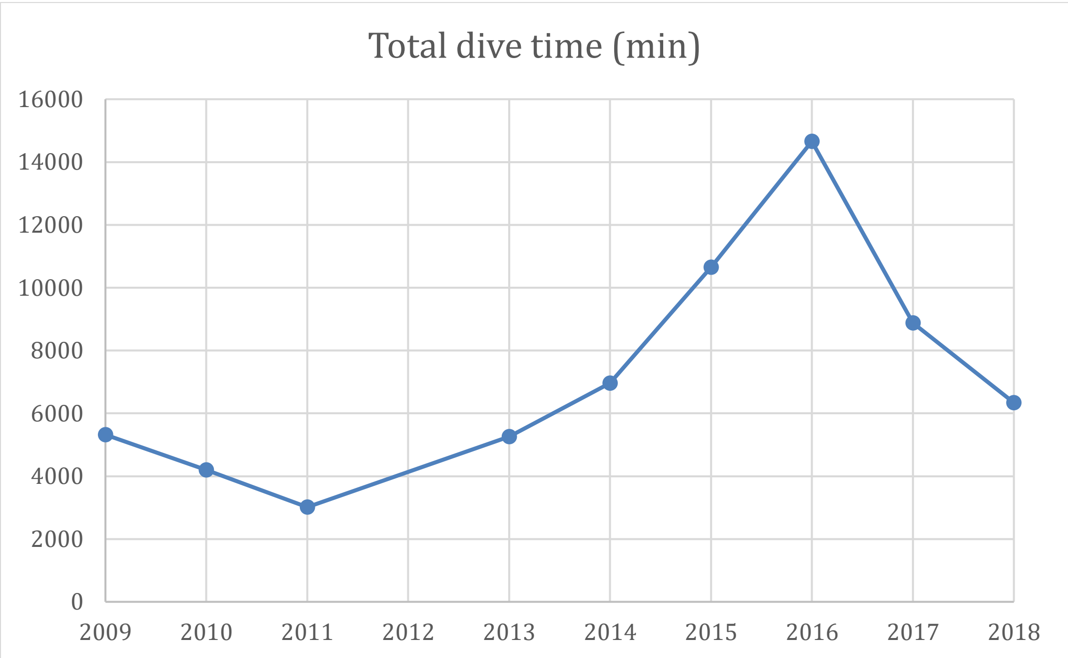

Figure 4 Total dive time during the expedition

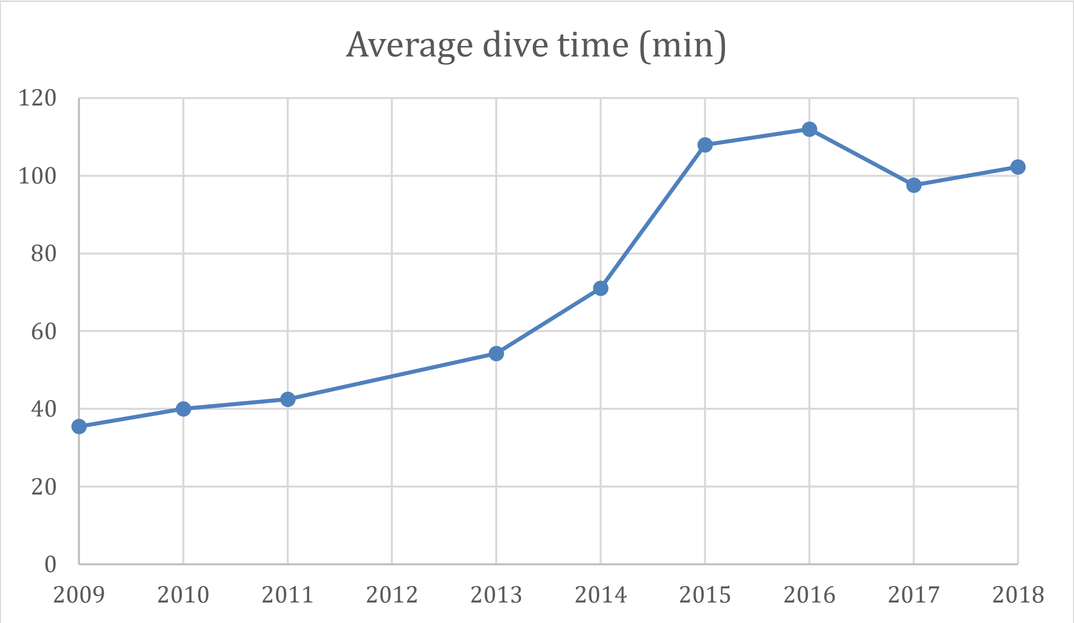

Figure 5 Average dive time per dive

Since the exploration at the end of the line did not give any significant results this year, more focus was given to the exploration of the other caves in the area. The next known divable cave (the D3 cave) is located only a few hundred meters downstream in the Bjurälven valley. A successful attempt to dive in a spring, located between Dolinsjön and D3 was made in 2018. The new cave was named Köldhålet (Cold Hole) for the extremely low air temperature, experienced at its entrance. 128 meters of passages were mapped in Köldhålet in the direction of Dolinsjögrottan, see Figure 6. EOL in Köldhålet is one of the most promising leads for the 2019-expedition.

