

MULU CAVES 2018

An Anglo-Malaysian Expedition to the
Gunung Mulu National Park, Sarawak



REPORT
on the findings of
THE MULU CAVES 2018
EXPEDITION
to the
GUNUNG MULU
NATIONAL PARK
SARAWAK
during January 2018

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Maps & Diagrams by Hugh St.Lawrence



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Rambli Ahmad with a giant red stalagmite in The Road to Hell, Clearwater Cave

Mark Jones

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Cover design by Hugh St.Lawrence from photos by Rambli Ahmad (front cover) & Mark Jones (rear cover). Both photos taken in the Road to Hell section of Clearwater Cave.

ABSTRACT

Between 12th and 28th January 2018 a team of eight cavers, with the close support of National Park staff and the Sarawak Forestry Corporation, set up a base camp at Park headquarters. The expedition had two major objectives, Airflow Studies and Surveying. Additionally we hoped to experiment with drone camera flights as an aid to surface exploration.

Although underground exploration was low on the agenda, as with all Mulu expeditions ‘caves are where you find them’.

Airflow Studies

Winds, or draughts, are a permanent feature of Mulu caves – indeed, caves are even named after them. Draughts are a guiding principle in cave exploration, but the mechanisms behind them are largely unexplained and little understood. The principle aim of the expedition was to initiate a programme of airflow studies which can be built upon by future expeditions. Over time it is hoped that data acquisition and analysis can help us to understand the airflow mechanisms of Mulu caves. The studies undertaken were seen as the first stage of a long-term programme which may eventually poll data from many different locations, both entrances and sites deeper into the systems.

Camera Drone Work

The advent of the drone has put a new means of landscape photography and reconnaissance at our disposal. Mulu is notorious for being ‘unable to see the wood for the trees’, an idiom which has a special resonance with surface explorers. With drone technology improving apace, and prices within (reasonable) reach of the private individual, the time had come to trial drone camera reconnaissance as an aid to surface exploration.

Surveying

The loss of raw surveying data from early Mulu expeditions means that a large proportion of the modern survey dataset, mostly in Clearwater Cave, relies on ‘fake’ data – measurements and coordinates obtained by reverse engineering of a drawn map. Whilst it was felt that this gave a generally accurate rendition of the cave in the Survex model, there were problems – most notably that all stations in a fake dataset are ‘virtual’ and cannot necessarily be located on the ground. This makes it almost impossible to tie in accurately any new surveys or explorations.

It was felt that installing a ‘de facto’ survey line along the backbone of Clearwater Cave, with fixed and clearly marked survey stations, would provide the essential start for Clearwater surveying to be updated to the modern dataset standard.

Exploration

As with all Mulu expeditions exploration is always an objective. Although this was secondary to the airflow studies, whilst the loggers were running there was opportunity to check out a few open leads in both Clearwater and Whiterock caves. Red Dwarf Chamber, in Clearwater, was revisited for the first time since its discovery in 1989. A new connection was made in Whiterock which improves access to the Zahara Dessert area of the cave. Although the discoveries were minor by Mulu standards they brought the total length of the Clearwater System to 227,196.25km.

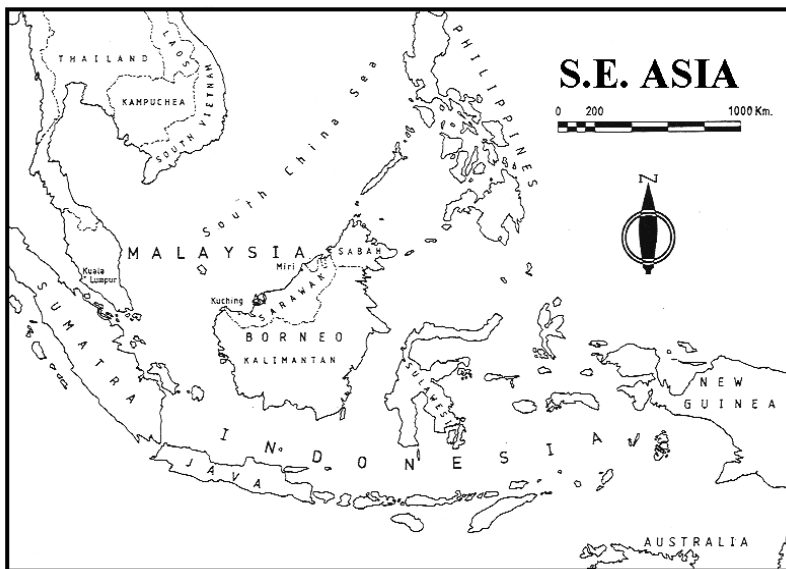
Results

Our ambitions were probably beyond a small team’s resources, in both time and manpower - and indeed so it proved, assisted by unforeseen factors such as poor weather and illness. Nevertheless, good headway was made in all aspects of the expedition, and the groundwork has been laid upon which to continue both airflow and re-surveying projects.

INTRODUCTION

LOCATION

The Gunung Mulu National Park is situated in north-eastern Sarawak, with its northern boundary forming part of the border with Brunei, (Figs. 1 & 2). It was officially constituted in 1974 and opened to visitors in 1985. Lying 4° N. of the equator it covers an area of 528sq km.



The Park is dominated by the sandstone mass of Gunung Mulu, which rises to 2376m. To the west of Mulu, and on its flank, lies a band of 'Melinau' limestone, which forms the lesser peaks of Gunung Api and Gunung Benarat. The lower slopes are covered in dense tropical rainforest, which rises to meet the montane forest of Mulu's upper slopes.

Figure 1: SE Asia

Mulu is a rich mixture of plant and wildlife and in the limestones, beneath the forest canopy, lie some of the world's most impressive caves.

HISTORY of EXPLORATION in MULU

The existence of large caves in the Gunung Mulu area of Northern Sarawak has been documented for over 150 years. In 1858 reference was made to "Detached masses of limestone, much water-worn, with caverns and natural tunnels" around the base of Mulu by Spenser St. John in his book *'Life in the Forests of the Far East'*, (St. John, 1862).

St. John was 'Consul General in the Great Island of Borneo' and made some of the earliest exploratory journeys of any European into the interior of Sarawak. His attempts to reach the summit of Mulu were thwarted by limestone cliffs, dense forest and sharp pinnacles of rock and he says, "It is almost impossible to conceive the difficulty of ascending this mountain". Mulu was to keep the secrets of its summit for a further 74 years until Edward Shackleton successfully climbed the mountain during the Oxford University Expedition of 1932, (Harrison, 1938).

In 1961 G.E. Wilford, of the Malaysian Geological Survey, visited the area to explore its caves. His work included the surveying of Deer Cave and parts of Cave of the Winds. He predicted that Mulu would yield many more caves in the future, (Wilford, 1964).

During 1977-8 the ***'Royal Geographical Society Mulu Expedition'*** spent 15 months in the area studying many aspects of the rainforest. This was the largest scientific expedition ever to leave the

UK. Included in the team were six speleologists who, in three months, explored and surveyed 50kms. of cave passages including parts of Clearwater Cave, Green Cave and others, (Brook & Waltham, 1978).

During the expedition a forest camp was established in Hidden Valley from where two major caves were explored. 'Wonder Cave' on the north side of the valley was found to have some of the largest passages in Mulu. 'Prediction Cave' on the south side also contained enormous passages which were almost filled with river sediments, (Meredith, Wooldridge & Lyon, 1992, p.10).

It was obvious from these findings that Mulu ranked as one of the world's foremost caving regions.

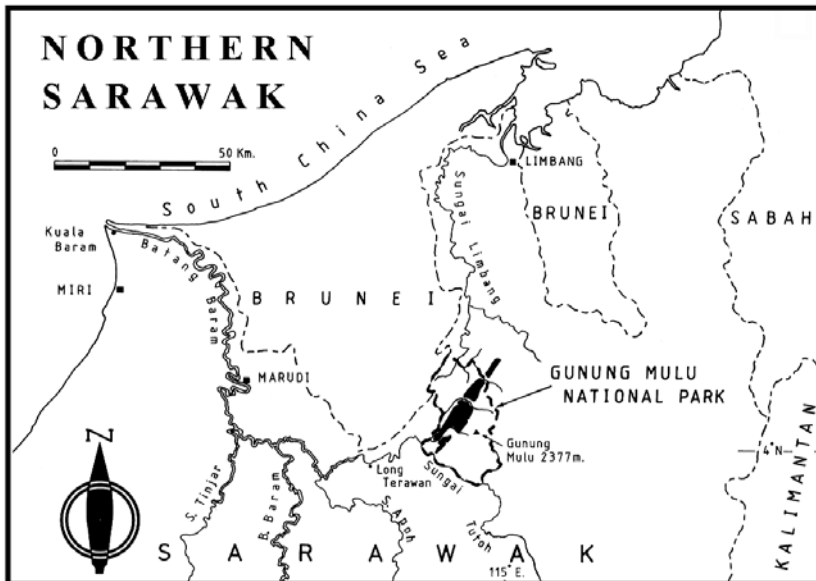


Figure 2: Northern Sarawak

As a result of the RGS expedition two large scale caving expeditions were mounted in the early '80s. The '**Mulu '80**' expedition explored and surveyed a further 50km of cave passages, including the largest underground cavity, in the world, 'Sarawak Chamber', which forms the final chamber of 'Lubang Nasib Bagus' or 'Good Luck Cave', (Eavis, 1981). The end of this chamber lies very close to the end of Prediction Cave in Hidden Valley and tantalising draughts at the end of each cave suggested a connection.

In 1984, the '**Sarawak '84**' expedition spent one month in the field and explored 54km of caves. Clearwater Cave was extended by 14km but a great deal of work was carried out in Benarat, where Cobweb Cave was discovered, adding a further 15km of passages to the Benarat total. Sarawak Chamber was also photographed for the first time.

These two expeditions carried out a great deal of scientific research associated with the caves, including dye tracing, geology, geomorphology, ecology, cave mineralogy, etc. However, although 150km of some of the largest caves in the world had been surveyed, some very significant areas of limestone remained totally unexplored, presenting enormous potential for further exploration, (Fig. 3).

During late '87 and early '88 plans were made to mount another caving expedition to the area. This would be the first expedition to visit the park since its opening to the public in 1985 and was primarily aimed at exploration, surveying and photography. Unlike the previous expeditions this was to be a lightweight venture with only six team members. The '**Mulu Caves '88**', expedition once again proved the potential of Mulu with a further 16km of passages explored. It was also shown that exploration in Mulu using a small team was both feasible and successful.

The major discovery of this expedition was Blackrock Cave lying to the north of Clearwater and almost certainly part of the same system, (Kirby 1989, p.28).

As a direct result of this discovery, an eight strong group, including five of the 1988 team, returned to the Park exactly one year later as the '*Mulu Caves '89*' expedition. Once again a lightweight venture proved to be successful, with over 24km of passages explored and surveyed in only one month. Major extensions were found in Clearwater Cave, totalling 15km, and the gap between it and Blackrock Cave was brought to within 90m. The Clearwater 5 streamway was discovered and explored for over 1km.

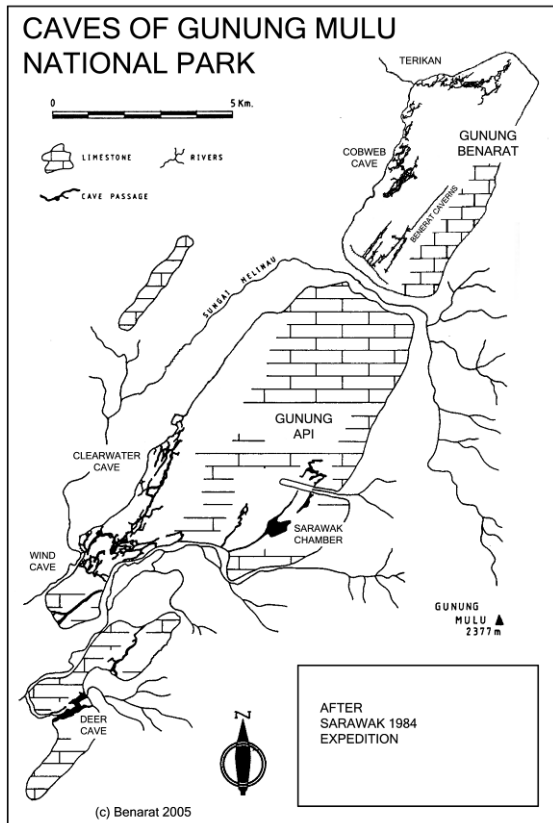


Figure 3: Exploration up to 1984

In 1991 a group of nine explorers, five of whom were from the '88 and '89 expeditions, returned to the Park to continue exploration in the Blackrock/Clearwater area. A connecting passage was discovered which linked the two caves. This discovery made the Clearwater System the seventh longest cave in the world at over 102km. This was the '*Mulu Caves '91*' expedition, (Fig 4).

A vast amount of work had, by this time, been carried out on the western flanks of Gunung Api and although discoveries were by no means exhausted it was becoming increasingly difficult to find major objectives which would justify another expedition to that side of the mountain. The remaining significant lead, the Clearwater 6 Streamway, was weather dependent and, therefore, could not be relied on as a sole objective.

Attention now focused on the more challenging eastern flank of Gunung Api with Hidden Valley as the first objective. This area was less accessible than the west as there were no major rivers which could be used for transport of stores and equipment.

Tentative enquiries were made in 1990 to see whether it would be possible to visit the Valley during the '91 expedition. A positive response was received and this became one of the secondary aims of that expedition. Unfortunately this was not achieved as other discoveries closer to park

A new cave, provisionally named 'Simon's Cave', but later named 'Racer Cave', was discovered and explored and water tracing experiments proved a hydrological link from the Melinau Gorge through Blackrock and into Clearwater Cave, (Kirby, 1990). The discoveries made by these two expeditions had greatly altered the map of Gunung Api's caves.