Table 1 Mapped length for the different caves in Bjurälven valley

	Mapped length [m]
Bjurälvsgrottan	300
Dolinsjögrottan	2432
Köldhålet	128
D3	162

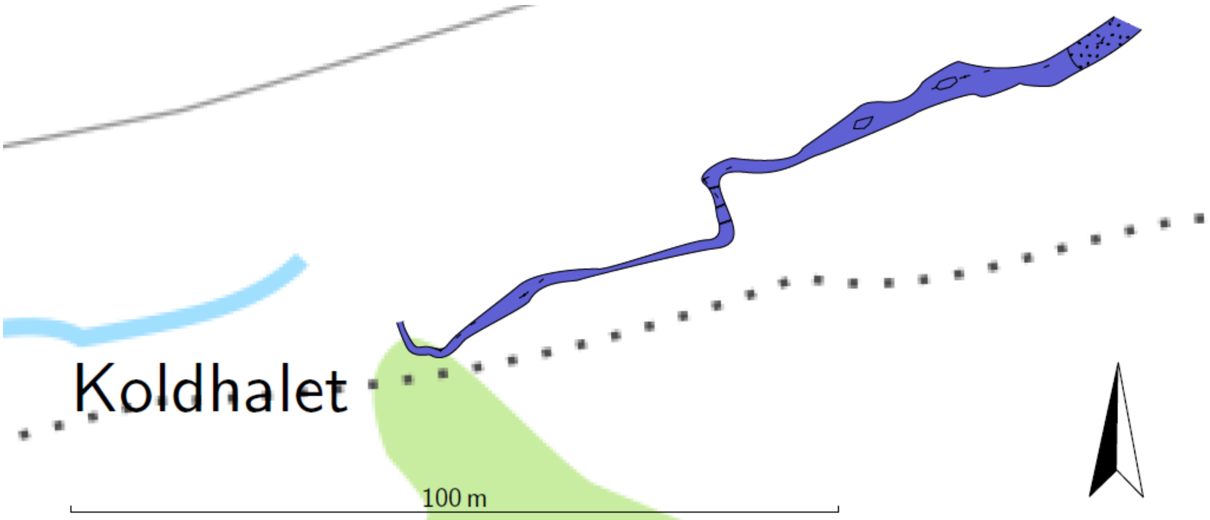

Figure 6 Köldhålet, discovered in 2018

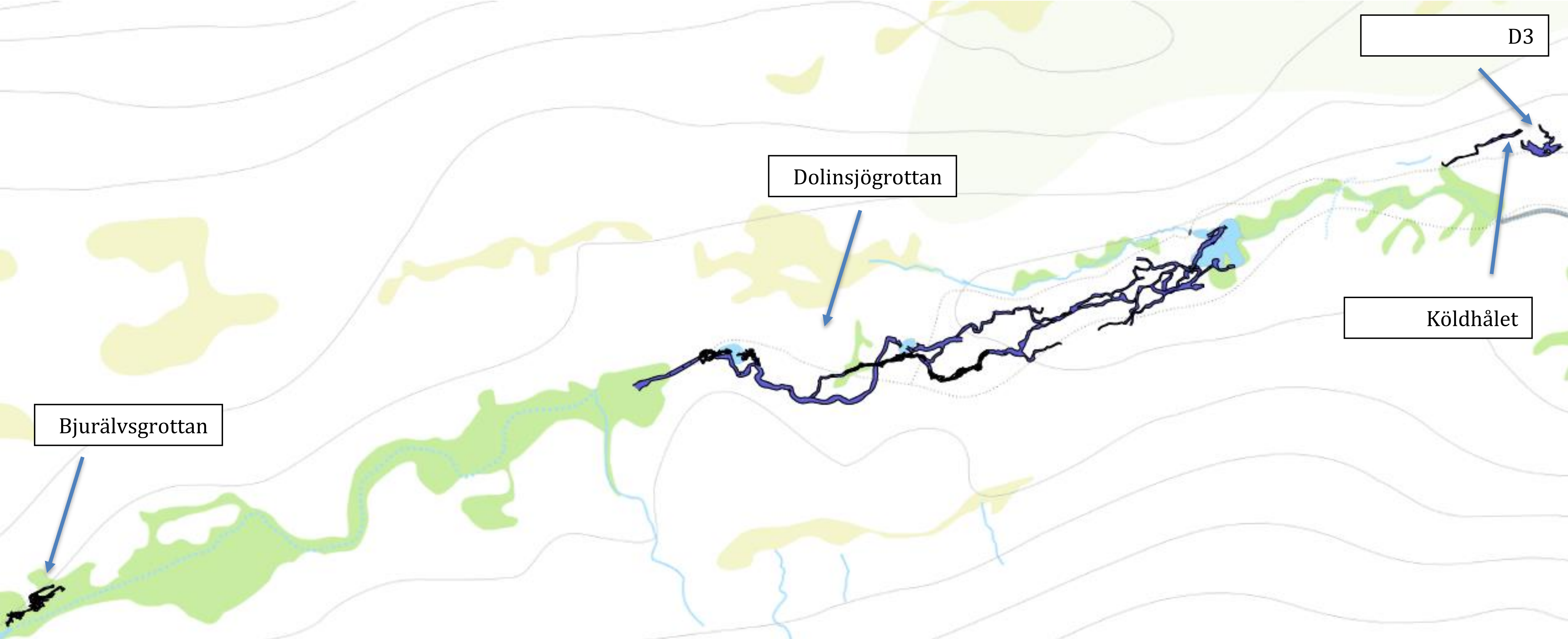

Figure 7 All the explored and mapped caves in Bjurälven valley

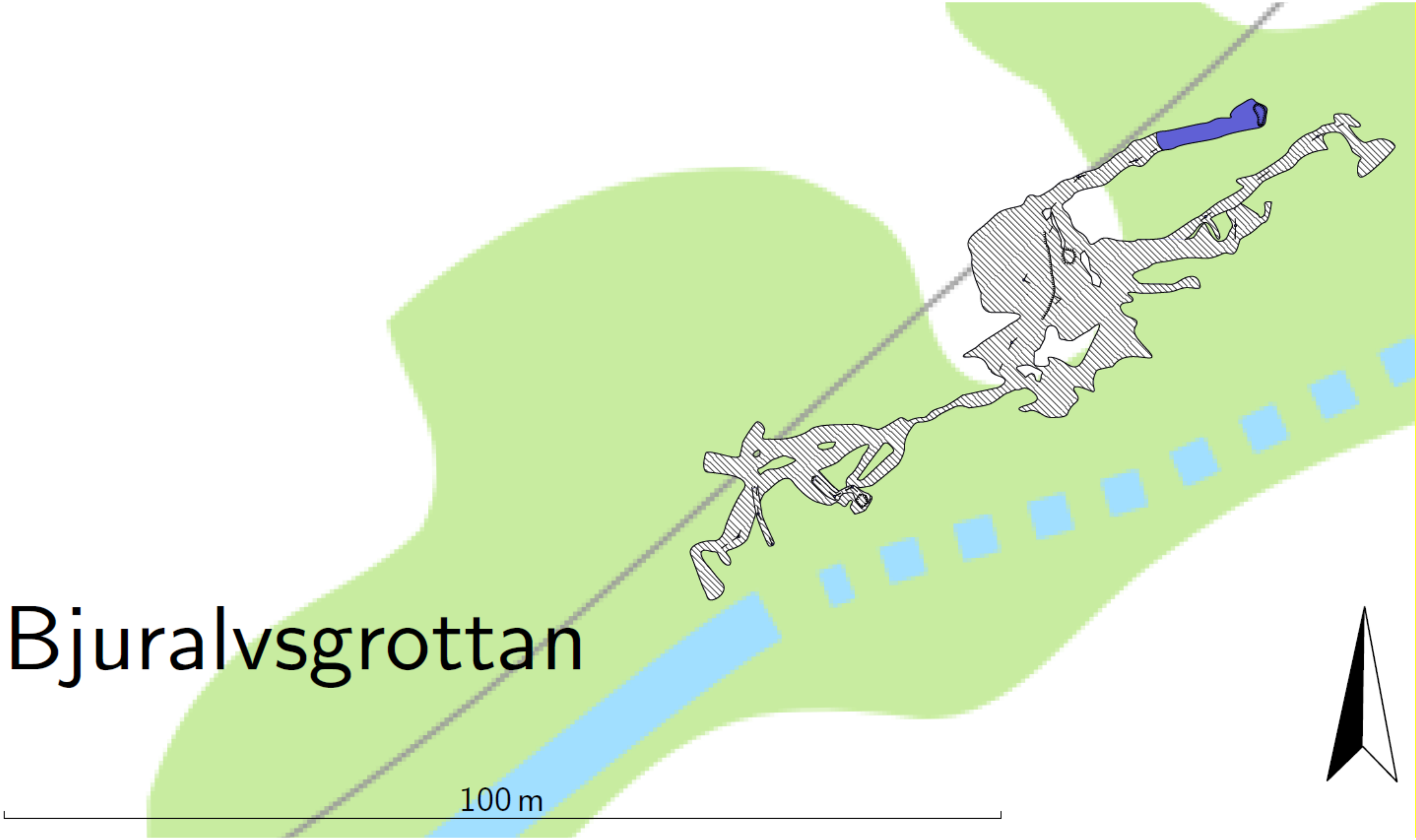

Figure 8 Bjurälvsgrottan, the inlet cave (mostly dry)

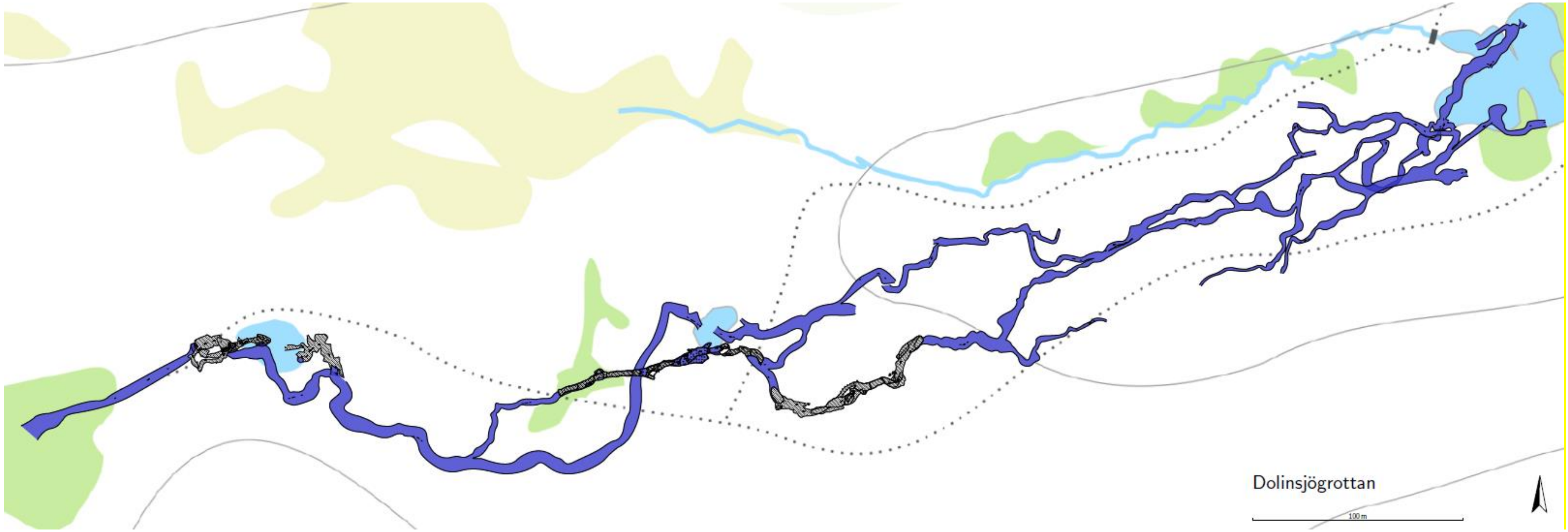

Figure 9 Dolinsjögrottan, the longest underwater cave in Bjurälven valley (consists of 5 sumps up to date)

Radiolocation

By Bo Lenander

During the last seven 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 communication. 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 exactly 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 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 week vertical return magnetic field and there it is very hard to get information about the direction of 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 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.