During 1990 another British team visited the Park and continued the exploration of Racer Cave. The Clearwater 5 streamway was explored to an upstream sump. Although a sump bypass was found to lead into Clearwater 6, rain caused the bypass to sump which prevented further exploration (Weight, 1990). A physical link was established between Drunken Forest Cave and Alexandra Palace in Clearwater.

During February 1991 a Korean Team visited the Park. Some minor discoveries were made. Unfortunately these findings were not published.

headquarters took priority. Instead, part of the '91 team returned approximately one year later in January 1993 as the '**Hidden Valley '93**' reconnaissance expedition with the sole objective of carrying out a lightweight reconnaissance of Hidden Valley.

The reconnaissance expedition proved a success with potential for further discoveries to be made in the two known caves within the Valley and a new cave discovered in the dolines to the west. Other entrances were noted for further investigation and surface reconnaissance suggested even greater potential further south in the deeper 'Third Doline', which was not entered.

With the Hidden Valley reconnaissance expedition indicating potential for further discoveries in Hidden Valley a full exploratory expedition, '**Mulu Caves '96**', was mounted and returned to the Park in October 1996. A base camp was established within the Hidden Valley gorge between the entrances of Prediction and Wonder Caves. Although very little was found within the main gorge exciting discoveries were made in the dolines to the south west. Arch Cave was explored in the second doline. Prediction and Bridge Caves were found within the third doline and the fourth doline revealed Cloud Cave which matched Deer Cave in scale. During the last few days of the expedition a descending boulder ramp was followed which led into the far reaches of Cobra Cave. This established a through route to the Melinau Paku valley.

During 1997 an American expedition, which was exploring Gunung Buda, carried out surface searching on the northern slopes of Benarat. This led to the discovery of Deliverance Cave on the north east corner of the mountain. 3.5km of passages were explored which were heading in the general direction of Cobweb Cave.

With the success of the '96 expedition a second Hidden Valley expedition, '**Mulu Caves '98**', was mounted which returned to the Park in February 1998. As the centre of exploration was to be in the dolines it was known that this would not be best served by a camp within the Hidden Valley gorge. Not only would a camp in Hidden Valley be remote from the caves, it would also be almost impossible to supply without helicopter backup, which would be very expensive and could not be relied upon.

With this in mind, a gamble was taken on being able to reach the 4th Doline from the Melinau Paku Valley via a route, over the surface, which had never been explored. It was thought that the route through the caves would be used only as a back up, however, the severity of the climb up from Nasib Bagus, together with the surface terrain proved to be far more difficult than the underground route via Cobra Cave, which soon became the main thoroughfare.

This expedition proved a great success with further extensions in Perseverance Cave and a connection established between Cloud and Bridge Caves establishing the Cobra – Cloud – Bridge system at 16.1km. with a vertical range of 459m, the greatest vertical range of any cave in the Park.

Owing to the El Nino year, river levels were exceptionally low so a further attempt was made to explore beyond the Clearwater 5 upstream sump into Clearwater 6. This led to another sump which was bypassed into Clearwater 7 and the inevitable upstream sump which was not passable. This expedition was the last to visit Hidden Valley.

Another American expedition visited Buda in 2000 and carried out further work in Deliverance Cave, bringing its total length to 4.3km.

With exploration in Api now without any significant leads the attention of the British team was drawn to Gunung Benarat. It had been sixteen years since a British expedition had visited the

mountain, during the Sarawak '84 expedition. The '**Benarat 2000**' expedition continued the exploration of Cobweb Cave, where a further 10.7km of passages were explored bringing the total length of the cave to 25.9km.

As a follow up to the 2000 expedition, the '**Benarat 2003**' expedition returned to the park. A further 4.4km were explored in Cobweb Cave, but the significant discovery of the expedition was made in Terikan Rising Cave where 12.5km of passages were explored. Included in the team were two Api veterans who were to use the expedition, based at Camp 5, as an opportunity to prospect the northern slopes of Api between the Melinau Gorge and Blackrock's Racer entrance. This revealed a significant entrance 2.8km south west of Camp 5. The cave was named Whiterock and within the remaining three days of the expedition it had revealed 3.7km of new passages. Owing to its proximity to Blackrock, it was thought that it would soon connect and might be of little significance.

During 2005, the '**Benarat 2005**' expedition, based at Camp 5, continued the exploration of Whiterock, which exceeded all expectations when a further 17.2km of passages were discovered, mostly lying above Blackrock. Two connections were made between the two caves, which linked Whiterock into the Clearwater System.

On the Benarat side of the gorge an attempt to climb up to an entrance high in the cliffs opposite Camp 5 was cut short when a small entrance was discovered only 60m above the ground. This cave was named Moon Cave and was explored for 6.6km in an almost straight line into the mountain. A connection was also established with Benarat Caverns making the total length of this system 16.4km

Included in the expedition were two divers who investigated the sumps in the Terikan system. This proved connections between the individual elements of the system to make a total length of 32.5km.

The total length of caves surveyed in Benarat was now 90.4km and in Api was 172.6km.

During January and February of 2007 the '**Mulu Caves '07**' expedition continued the exploration of Whiterock and Moon Caves. Significant discoveries were made in the northern section of Whiterock, where two major passages were discovered, both of which came to within 400m of Camp 5 with no apparent entrances/exits found. These two passages, the Northern Line and the 1954 Series, ran northwards in parallel with 60m of vertical separation.

A great deal of in-filling was carried out, with new passages providing short cuts between previously discovered trunk routes. This reduced considerably the travel times to the northern reaches of the system. These discoveries extended the known cave to 42.9km. A major success of the expedition was the connection of Moon and Cobweb caves via an unexplored passage in Moon Cave. This connection linked Benarat Caverns, Moon Cave and Cobweb Cave to produce the Benarat Caverns System, which ranks as the second longest system in the Park at 50.7km. In the Melinau Gorge, considerable surface survey work was carried out to tie together all the known caves on the Api side of the river and link these back to the datum at Camp 5. This allowed them to be linked into the Survex master dataset. Some minor entrances were explored in this area.

During January to March of 2009 the '**Mulu Caves 2009**' expedition continued to explore Whiterock Cave and discovered a further 24km of passages. Owing to the proximity of the northern passages to the cliffs in the Melinau Gorge, a considerable amount of effort was given to establishing a northern entrance. Five days were spent attempting to gain entry via a small cave to the east of Camp 5. Unfortunately this ended in a boulder choke with a draught emitting, within 100m of Whiterock. A significant discovery in Whiterock brought its northern passages to a point underneath the Pinnacles track and even closer to Camp 5. Late in the expedition a steeply descending ramp off 1954 led into

the Whiterock River, the upstream continuation of Clearwater streamway. Although not fully explored, this streamway was left at a point 60m beneath Camp 5 with potential for further discoveries.

During May 2010 a small team visited the Park. The '**Mulu Caves 2010**' expedition was to be a small-scale venture, based at Park headquarters, with the aims of photography, science and surveying. Modern digital images were made of the caves close to Park headquarters. Further samples of speleothems, sediments and quartz were collected to enhance the scientific programme. 14.6km of surface survey was completed to tie together all the known entrances in the Southern Hills. Although not a primary aim of the expedition, a small amount of exploration was carried out, with 2.4km of previously undocumented caves explored and surveyed.

During 2011 the '**Mulu Caves 2011**' expedition spent two months in the field. This was a two-centre, two-month expedition the first month based at Park HQ and the second at Camp 5. The expedition successfully laser scanned the vast Sarawak Chamber allowing volume calculations for be made. Radio-location was used in Whiterock Cave and the Melinau Gorge to determine the precise position of the end of the cave in relation to the surface topography. A series of Geodetic GPS fixed points were established around the park to better understand the relative levels of the caves within the Survex dataset. In Whiterock Cave 13km of new discoveries were made. A series of sampling was carried out for Uranium series dating.

The '**Mulu Caves 2012**' expedition was to be the 20th in the series of Angle Malaysian ventures and was based at Park HQ. A series of high level caves were found in the Melinau Paku valley with Train Cave extending the Cloud/Bridge/Cobra system to 20km. Attempts to connect Lagangs Cave into Racer Cave were unsuccessful but the cave was extended to 5.7km

October 2013 saw the '**Mulu Caves 2013**' expedition based at Camp 5. Scientific work was carried out in Whiterock cave to better understand the geology and geomorphology of this area. Further sampling was carried out for uranium series analysis. A further 7km of new passages were explored in Whiterock Cave and Deliverance Cave at the northern end of Benrat was re-visited without any major breakthroughs.

During April/May of 2013 the '**Mulu Caves 2014**' expedition was focused on exploration at the southern end of Gunung Api. Based at Park HQ the expedition continued the attempt to connect Racer and Lagangs cave into the Clearwater system. Although the connection was not made a new cave was discovered, Easter Cave which proved to connect with the higher levels of Racer Cave. The significant success of the expedition was to discover the 8km of passage in the Creedance series which forms the fourth horizon of development 450m above base level confirming the existence of higher levels within the cave. This discovery pushed the total length of the Clearwater System to over 200km.

The '**Mulu Caves 2015**' expedition was an ambitious project centered on three locations, Southern Api, Hidden Valley and Camp 5. In Hidden Valley a lightweight recce was carried out to investigate a large entrance identified from helicopter video footage in the north wall of the gorge. This revealed Conviction Cave which connected into Wonder Cave, unfortunately a serious accident curtailed some of the work here. Further exploration was carried out in Racer and Lagangs caves but no connection made. From Camp 5 8065m of new passages were explored in Whiterock Cave where a new level was entered 100m above anything previously discovered. This was 380m above the lowest part of the cave confirming the existence of higher levels within the cave and potential for far more discoveries in the future.

During April 2017 the first of two '*Mulu Caves 2017*' expeditions visited the park and was based at Park HQ. Further work was carried out in southern Clearwater and in Cave of the Winds where the Eureka series was discovered lying just above the river passage.

The second expedition was based at Camp 5 during October where 4.2km of new passages were explored in Whiterock Cave bringing the total length of the cave to over 100km and the Clearwater System to 226.3km (Fig 4). Within just 15 years Whiterock had become a 100km cave, the longest cave in the Park.

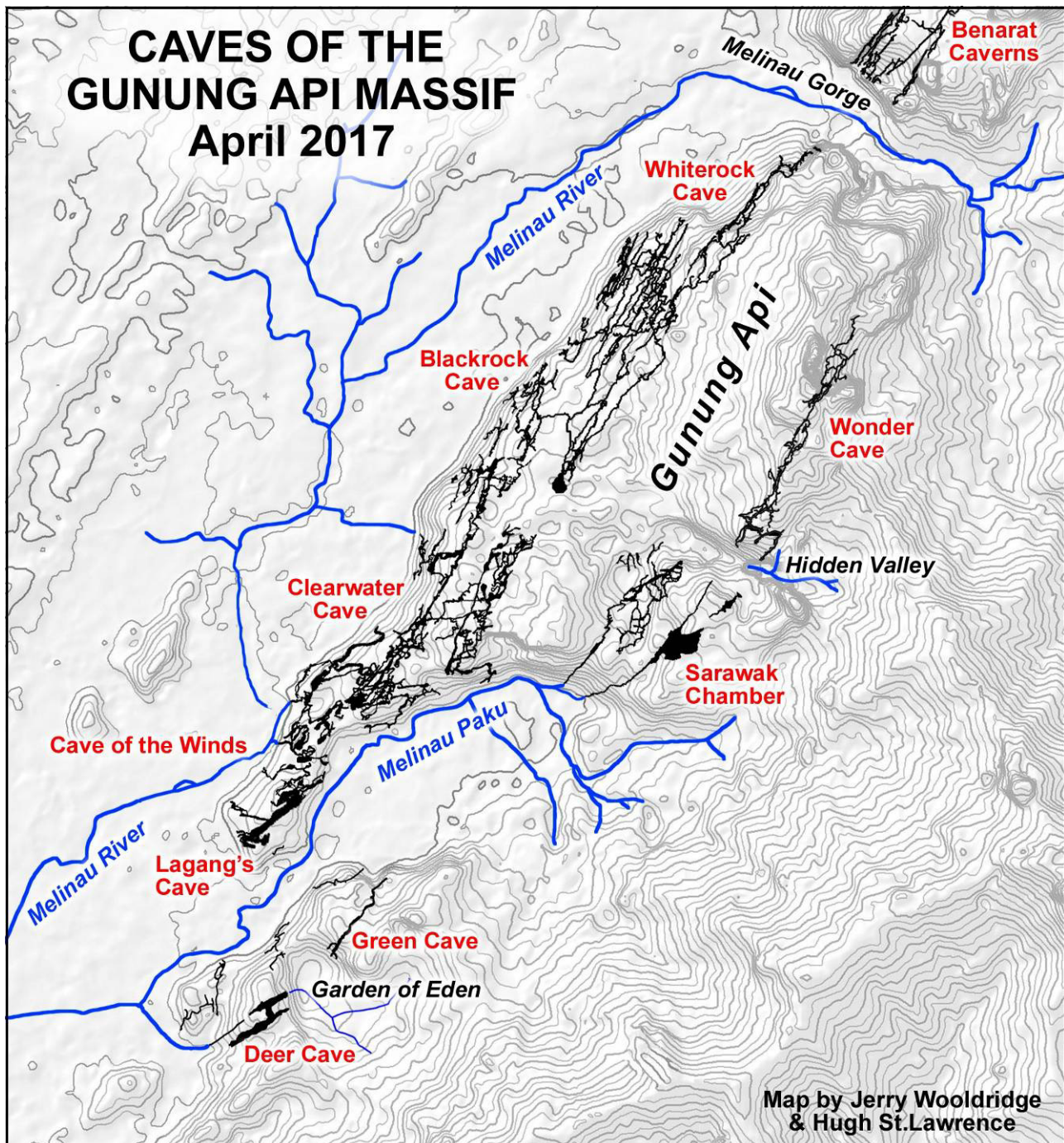


Figure 4: Caves of the Gunung Api Massif after the 2017 Expeditions

THE MULU CAVES 2018 EXPEDITION

BACKGROUND TO THE EXPEDITION

For a few years the idea of carrying out airflow studies in Mulu had been considered as a worthy project. After a couple of false starts the project gained a boost when Gill Instruments donated one of their 'Windsonic' anemometers. Planning started immediately, a team was put together, flights booked, a second anemometer and data loggers were sourced, the necessary permits were gained and within three months we were in the field ready to go.

OBJECTIVES

Although the main driver for the expedition was the airflow studies this was not the only aim. It was recognised that whilst the loggers were running there was opportunity for other work. The objectives of the Expedition were:

1. **Airflow studies:** to investigate the draughts within the caves using wind and pressure/temperature loggers.
2. **Resurveying:** to commence a comprehensive resurvey of areas of cave for which the original survey data is no longer available.
3. **Camera Drone Work:** to search for cave entrances and features in the Melinau Gorge using a camera drone.
4. **Exploration:** To carry out small scale exploration where time and opportunity allowed.
5. **Surface exploration:** To carry out surface exploration in and around the Melinau Gorge and southern Benarat to identify new entrances.

ACCESS TO THE CAVES

Access to Clearwater & Cave of the Winds

Both Cave of the Winds and Clearwater were accessed using boats from Park HQ. Owing to heavy rainfall and high water levels there was no requirement to push boats upstream which made for easy access and rapid travel times. High water levels rendered the Clearwater streamway impassable beyond the Balcony series, so Clearwater was entered via the Cave of the Winds connection and exited via Snake Track, a fantastic through trip.

Access to Whiterock Cave

Whiterock's entrances are located on the northwest flank of Api just to the south of a prominent north facing white cliff. The normal route to the cave follows the Headhunters Trail south from Camp 5 to a point mid way between the 4km marker and the first river crossing. From there a cut track heads across swampy land to the Midnight entrance. Owing to a storm, which had caused considerable tree fall, the route across the swamp had become very confusing and difficult to follow. During the October 2017 expedition a new track was cut which started from the first river crossing and rejoined the original track approximately half way to Whiterock. The track arrives at the base of the mountain just south of the entrances at a point known as Whiterock Junction. Turning north the track up to the upper (Midnight) entrance is found after 50m and the lower, original, entrance is located a further 250m north from here. The upper entrance is now the favoured route into the cave as it bypasses an awkward step and the 60m ramp up to the Ashes Series. This track climbs 115m steeply up the footslopes and is well worn with loose rocks and slippery vegetation.

AIRFLOW STUDIES

Background

Hugh St.Lawrence

The Mulu Caves 2018 Expedition was conceived and organised at short notice after learning in October 2017 that we were very kindly to be provided with some anemometer and data logging equipment from sponsor companies Gill Instruments Ltd. and Richard Paul Russell Ltd. (R-P-R). Measuring and trying to make sense of the draughts and airflow in the Mulu caves was a study I always felt would be interesting, revealing and potentially useful for future exploration.

Like many other expeditioners to Mulu I've often come away wondering where the wind in a passage came from, or where it went. As in caves all over the world, the draughts in Mulu tease us constantly, sometimes leading us to fabulous discoveries, sometimes leading us down the garden path. Sometimes the draught is mysteriously absent when only a day or a week before it was a blowing a gale. Whiterock Cave was discovered by chance when some forest walkers felt a strong breeze falling down the mountain slope; the cave is now over 100 kilometres long. Draughts are important. As explorers, the cave winds feed our curiosity and often fuel our activity. Cave of the Winds is not named out of fancy! We follow the winds because it's a golden rule. We don't know why it's a golden rule, but it is and it leads us on.

But we don't understand the winds. Here in the 21st century we probably know less about cave winds than 16th century sailors knew about sea breezes - a finger in the air is not too far off the mark. Marry that to bare experience and intuition and draughts often lead us to great discoveries. But we still don't understand why - we don't understand what creates the winds, why they vary in strength and direction, why they blow some days and not at all on others. I felt it was time to try and find out, to see if a little bit of science could help us establish patterns or trends of airflow behaviour. In time, who knows, we might even be able to proffer an airflow model - although prediction itself might be a little farther off!

For several years I'd maintained correspondence with both Gill Instruments and R-P-R, leading companies in the field of airflow measurement. This came to fruition in October 2017 when both Gill and R-P-R agreed to support the project with a donation of sensitive anemometer and data logging equipment. The project is grateful for their generous assistance.

With the means to measure winds now in our hands, we rapidly put together a small team of people who had previously expressed an interest in this project or who had the required technical or analytical skills. A 3 week window in January 2018 suited everyone, flights were booked, and a lot of time was spent by several people, particularly Nick Williams, configuring the instruments and packaging the sensitive equipment into lightweight, waterproof containers for rough cave transport.

Several subsidiary projects would fill our time while sensors and loggers were collecting data over 24hr or longer periods - these are reported elsewhere.

Equipment

Nick Williams

The instruments chosen for the airflow experiments on the trip were a Gill Instruments Windsonic anemometer connected to an R-P-R (Richard Paul Russell Ltd) W10 Spacelogger. For measuring temperature and humidity we used a UNI-T UT330C USB Temperature, Humidity & Pressure Datalogger in the caves and a Voltcraft DL-121TH temperature and humidity logger at Park HQ as the control unit. We had two sets of the Windsonic/Space logger combination and two of the UT330c units. One of the Windsonic units was purchased on e-bay and the other was donated by

Gill Instruments, both Spacelogger units were donated by R-P-R. The UTC330's were purchased by the expedition.

We also attempted to obtain meteorological data from the weather station at Mulu Airport but we never received a reply from the weather department in Kuching which Mulu put us in touch with.

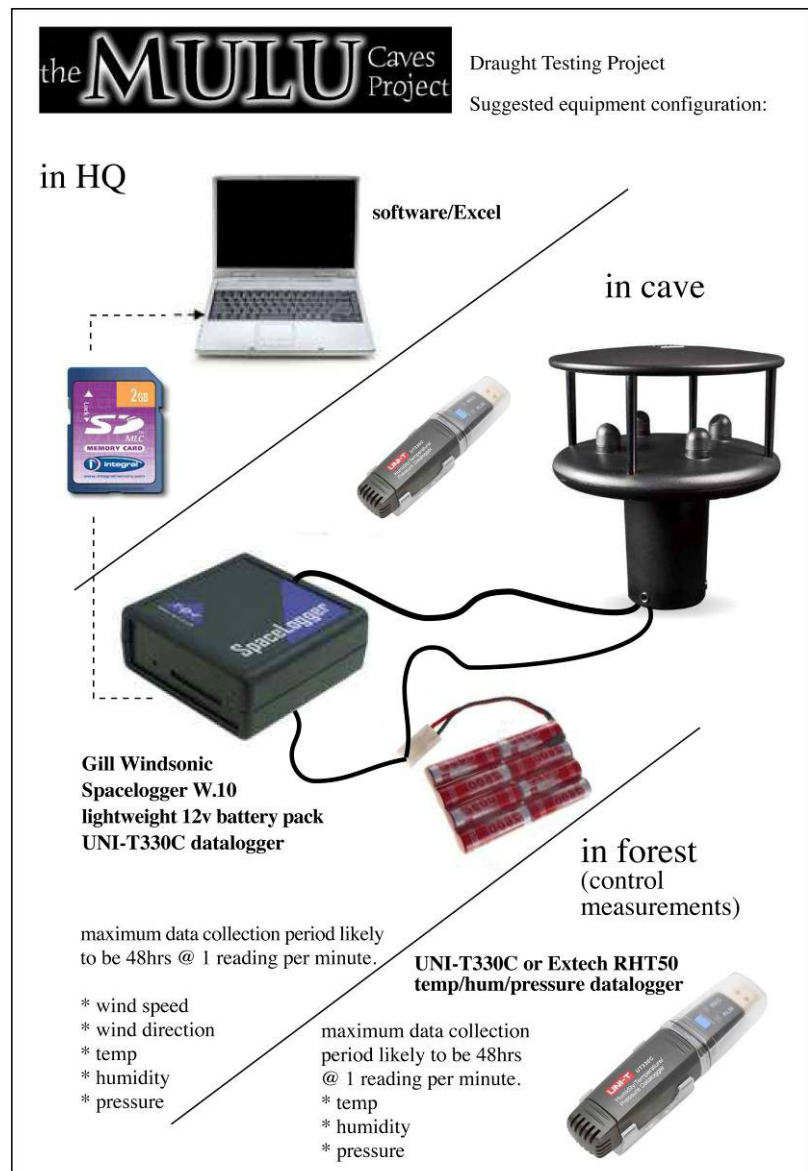
Prior to the expedition we had investigated the use of the Kestrel 'Drop' instruments for T/Rh/P logging but these use a Bluetooth link to a phone app (IOS or Android) and need a WiFi link to get the data off the phone. They would thus be unsuitable for use at Camp 5 where there is no internet and only limited electrical power.

The Windsonic units communicate via an RS 232 link which is also used to programme them. The Spacelogger units are designed to take the ASCII text message received via RS 232 and write it to an SD card.

The Windsonic message includes wind velocity and direction (bearing). The message interval can be adjusted between 0.25 sec. and 4 sec. The time stamp is added by the data logger and to get longer than 4 sec. intervals between measurements the logger must be programmed to discard intermediate readings. Even at one reading every 4 seconds, a day's logging represents a very large number of data points but measurements in the caves indicated that the rate of change of draughts is such that 1 second logging intervals are required to resolve the details of the variations.

The combined current consumption of the Windsonic units and the space loggers is about 20mA. Initially we considered using rechargeable Li-Ion batteries for the power supply but having concluded that the maximum period of unattended logging was unlikely to exceed 36 hours, it was concluded that powering the units from Li-Manganese AA primary cells with a capacity of around 3000mAh would be more convenient, both because it reduced the weight and complexity of the batteries but also because it meant that we could avoid problems with carrying Li-Ion secondary cells by air.

The Space logger units are by no means environmentally sealed so these were built into a standard clear-topped ABS enclosure, along with the batteries (8 batteries per logger to give a 12V supply).



Connection to the Windsonic units was via a 3m cable to allow the logger box to be placed on the floor while the anemometer was held at around 1.2m from floor level on a photographic tripod, using specially made brackets to mount on a standard 1/4 BSW tripod thread. Accessing the SD card to remove the data required the box to be opened but since the logger simply adds data sets to the card and does not over-write data until it is full, it was not necessary to open the boxes to offload the data until the boxes were back in the relatively benign environment of the bungalow at Park HQ. The connecting lead was configured so that power to the logger and the anemometer was switched on only when the interconnecting lead was plugged into the logger box. The connectors used sealed with a screw-in waterproof cap when the cable was not plugged in. The whole assembly (anemometer, logger, cable and tripod bracket) was just small enough to fit inside a BDH drum which made it easy to carry and provided some protection against water ingress.

Reading the data off the SD card and importing it into an Excel sheet was relatively straightforward. Matt coded a sheet which resolved the direction data of 'air flowing into the cave' and 'air flowing out of the cave'.

Both types of t/Rh/P logger have a built-in USB connector and are plugged directly into the laptop port to offload the data. Unfortunately, both use proprietary (Windows only) software on the laptop to talk to the logger and the data is then sucked into the manufacturer's own graphing programme. There were some issues with getting the drivers to work on some machines. Although it is possible to save the raw data for import into a spreadsheet, this is far less convenient than the platform independent RS 232 ASCII text messages written by the Windsonic units which made offloading and processing the data on any laptop very straightforward.

The biggest challenge in handling the data was ensuring the clocks in the loggers were synchronised to local time.

Methodology

Matt Kirby

We arrived in the field with two Windsonic anemometer with associated RPR loggers and the atmospheric loggers. The plan was to place one of the atmospheric loggers at base camp as the control which would record the atmospheric pressure, temperature and humidity. A second atmospheric logger would be taken into the cave and left to run for the duration of each of the air flow studies. The plots would be combined to investigate the airflows in relationship to the atmospheric conditions both inside and outside the cave.

Site Selection

Matt Kirby

In total six sites were selected for recording airflow. These were known to host reliable draughts which would hopefully provide good results. Other sites (discussed below) were considered and not used either because of their accessibility or some physical factors which did not lend them to anemometer sites.

- **Lower (River) Entrance, Cave of the Winds:** The lower entrance to Cave of the Winds was an obvious place to study air flow. The cave was named after the enormous draught which emits from the entrance. With the apparently constant wind blowing from this entrance there would be a good chance of positive results. Once in the field it became apparent that this site could not be used owing to high rainfall and the risk that the site would be inundated by floodwater.
- **Overtime Passage, Cave of the Winds:** Previous trips into this cave had indicated a good draught where Overtime narrows down approaching the boulder choke before Babel. This site was to be used in conjunction with the lower entrance site.

- **Illusion Passage, Cave of the Winds:** This site was chosen in the field following the abandonment of the lower entrance site.
- **The Snow Slopes, Clearwater Cave:** the first section of the Snow Slopes passage, leading from Scumring bivouac site to Armistice, was known to host possibly the largest and most impressive draught in Mulu. Stories existed about carbide lamps being blown out by the powerful wind in a passage 8m wide by 5m high. This was at the top of the list of sites for the study. Would there be any reversal of airflow here?
- **Ronnie's Delight, Clearwater Cave:** Although a powerful draught comes from the Snow Slopes it was known that another draught emits from the Ronnie's Delight passage and flows across the Scumring bivouac site. Anecdotal evidence exists about sleep mats being blown away by a temporarily powerful air flow across the bivi site one evening. This was a high priority for further investigation and would tie in nicely with the Snow Slopes study.
- **Lower (Original) Entrance, Whiterock Cave:** Although the lower (original) entrance was known to support a healthy draught (which had led to its discovery in 2003) it is less accessible than the Midnight Entrance and the nature of the portal, a shaft with a narrow constriction at the bottom, is not best suited as an anemometer site. It was known that the entrance is regularly used by swifts and that they enter the shaft and pass through the constriction at high speed. To place a sensor here would risk an impact which could damage the equipment and a swift. The decision was made to utilise the Midnight Entrance instead.
- **Midnight Entrance, Whiterock Cave:** The upper entrance was known to host a good draught which would refresh explorers who had just made the steep, 115m ascent from the alluvial plain. Just inside the entrance is a calcite constriction which would provide an ideal site to study air flow.
- **No Country for Old Men:** This entrance was known to host a good and reliable draught as it passes through the entrance squeezes. Although small and constricted it was close to Camp 5 and relatively easy to access.