Three fix points in the Bjurälvsgrottan (depth under the ground surface was 13-33 meters) and one fix point in the D5 cave were localized in 2018 using a 32 kHz locator. Direction finding receiver M-15R, direction finding receiver M-16R and pinger M-16P were used. All the equipment was developed and built by Bo Lenander (SM5CJW). The pinger has been tested in an EMC-lab to verify that it does not give a dangerous magnetic flux density (B).

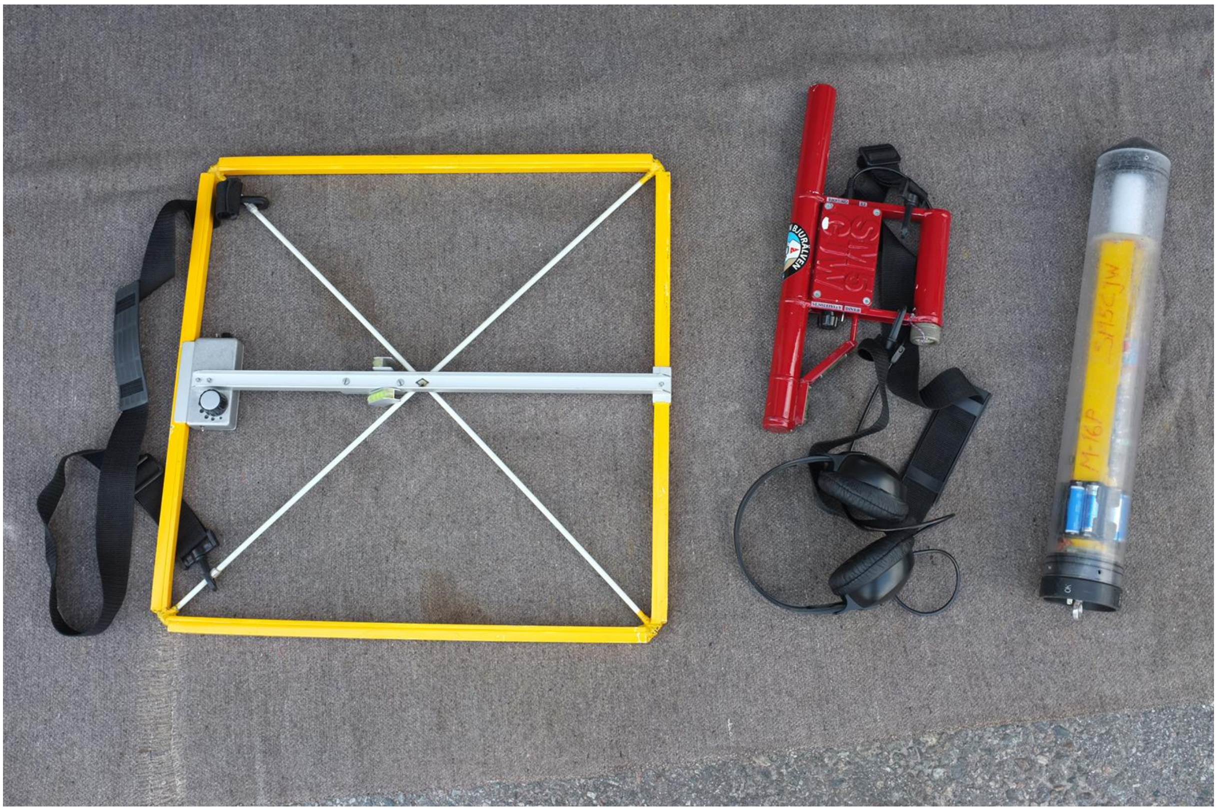

Figure 10 Direction finding receiver M-15R, direction finding receiver M-16R and pinger M-16P.

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 2018. 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 11 Icom IC-F51V radio (5W, 155 MHz, IP67) and the GP antenna for the base station.