The results from the studies are shown later in this chapter. The series of plots shown in this section indicate wind speed against 'surface' humidity, temperature and atmospheric pressure. The wind speed trace has a superimposed smoothing average plot shown in orange. Polar plots for each site can be found in Appendix 3.

Analysis of the Data

Ben Kent/Matt Kirby

Gaining the necessary instruments for air flow studies was only the first step in bringing the project to fruition. The means of analysing the data required some thought. Windsonic anemometers produce results which not only indicate wind speed but also wind direction both recorded against time. In an open air environment this is essential information but how to interpret this for a cave environment was the key question. The anemometers are designed to be aligned to north when they are installed. They don't contain a compass so this alignment is essential to interpret the actual direction from which the wind is coming; the instrument simply records the direction which the airflow collides with the instrument relative to the instrument not necessarily the actual compass direction it originates from. As long as the instrument is aligned to north the two readings will be the same; recorded and actual.

It was decided to set the anemometers to record every four seconds in the theory that the more information we gained the better the results would be. This decision is discussed further in 'Conclusions' at the end of this section.

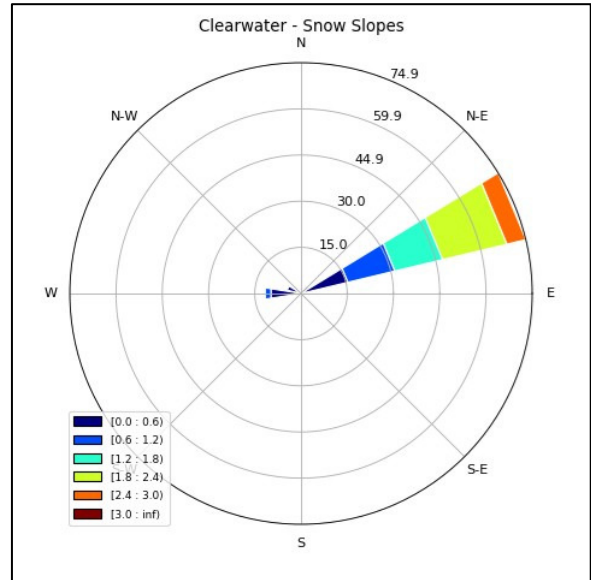
It was decided to use the convention that an outward flow of air was a positive result and an inward flow negative.

Two methods for analysing were devised independently both of which produced the same results, each is discussed below.

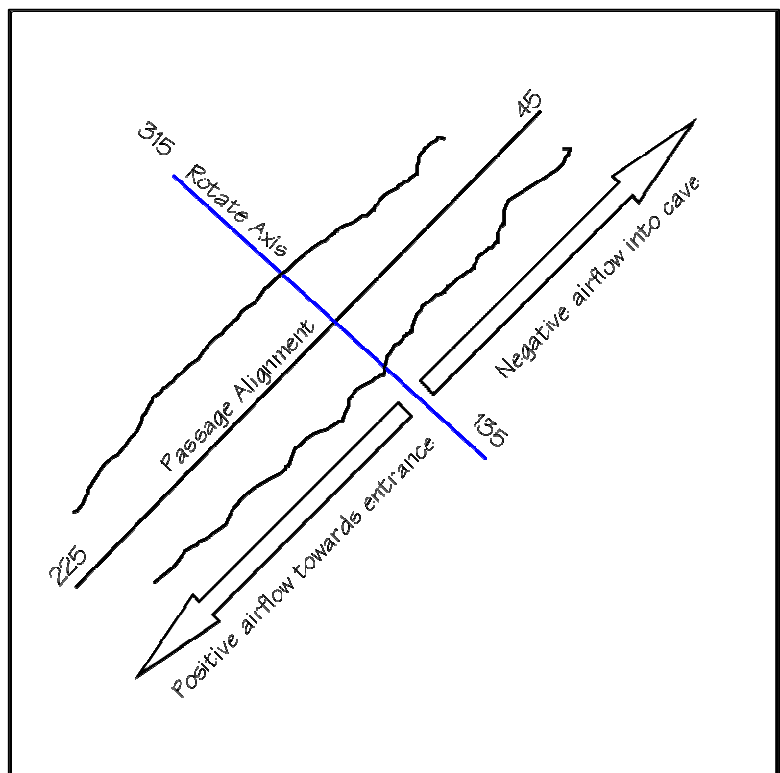
- **Polar Analysis Method:** Using Python software, wind data is plotted in polar form indicating the time spent in each direction and the strength as coloured bars. From this, the dominant draught axis is obvious and the data is projected onto the axis to allow analysis of strength and reversals. This is achieved using the following equation:

$$\text{Projected Wind}(n) = \text{Wind Speed}(n) \times \cos(\text{Bearing} - \text{Draught Axis})$$

The running mean over 1000 samples is also calculated to smooth out fluctuations. This is plotted as an additional line in the projected wind speed plots. This is then plotted against the temperature, humidity and air pressure for both in-cave and surface measurements (where available). The difference between in-cave and surface measurements is also plotted against the wind speed.



- **Passage Alignment Method:** When measuring air flow in a cave passage the important thing to understand is whether the air is moving into the passage or out of it (flows and reversals) and the strength of the recorded flows in each direction. Measuring airflow in a cave passage is significantly different to measuring it in an open air situation. Unless in a massive passage or chamber the passage itself will control the alignment of the airflow, channelling all the results into either one direction or 180° opposite to that with little or no other readings in between; the Polar Analysis method subsequently verified this. With all flows nicely aligned along the passage axis the only question was whether it was an inward or outward air flow.



Knowing the alignment of the passage, a line at 90° to this (i.e. across the passage) provides the base line around which flows and reversals rotate (the rotate axis). Calculating whether each

reading was positive or negative was achieved by using a relatively simple formula in Microsoft Excel. This took the rotate axis and allocated either a +1 or -1 result against each wind speed reading based on the airflow alignment. The formula used is as follows: =IF(AND(D2>\$I\$3,D2<\$J\$3),1,-1) in laymans terms *IF the recorded wind direction is greater than the lower rotate axis value AND less than the higher rotate axis value then allocate a +1 otherwise for all other readings allocate a -1*. In other words assuming passage orientation of 150-330 the rotate axis would be 60-240. If the airflow direction is more than 60° and less than 240° it is allocated a +1 otherwise (for all other readings) it's a -1 (reversible depending on the direction to the entrance). The wind speed for each data point is then multiplied by this value to produce a positive or negative wind speed value.

Unfortunately this method relied on Microsoft Excel which, although it produced the same results as the Polar Method, could not handle the volume of data (logged every four seconds) which the longer multi-day studies produced. For example an Excel graph is limited to 32,000 data rows. The Whiterock study produced 194,400 rows of data. To produce graphs showing the complete period from the Whiterock study required six graphs to be stitched together outside Excel. In this respect the polar method using Python software was the preferred method for producing the charts shown in this report.



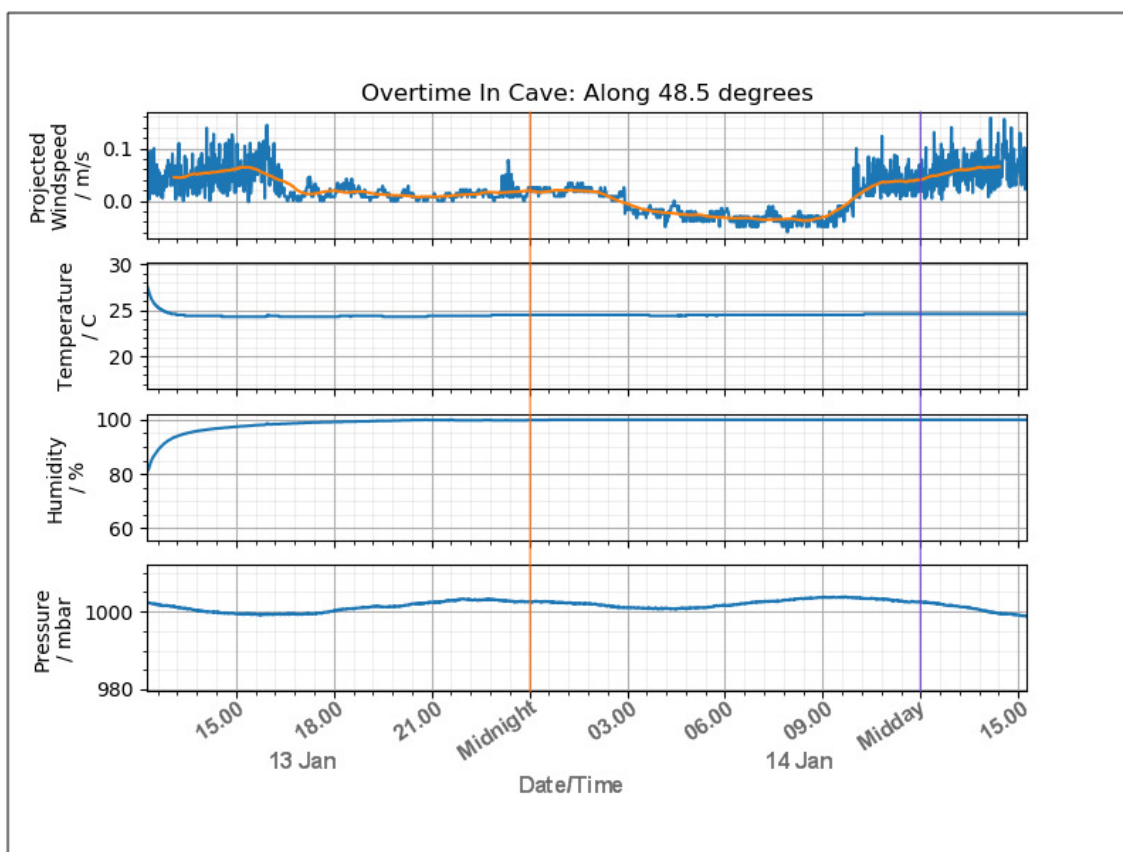
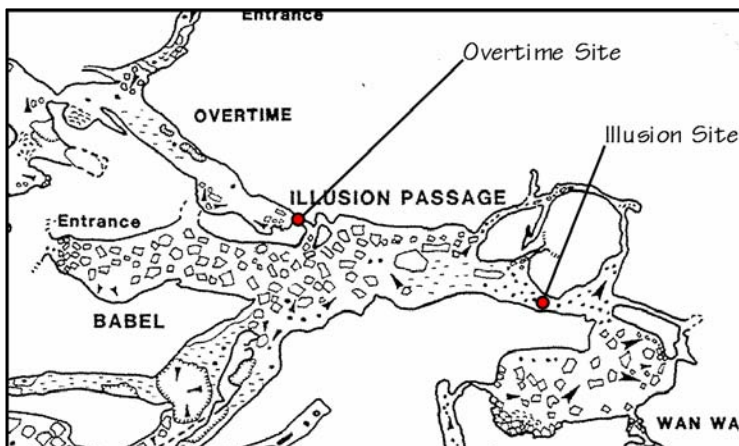
Typical arrangement: Windsonic anemometer, aligned to north, mounted on a lightweight plate and tripod and connected to the W10 Spacelogger via a 3m cable. The UNI-T330C Datalogger is on the mounting plate beside the anemometer and is held in a clip.

Matt Kirby

Results

Overtime, Cave of the Winds

Upon approaching the boulder choke which leads up to Illusion Passage and Babel, Overtime Passage reduces in size to a point where there is a noticeable draught. A single sensor was installed at 10.30 and left to run for 27 hours. A small reversal of air flow was detected between 03.00 and 10.30 the following day. Unfortunately the necessary batteries had not arrived to power the external logger so there was no surface data for either of the Cave of the Winds studies. Underground data is shown.



The internal logger readings indicate an immediate reduction in temperature as the logger cools down from the external to the ambient cave temperature. Following that there is little or no alteration in cave temperature. A slight variation in pressure is noted. The humidity is also seen to rise as the instrument starts to see the internal ambient humidity. This then settles down to a constant value.