VHF-communication between the surface and the cave

Successful attempts to establish VHF communication using 5 W/155 MHz hunting walkie-talkies were carried out from Bjurälvsgrottan and from the Rain Hall in Dolinsjögrottan. It was also possible to establish communication from Bjurälvsgrottan (34 m under the surface) to the base station in Dolin lake base camp located approximately 1600 meters away. From the Rain Hall it was possible to establish communication within an area on the surface directly above measuring approximately 100x50 meters.

While communication based on 155 MHz signal was successful on multiple occasions during Expedition Bjurälven, it was not possible to establish communication based on the same signal strength during Lummelunda expedition on Gotland. There are several significant differences between the two expedition sites. On the island of Gotland, the base rock consists of unchanged and porous limestone. Cracks in the limestone are often filled with ground water or wet clay, which has strong dampening effect on radio signals (155 MHz signals have wave length of around 2 meters). In the mountains and the Bjurälven valley, close to the centre of the compression that elevated the mountainous border territories towards Norway, the limestone was pressed down and exposed to high temperature and pressure. This led to its transition into a different crystalline state, marble. Cracks in the hard marble are filled with ground water when it is present, although there probably isn´t much ground water above the caves where the communication was attempted from in Bjurälven. If the marble layer does not reach all the way to the surface it is covered by a moraine. These layers of gravel dry and drain much easier than clay and there is significant chance that the moraine above the caves contain a lot of air. This is especially true when the flow of ground water is weaker during the winter months. All this contributes to less dampening of radio waves in the rock of Bjurälven and suggests that the signal dampening is weak enough to allow communication.

Using standard durable radio stations with high frequency for cave communication is a big advantage since the antennas are so small (10-30 cm). The short wave length 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.

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, 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 12 Leica CS15 field computer.

Our equipment consists of a Leica Viva GS15 rover on a 2.0-meter-high carbon fibre pole and a Leica CS15 field computer, seeFigure 12. 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® from Esri, see Figure 13. Thirteen new points were measured with the GNSS in 2018 and this included the new findings in Doline no. 5 (D5). This year we were not able to make a RINEX post process, so the measured data had a little less accuracy than earlier year.

LiDAR-data and drones.

Last year 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 Inspire drone were used for the third time to collect orthophotos from the areas of Dolinsjön, ”The Eight Dolines” and Bjurälvsgrottan. The photos were processed in

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 14.

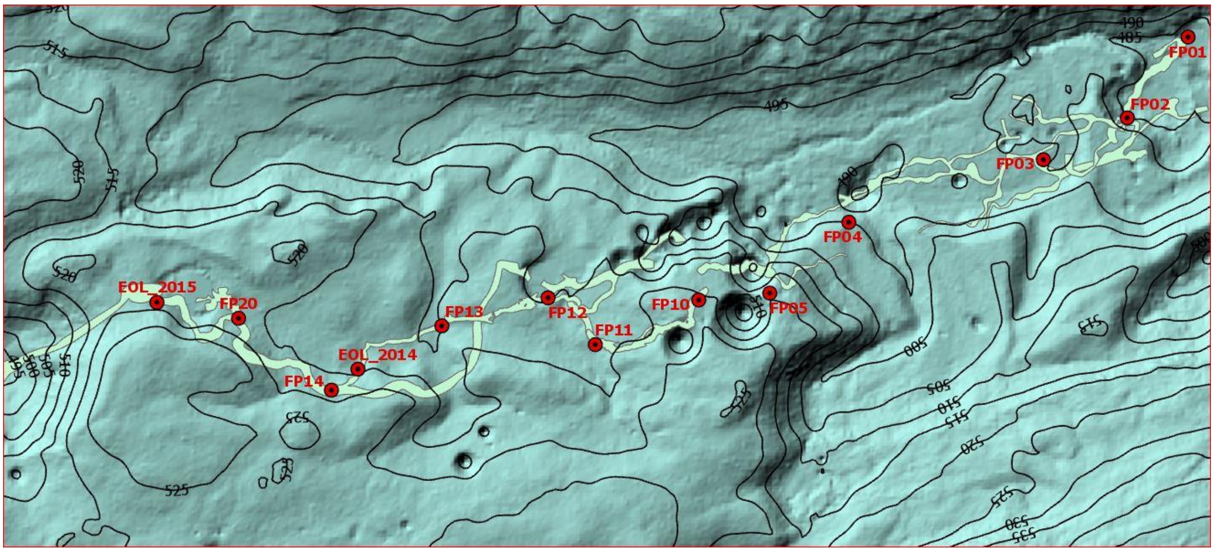

Figure 13 Fix points in Dolinsjögrottan.