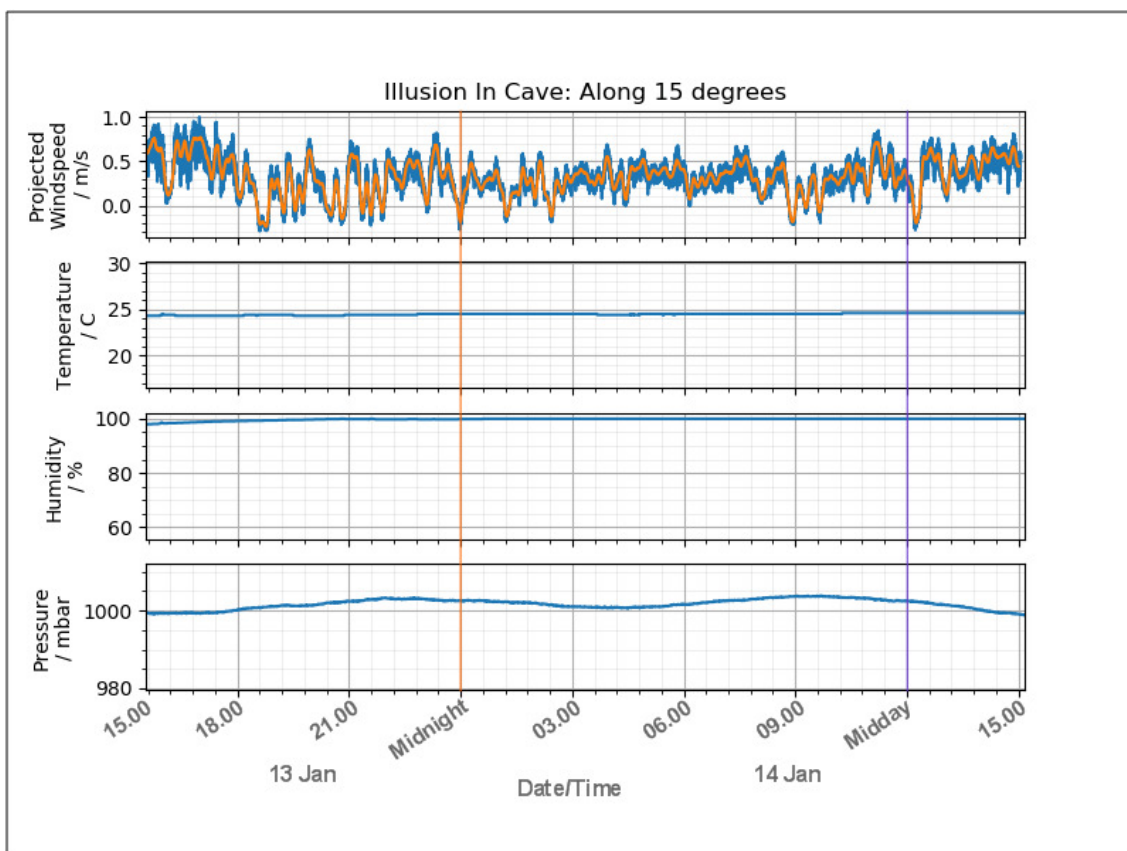
The absence of surface metrics makes the Overtime location difficult to analyse. Nevertheless, a draught reversal is noted between 03.00 and 10.00hrs. And whilst never particularly high, wind speed drops from about 17.00hrs right through to 10.00hrs. With in-cave climate being remarkably

constant, this wind reversal suggests a correlation with falling temperatures outside (overnight) or a change in air pressure, or perhaps both.

Illusion Passage, Cave of the Winds

This site was chosen after the main entrance site was abandoned. A draught had been detected in a narrowing of the passage between Babel and the climb up to the final chamber before Wan Way Street. The logger was installed at 15.00 and left to run for 24 hours. This site is potentially complicated by entrances at the top of Babel and also at the base of Illusion Passage where a small entrance emerges into a doline.

The draught in this location was small and did reveal minor spiked reversals but not the same obvious reversal as had been seen in Overtime. Temperature and humidity readings were almost constant possibly because the instruments had more time to acclimatise before they were set to run. The same pressure fluctuations were noted as in the Overtime study. Underground data is shown.



Although minor reversals of airflow were noted at both Cave of the Winds sites, the time of these reversals did not correlate with each other. The complicated arrangement of entrances and connections in this cave will require further study to better understand the air flow patterns within this section of the cave. Surface climate data must be collected, and the test period also needs to be considerably longer to get a view of regular patterns of draught behaviour or to indicate anomalies.

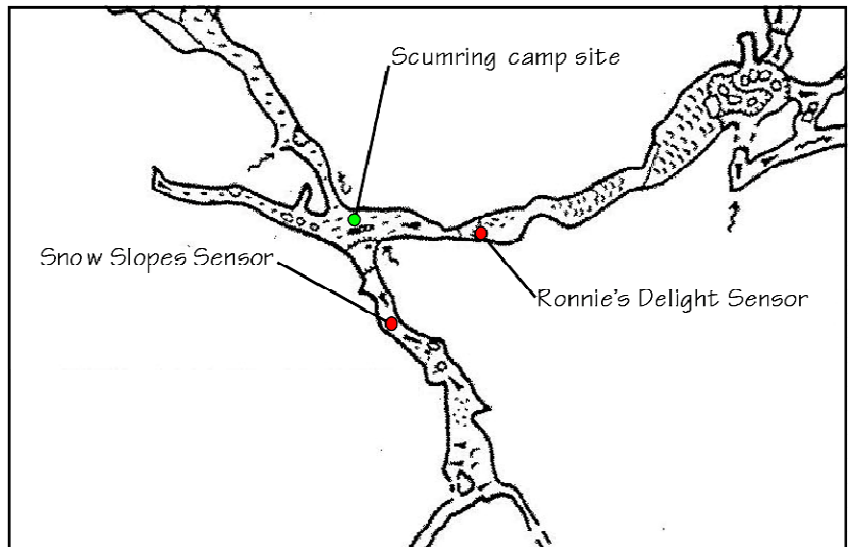
Cave of the Winds Gate

Following the initial trials in Overtime and Illusion a short duration calibration test was carried out adjacent to the gateway in the Cave of the Winds Show Cave. The two anemometers were set up next to each other to check they were returning the same readings. The results indicated that the instruments were calibrated correctly.

The Snow Slopes, Clearwater Cave

Since their discovery in 1989 the Snow Slopes above Scumring bivouac site have been known to support one of the most impressive draughts in Mulu. This was an obvious site for an air flow study.

With passage dimensions of 8m wide by 5m high and with a maximum air flow of 2.5m/s this represents 100m³ of air passing the site every second. The origins of this draught are believed to be the overlying Creedence Series via Downdraft Passage, although some component of the draught may originate from the Armistice Series.



Setting up the instruments in the Snow Slopes passage

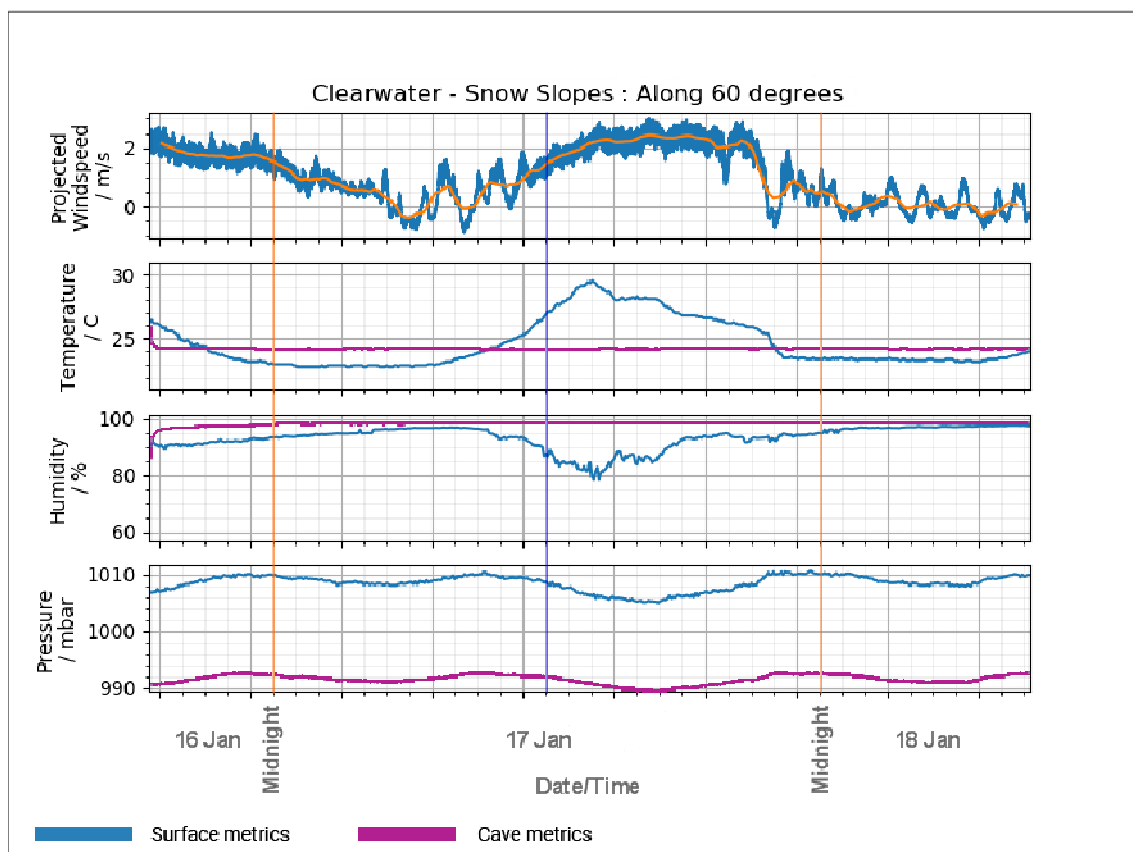
Matt Kirby

The test period was 40hrs long - once again not long enough to establish true pattern behaviour of the draught. But the results here clearly show a marked increase in wind speed as outside temperature rises during the daytime. Outside humidity correspondingly falls, presumably as the sun

‘burns off’ air moisture. Pressure also takes a dip as temperature increases. Peak wind speed is reached a couple of hours after peak surface temperature, probably around 4pm in this instance.

On the night of 16th Jan, wind speed can be seen dropping steadily, much in line with falling evening and night temperatures outside. On the night of the 17th Jan, however, the wind speed falls very steeply in a short period and then takes on a ‘spiked’ pattern of wind reversals for almost 12 hours. This end of the graph corresponds to the time of the flash flood at Scumring camp, so may be an anomaly to normal behaviour.

A 3-4 day test should ideally be conducted at this (and Ronnie’s Delight) site to establish a clear pattern of wind behaviour. Scumring is an ideal and comfortable camp from which to run these experiments.

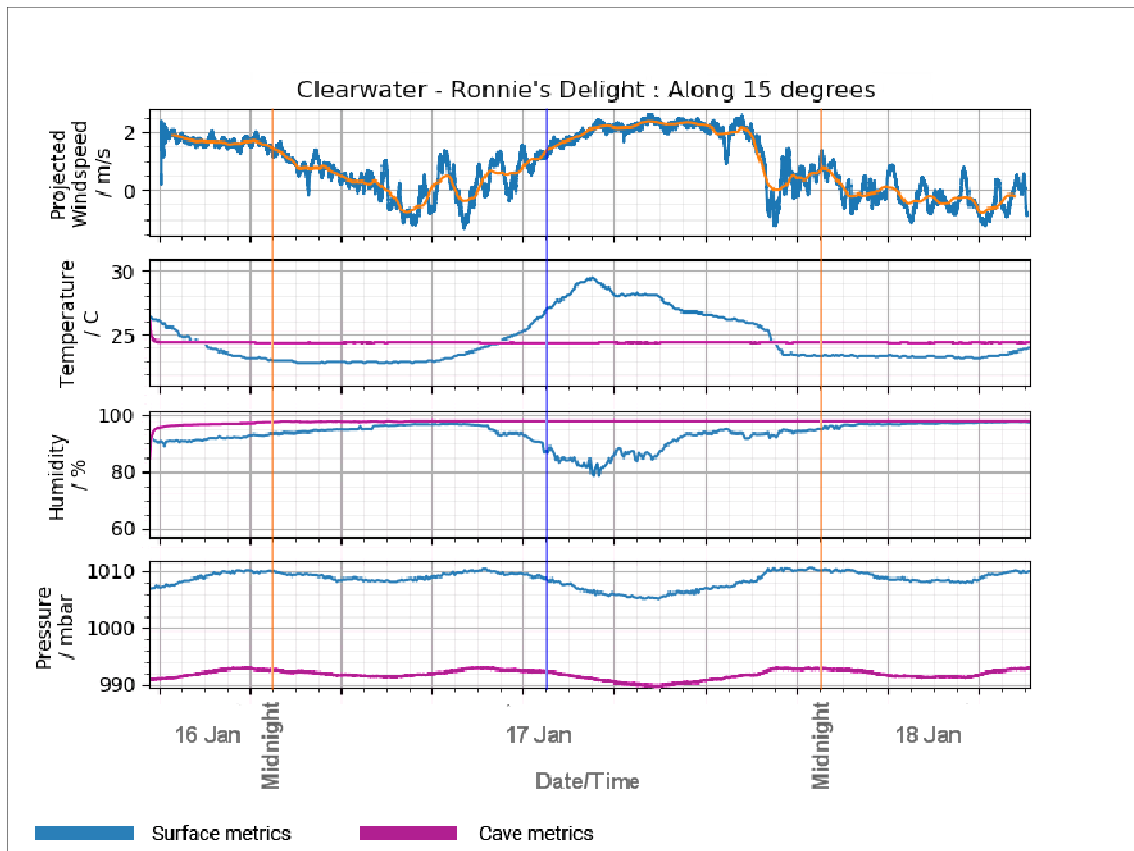


Ronnie’s Delight, Clearwater Cave

The passage leading to Ronnie’s Delight has been known to support a strong draught since its discovery in 1980. On one occasion a group arrived at the Scumring site and started to make camp but upon laying their sleep mats on the ground they were immediately blown away owing to the strong draught emitting from the passage. Later that evening the draught died down and since then a draught of this strength has never been witnessed at this site, although there is regularly a respectable draught.

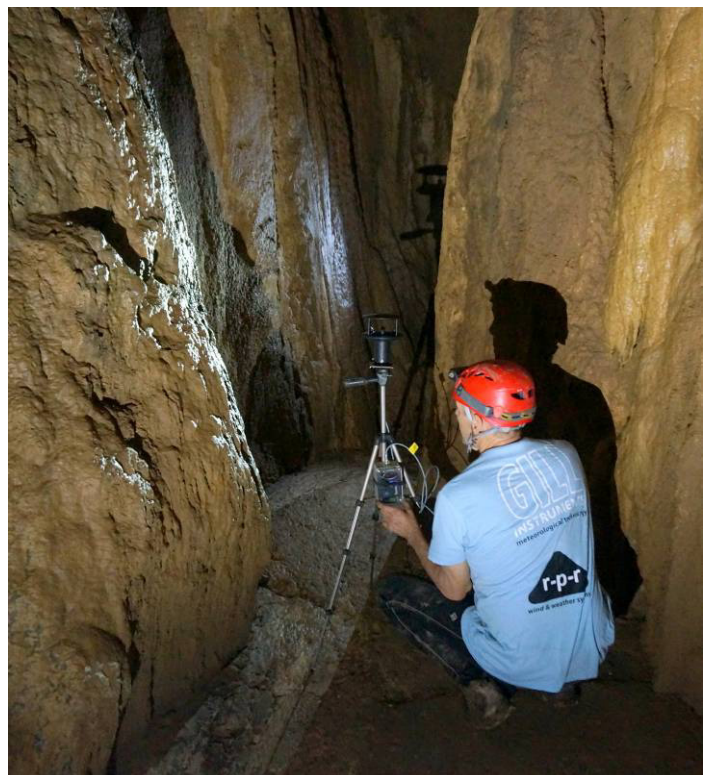
A single wind sensor was set up in the narrow section of passage immediately above the flowstone cascade above the camp site. At the time this passage was dry, in fact it had never been seen to carry any water before. The following night, at around 20.00, a large storm event occurred which caused inlets to start running around Scumring camp. The normally dry flowstone cascade to the north of the camp site became a roaring waterfall the source of which was via a waterspout above the top of

the cascade. The sensor was dry but its tripod was standing in approximately 10cms of water. A second inlet was cascading in just past the sensor. The equipment was left to run throughout the event with no damage occurring. At the same time water was cascading down the snow slopes and the tripod there was standing in flowing water.



The graph for Ronnie's Delight is remarkably similar to that of the Snow Slopes - indeed, we had to check we weren't mistakenly using the same graph for both! Again there is a marked rise in wind speed with air blowing out of the cave (i.e. towards the Volcano and Revival) as the outside temperature rises, and corresponding decline in speed, and even wind reversal, as outside temperature falls.

The results from the Snow Slopes and Ronnie's Delight are very interesting. These passages appear to channel vast quantities of air from deeper or higher inside the cave. Although similar wind speeds were recorded at each site, the cross sectional areas are vastly different. The Snow slopes are approximately 8m wide by 4m high and support a flow rate of 100m³/s whereas Ronnie's Delight at 1m wide by 3m high is supporting a flow rate of 6m³/s.



Setting up instruments in Ronnies Delight

Ben Kent

It is likely that the air arriving at both sites is derived from the extensive overlying Creedence Series. But in the case of the Snow Slopes it is possible that a portion of the air is coming from the Armistice passages. Further studies are required here to determine the source of the air at this location. Loggers would be placed before the connection up into Creedence, and then further up the passage towards Armistice beyond the Creedence connection.

Whiterock Midnight Entrance

As discussed previously, the Midnight Entrance was chosen in preference to the original entrance as it was known to host a reasonable draught. On arrival at the entrance the team were surprised to find that rather than emitting a cooling draught the air was being drawn into the cave as a negative air flow. The instruments were set up in the narrow calcite constriction 50m from the entrance portal and left to run for five days. Upon retrieval it was apparent that a swift had collided with the instrument as there were feathers on the cowl.



This test of 5 days was much longer in duration than the Clearwater experiments, and the benefits were a much better 'cyclical' view of draught behaviour and climatics. The results show a clear correlation between wind speed, wind direction and surface temperature. But unlike with the Snow Slopes example, increasing surface temperature caused air to be drawn into the Midnight Entrance

rather than exhaled. This was unexpected; as per the Snow Slopes, we assumed air would be expelled from the cave as the outside temperature rose.

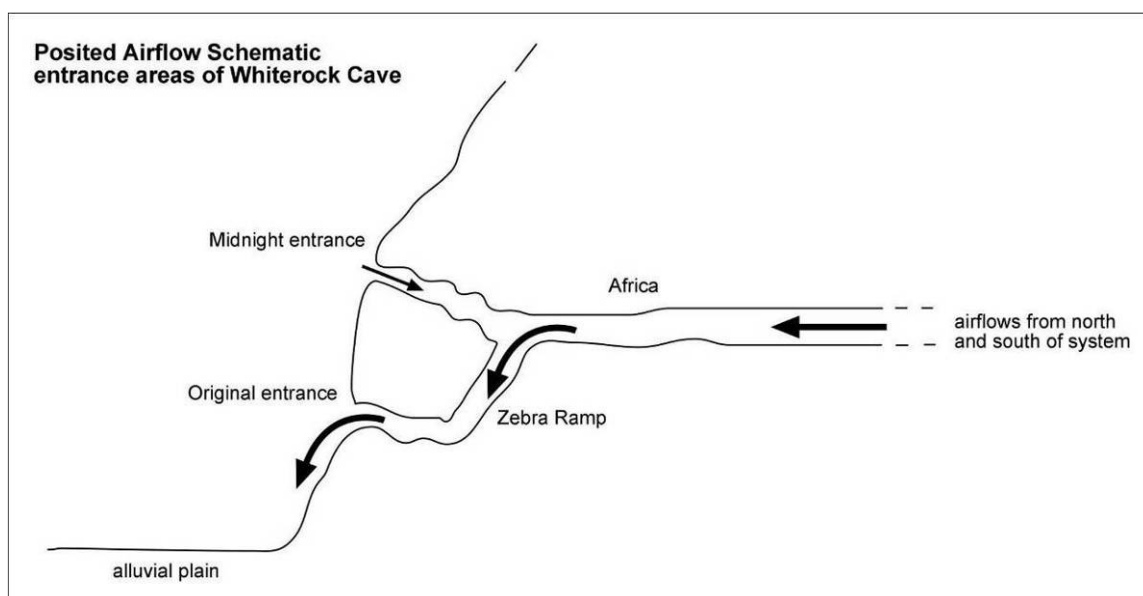
A possible answer to this behaviour was worked out after taking anecdotal wind measurements (Extech hot-wire anemometer) further into the cave. The draught at the constriction in the Midnight Entrance, whether in or out, was generally quite low, with a mean wind speed below 1m/sec. In parts of Africa, however, wind speeds of 0.5m/sec to 0.9m/sec were measured, often in much larger passages with a cross-section of 50-150sq.m. This is vast volumes of air, incomparable with the volume at the Midnight Entrance. But most significantly the wind direction in these locations was outwards...while the Midnight Entrance was blowing in.



Setting up the instruments in the Midnight entrance
Frank Pearson

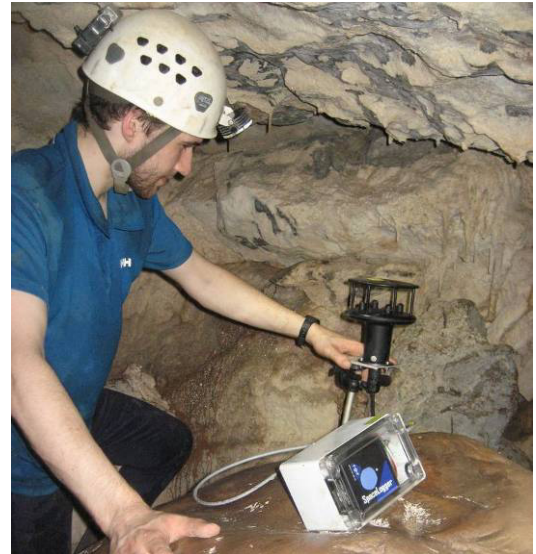
The explanation seemed to be that as outside temperatures rose, cave air was indeed trying to flow out of the cave. But being colder, denser air it had a natural propensity to fall downslope – thus it would flow to the lowest levels of the cave where possible, via ramps known or unknown. An obvious example is the Zebra Ramp between Africa and the Midnight Entrance, which connects directly into ‘old’ Whiterock and the original entrance. Our theory is that exiting air falls downslope when it reaches the Zebra Ramp (there are many other pits and ramps in the vicinity, too), from thence to be pushed out of the original entrance. This steep ‘airfall’ acts like a venturi pump effect, drawing air IN from a higher entrance, the Midnight Entrance.

As well as a longer period of testing at the Midnight Entrance, the next study should place a second anemometer in the Original Entrance to test whether the above theory is correct.

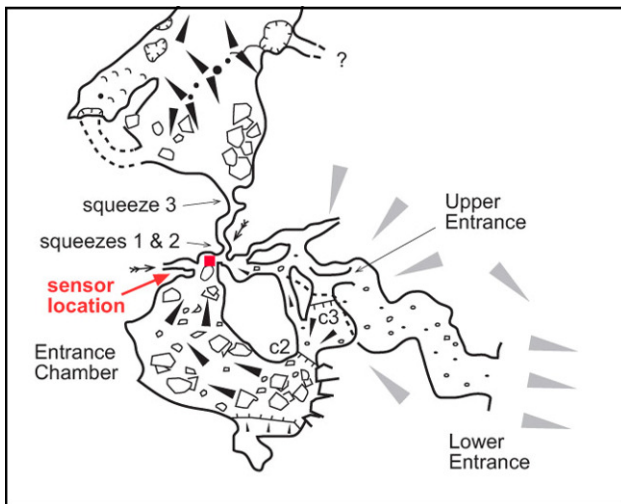


No Country for Old Men (Parang Cave)

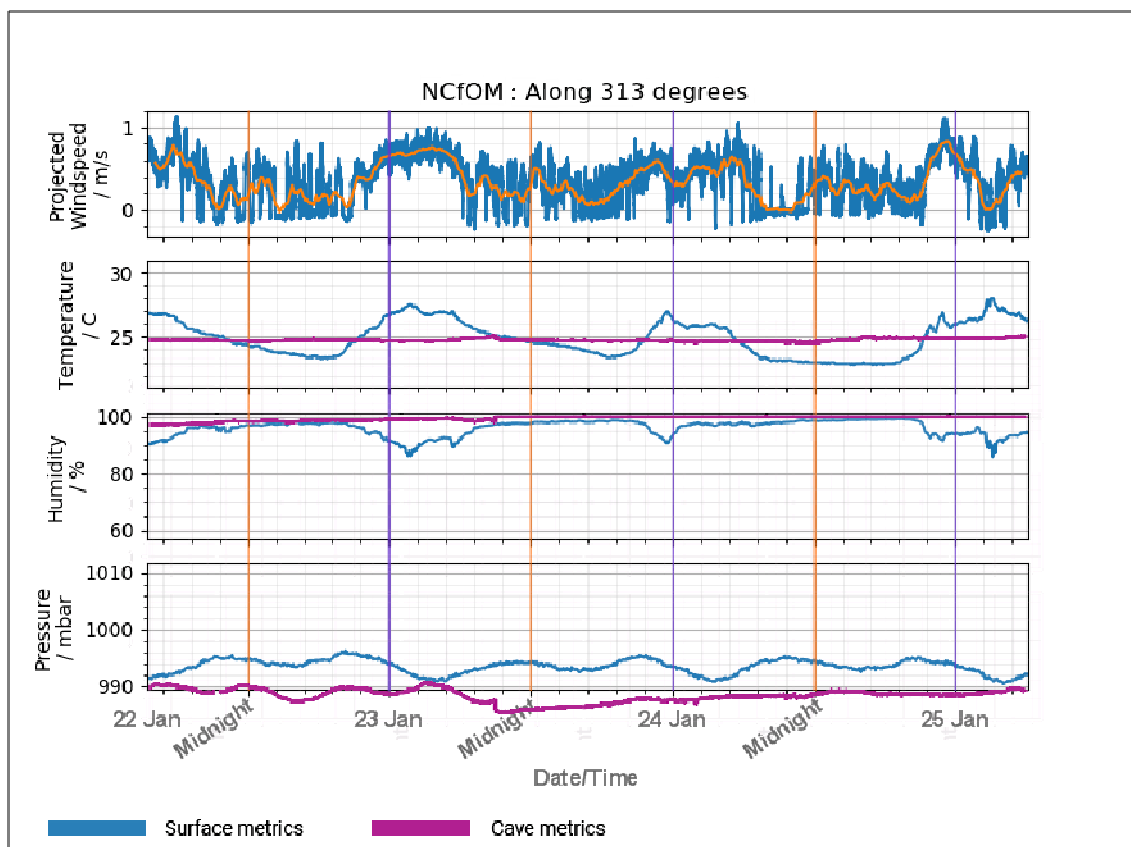
No Country for Old Men is situated in the cliffs to the south east of Camp 5. It is a cave known to draught and is at approximately the same horizon as the Northern Line in Whiterock Cave. The entrance series is notoriously tight with five serious squeezes which channel a respectable draught. A Windsonic anemometer was installed in the boulder chamber just outside the first squeeze. Owing to the constricted nature of the squeeze it was not possible to install the instrument in the squeeze itself. The instrument was left to run for five days. Unfortunately it was found that the batteries had expired after only three days. Nevertheless useful data was collected.



Instruments in No Country for Old Men



This cave supports a healthy draught but the volume of air moving is probably small because the draught is really only noticed in the tight squeezes which channel its flow. The sample site sees draughts which emit from the entrance squeeze and also a small tube in the floor of the chamber where the instruments were situated. These combined flows then exit the cave normally via the lower entrance.



Results from this trial showed this site was the only location where no reversal of air flow was recorded. However, there are times when the flow dies down significantly. Also the wind speed generally increased with the rise in outside temperature, tending to peak in mid afternoon. This corresponds with airflow behaviour at both the Midnight Entrance and the two Scumring sites, albeit Midnight Entrance being an inward flow (as explained above.) Previous trips into this cave have attempted to find the source of the draught but the study would suggest that there is an optimum time of day to be looking. Perhaps previous exploration was carried out when the draughts were at a minimum. It may be useful to place the logger at each of the squeezes to better understand the source of the air flow. Not an insignificant task as the first two squeezes are only for the slimmer caver. Further work is required in this cave to better understand the airflow.

Other Data

Whilst the main data was collected using the Windsonic instruments, an EXTECH Hot Wire Thermo-Anemometer was used to take spot readings. This instrument was used when the Windsonic device was set to run as a general check and at other sites.