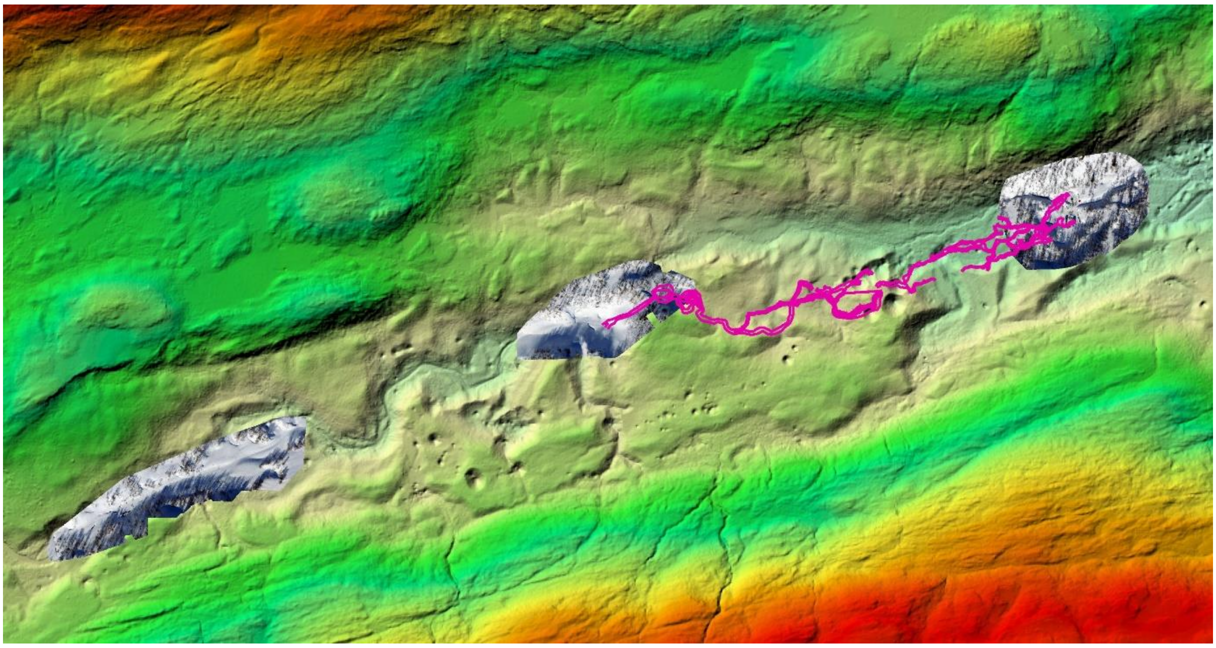

Figure 14 Map, showing LiDAR-data, orthophoto collected from drones and cave map.

Internet connection

The terrain, valley with high mountains around make 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 analyse 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 wears 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 2018

Several divers had problems with leaking gloves and/or dry suit. All divers could exit the cave in a safe manner and none of these divers was hypothermic after these dives. One diver had a problem with the air outlet on the dry suit. This did affect the ability to control buoyancy but did not result in any major difficulties to end the dive in a controlled and safe manner.

During this expedition we made an effort to explore dry parts of the system of the Bjurälven valley. As a result, we had several incidents related to dry caving and/or caving with dive gear. We had two divers who got their dry suit cut open by a rock in the cave roof. Both divers had to abort their dives because of heavy leakage. The divers got cold but not hypothermic. One diver fell in the fourth dry chamber and got a minor injury of one elbow. This had no consequence for the rest of the dive.

We had two accidents involving snow mobiles this year. During a trip to the advanced base camp one snow mobile, with driver and passenger, fell off the snow mobile track and turned upside down. The two persons got no injuries from this accident. There was also damage to the brakes on one of the snow mobiles due to driving with the parking brake on.

When the safety tanks were brought back from the cave, several of the regulators free-flowed due to freezing. The tanks were all filled before the transport to the Expedition and all had different primary/secondary stages. One diver got problems due to a pebble in the second stage of the regulator. As a result, the device delivered air mixed with ice slush, breathable only with difficulties. The diver switched regulators and ended the dive 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.