ExTech Hot Wire Thermo-Anemometer reading in the Africa passage

The sites recorded were as follows:

1. **Whiterock Entrance**, same location as main device:
wind speed: 0.2-0.3 m/s
temp: 23°C
direction: IN
est. x-section area: 7.5sq.m
2. **Africa**, just before Dancing Queen
wind speed: 0.5-0.9 m/s
temp: 23.0°C
direction: OUT
est. x-section area: 60sq.m

3. **Out of Africa**, top of scree slope opposite Dr.Disto ramp
 wind speed: 0.2-0.3 m/s
 temp: 23.5°C
 direction: OUT
 est. x-section area: 150sq.m
4. **Daydream Believer**, on corner just beyond the big stals
 wind speed: less than 0.1 m/s (below instrument threshold but felt on face)
 temp: 23.5°C
 direction: OUT
 est. x-section area: 250sq.m

Conclusions/Lessons Learnt

Whilst the airflow studies revealed some interesting results there were a number of lessons learnt which should be observed to streamline future tests:

- Although the sampling rate for the Windsonic instruments was considered at an early stage the decision to sample at four second intervals was not necessarily the right way forward. This produced an enormous amount of data which proved difficult to handle. Although Excel spreadsheets are an easy way to interpret the results (paste the raw data in and get an instant graph) Excel graphs can only handle 32,000 rows of data. The Whiterock study produced 194,400 rows of data. It may be better to set the sample frequency to either thirty seconds or one minute intervals. It would be advantageous to carry out some trials in the UK, before returning to Mulu, to determine the best frequency.
- At the time loggers were set to run the necessary information was recorded on a mobile phone as a note. Although this did work some information was missed and in future, to overcome this, it would be better to have a standard tick/prompt sheet to ensure all the necessary information is gathered. An example of the required information is shown below.

Date installed	15-Jan-18
Person installing	HSL
Cave	Clearwater
Location in cave	Snow Slopes
Passage cross section (width/height)	5x4
Wind sensor ID	1
Set to North?	Yes
Passage orientation	60
Pressure sensor ID	2
Time installed	18.00
Draught direction at time installed (in/out)	Out
Date off	19-Jan-18
Time off	12.54
Draught direction at time off (in/out)	Out
Comments	Evidence of collision by swift

- The batteries used to power the Windsonic instruments also powered the associated loggers. On two occasions we found that the batteries had expired before the instruments were retrieved. In future it may be worth beefing up the power supplies to allow longer record periods, potentially up to one week at a time.

- Synchronisation of clocks throughout the various instruments is all important. When bringing instruments from the UK to Mulu it is important to set all the clocks to the local time. It is also important to ensure the dates on each instrument read the same.
- Each piece of kit should be clearly referenced with an ID number and this should be noted at the time of placement so that any problems can be tracked down to the particular instrument which took the readings.
- It is important to record accurate passage cross sections to allow volumetric measurements to be calculated. With only a velocity and no cross sectional area it is impossible to say what volume of air was passing the sample site.

The airflow study revealed conclusively that draughts can reverse and that there is an optimum time when they are at their peak. In this respect it is important that when surveyors detail a draught in their notes they also record the direction and the time of day. This could have significant implications for future explorers looking for the same draught. It is equally important to note time and direction of draughts when exploring entrances on the surface; there is no point returning to a site expecting to find a massive draught if it only blows at a certain time of day.

In the vastness of Mulu the placing and retrieving of instruments can take a considerable time. A return trip to Scumring takes a day, and trials deeper into the caves could require an overnight camp.

This expedition used the run-time of the instruments in which to carry out other exploration and surveying so as to minimise the trips in and out of the caves and maximise the productivity of the expedition. Future expeditions should plan to combine airflow studies with other work to make the most efficient use of their time.

Can we predict anything?

From a scientific viewpoint, no. We shouldn't really draw conclusions from first time trials with varying test periods and methodology teething problems. But as cavers it's hard to resist having a go!

Early indications suggest that airflow increases with rising outside temperatures, and airflow direction is generally outwards with that same rise. Outflow speeds, and thus airflow volume, appear to peak at roughly mid to late afternoon.

It's very early days to be recommending anything. But it possibly suggests that mid to late afternoon is a good time to be looking for entrances in the forest - and that certainly fits with the time Whiterock was discovered! It could also suggest that if a cave is found at that time of day but with an inward draught, it may still be worth pursuing – it could be an upper entrance to a system.

That's a very wobbly yardstick at the moment, and much more work needs to be done if any reliable airflow model is to be put forward.

Aims

Discovering new cave entrances on the footslopes of Api and Benarat is hard work and demands significant commitment. Over the years the only way to locate new entrances was to put feet on the ground and search for the telltale signs of an entrance, draughts, smells of guano, swift/bat activity etc. To date many cave entrances have been found in this manner. Within the Melinau Gorge some entrances were obvious, such as Upper and Lower Tiger Caves and Hole of the Moon Cave, but many more have required hard work to locate them. Moon Cave for example was only found when a team were attempting to bolt 350m up to the obvious entrance of Hole of the Moon. Moon Cave was found after 48m of climbing, hidden behind foliage which grew over its entrance.



Looking into Hole of the Moon Cave, 358m above the heli pad

Matt Kirby

On the Api side of the gorge extensive tree cover has prevented entrances being seen from the ground or from helicopter fly-bys, and where hints of entrances have been seen behind trees these have turned out to be alcoves or dark shadows. Now with the advent of the camera drone we have new technology which can obtain close-up images of possible entrance sites without the need to climb or put feet on the ground.

The expedition had seen images from a camera fly-by which indicated a possible entrance in the approximate position of Whiterock's 1954 Passages - could this be a way into the system from the gorge? This site was close to Camp 5 and could provide relatively easy access to the northern extremities of the Clearwater System. Further up slope on the Api side, other sites were of interest such as Canopy Cave which could be clearly seen from a helicopter. Various attempts to enter this feature had been unsuccessful owing to the remoteness of the site and large sediment banks which guard the entrance. Was this a cave or another massive alcove?

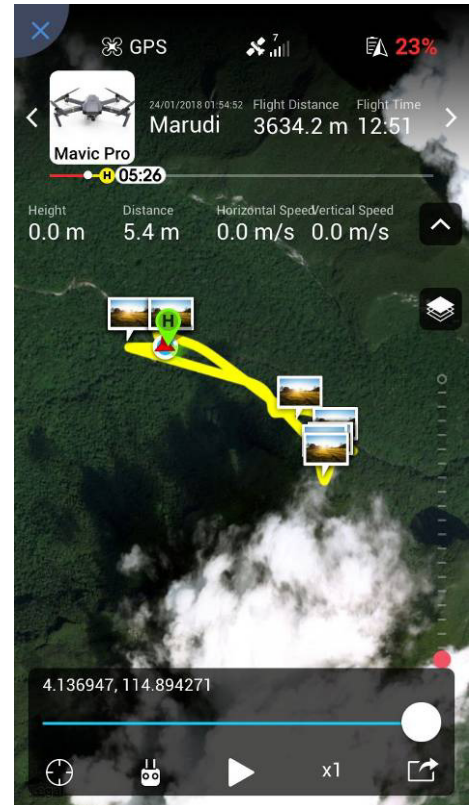
On the Benarat side another large entrance feature had almost been accessed during 2015 but steep slopes and loose rock prevented the explorers reaching the portal. Could a drone look into this?

Equipment & Software

The expedition took a DJI Mavic Pro drone (quadcopter) to Mulu. The advantages of this drone is that it is foldable and lightweight making it very easy to transport. It has a very good power to weight ratio which provides longer flight times compared with other drones. The DJI GO4 software records flight paths and provides latitude-longitude reference data which can be used to pinpoint entrance sites.



DJI Mavic Pro & Controller with iPhone



Flight record

On start up the drone uses its GPS receiver to establish its geographical Home Point (the point which it is launched from). Communication between the drone and the hand controller during the flight is essential for control of the aircraft. In the event of loss of signal the drone will initiate a 'return to home' and would take a direct route back to its home point where it would land autonomously. In order to avoid tall objects during a return to home it is possible to pre-programme a return to home altitude (normally this would be to avoid buildings or trees). This ensures that if the drone loses communication it will climb to a pre-set altitude before returning to home.

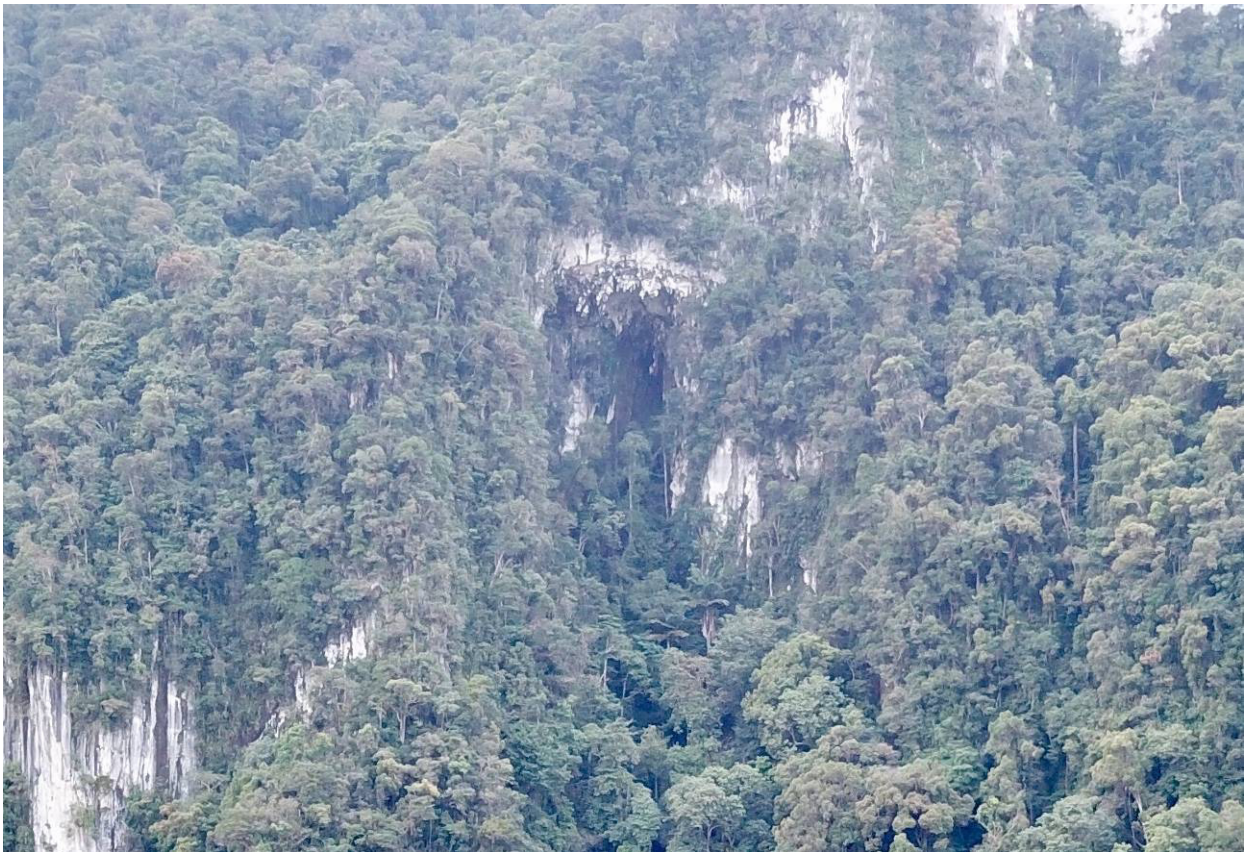
The Mavic Pro establishes fixes with global positioning satellites and a minimum of 10 satellites are required to allow the aircraft to fly when in GPS mode. The heli pad opposite Camp 5 provides an ideal site from which to launch a drone. Not only does it provide a good flat surface with no tree cover but it is the only site which allows a good line of sight up the gorge which maximises the communication range between the drone and the controller. The only downside of this site is the proliferation of sand flies at all times of day which snap at any exposed ankles or flesh which care to stand around on the tarmac.

Results

On Api

- **Canopy Cave**

One existing 'entrance' which has eluded explorers for many years is known as Canopy Cave. There has always been some doubt whether it is in fact a cave entrance or simply an alcove of rock and many expeditions have tried unsuccessfully to gain access to this prominent feature. Flying a drone close to this entrance was always going to be challenging.



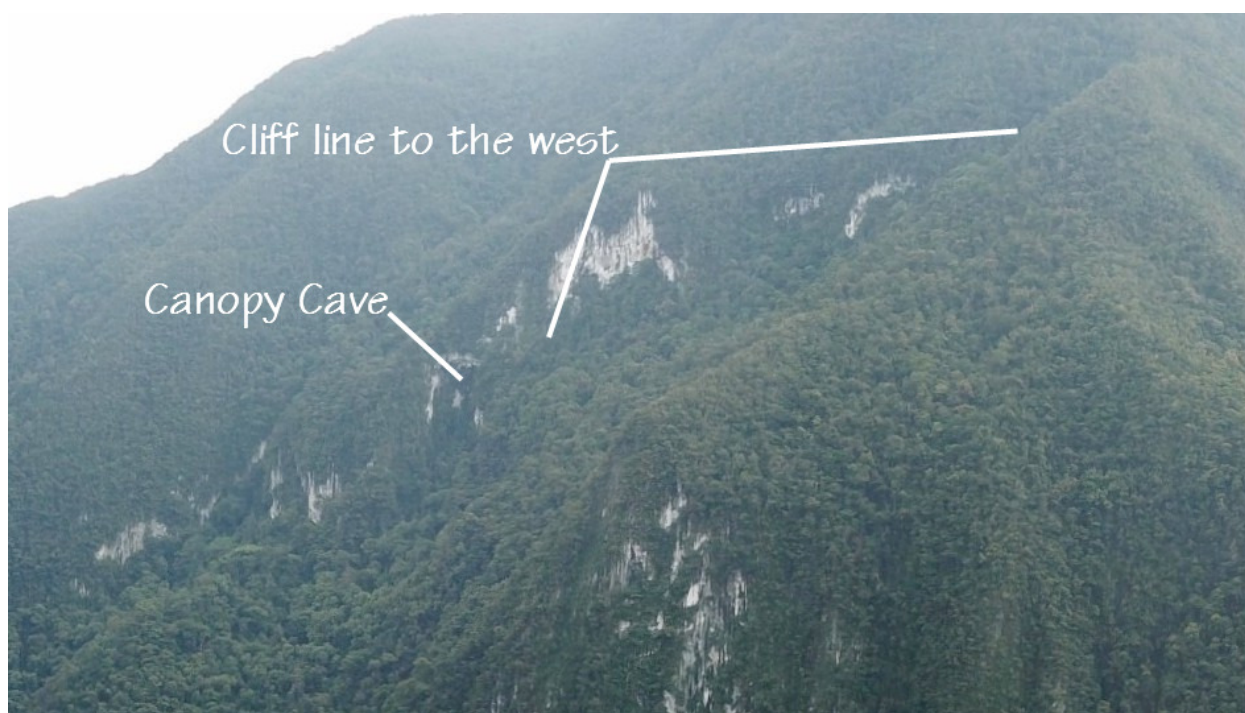
Canopy Cave seen from approximately 450m distance

Matt Kirby

The drone was flown from the heli pad at Camp 5, although this site gives a good line of sight along the gorge, Canopy Cave entrance is not visible from here so the risk of loss of communication with the drone was a high possibility. It was known that if communication was lost, the drone would initiate a 'return to home' and fly in a direct line to its launch point, but this route crosses a high ridge so there was a possibility of a collision on the return route. Setting a return to home altitude to climb over this feature was considered, but without knowing the precise altitude to set, such a strategy would be very risky. In addition, in order to see into the entrance it was necessary to climb to an altitude of 470m which put a considerable demand on the battery. If the drone was then programmed to go even higher to enable it to return to home safely there would be a chance that the battery would expire before it made it back to base. After much consideration it was decided that a close inspection of the entrance was not possible. A future expedition may consider flying from the Benarat Caverns area if a suitable launch point can be found.

- **Cliffs to the west of Canopy Cave**

A line of cliffs lies to the west of Canopy Cave between it and the Pinnacles track ridge. This is in ground which would be very difficult to access on foot. These cliffs are at an even greater altitude than Canopy Cave. This presented two problems, firstly the potential for loss of signal, and secondly the available battery power to gain sufficient altitude to access the various sites. Once again the risk of signal loss was considered high, so close inspection was not possible although a clear view was obtained from the Benarat side of the gorge. Future flights could potentially be made from the ridge leading up to the Pinnacles if a suitable launch site can be found.

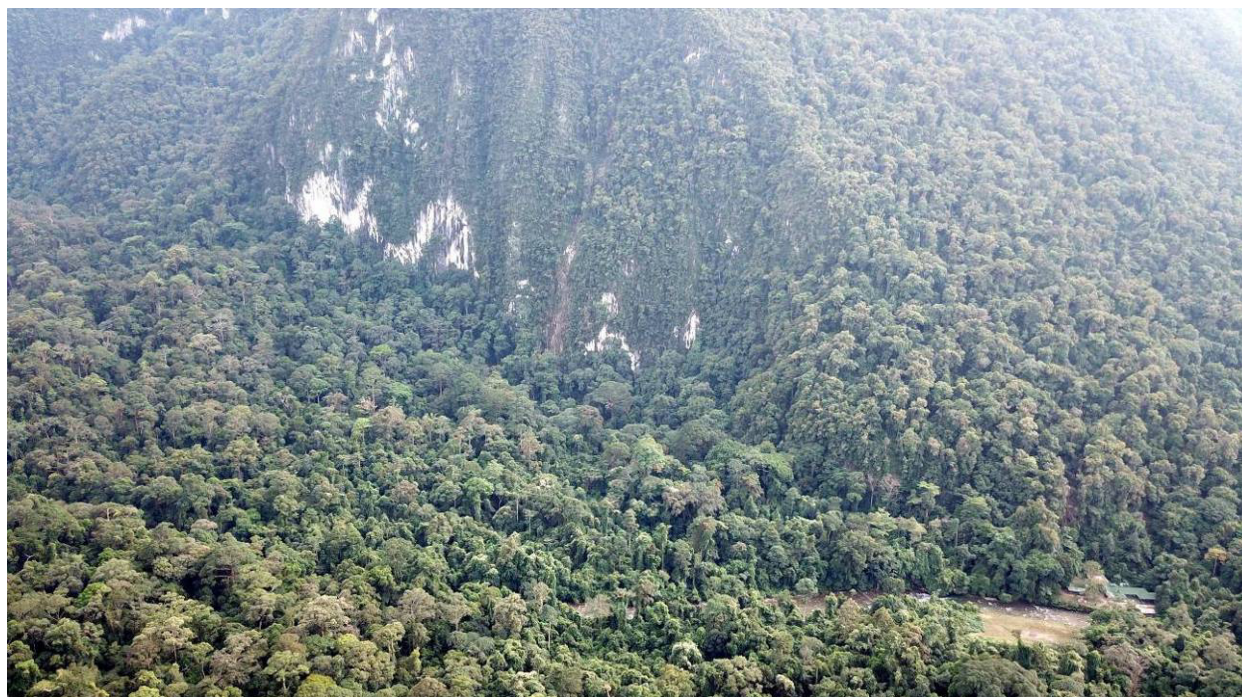


Cliffs to the west of Canopy Cave, leading up to the Pinnacles ridge

Matt Kirby

- **Cliffs to the rear of Camp 5**

The northerly trending passages of Whiterock Cave all end in calcite blockages extremely close to the cliffs behind Camp 5. Unlike the Benarat cliffs, where entrances are obvious against the white limestone face, on the Api side of the gorge the slopes are heavily vegetated and it has so far been difficult to find entrances which may connect into the Whiterock system.

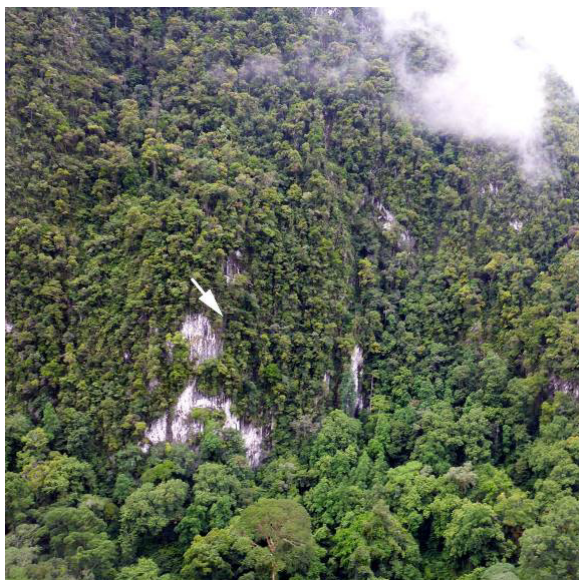


Cliffs to the rear of Camp 5

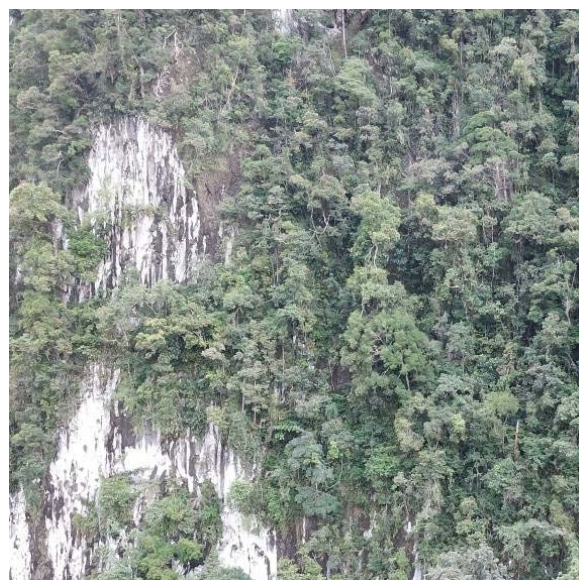
Matt Kirby

Some photographs taken during helicopter fly-bys have hinted at entrances behind the trees but it has been uncertain whether these are indeed cave entrances or just shadows. The use of a camera drone to gain close up images has been seen as essential to determine whether the dark shadows

are cave entrances which require further investigation by climbing. One such site had been identified, appearing as a dark area behind trees. Unfortunately, close up photography of the site did not reveal any new entrances, indeed various fly pasts did not reveal anything of interest in this area.



Dark Shadow site seen from Heli flight



Drone's eye view of the same site **Matt Kirby**

On Benarat

Various missions were flown past the Benarat cliffs which provided fine views into the high entrances of Upper Tiger Cave and Hole of the Moon.

Two possible new entrance sites had been identified using binoculars from Camp 5 (Sites 1 & 2). The drone confirmed that these do appear to be cave entrances, although approximately 340m above the heli pad.



Composite view of Benarat Cliffs showing key features

Matt Kirby

The two sites were visited on the same fifteen minute, mission on 25th January with both still and movie footage obtained. Latitude/longitude information was recorded from flight data for each site.

This proved the value of the camera drone in investigating difficult-to-reach sites with relative ease without the need for ropes, climbing gear or helicopters. Whether these two sites will ever be investigated further is up to the determination of future explorers.

- **Site 1: entrance to the east of Melinau View Cave**

Approx lat/long ref: 4.137432, 114.903793, at 353m above the heli pad.

This feature appears as an elongated sloping entrance which is towards the top of the cliff. Video footage confirms this to be a very interesting site which has potential for exploration.



- **Site 2: entrance on eastern prow of main cliff, east of Melinau View Cave**

Approx lat/long ref: 4.136911, 114.903819, at 320m above the heli pad

This feature is partly shrouded by tree cover and it was not possible to see clearly into the entrance. However, video footage does confirm that this is an entrance or at the very least a deep alcove.



Other views

Various other photographs were taken which give a new perspective on the area:



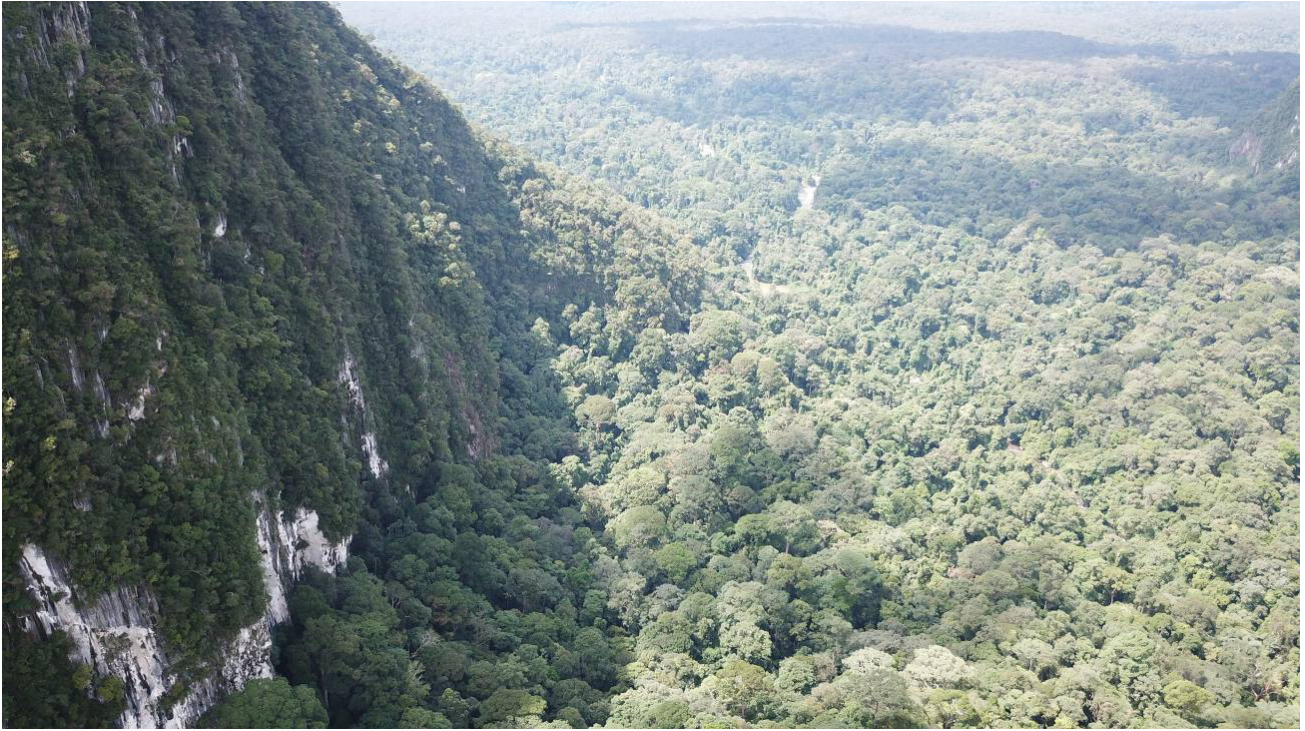
Above the clouds looking east up the Melinau Gorge

Matt Kirby



Camp 5 and the Heli Pad with the new bridge to the right

Matt Kirby



Looking west along the complicated ground behind Camp 5

Matt Kirby



Camp 5 with white cliff above Whiterock and Bukit Berar in the distance, as seen from Benarat cliffs area MK

Conclusions and Recommendations

The camera drone is undoubtedly a fantastic tool in the arsenal of the cave explorer. In basic use drones can take pretty pictures, but they come into their own when it comes to accessing difficult-to-reach sites. In only fifteen minutes two potential sites were confirmed as entrances, a task which would previously have required considerable planning, some serious climbing, lots of hardware and a certain health and safety risk.

To comply with regulations permission is required from Sarawak Forestry for any drone operations within the National Park. A permit was granted in advance of the expedition and was taken into the field.

The terrain of the Melinau Gorge and Mulu in general does not leave any room for error, it is a challenging environment in which to fly a drone. With steep slopes and vertical/overhanging cliffs the risk of loss of GPS signal and collision with the ground is ever present. The deeply forested nature of the area would almost certainly render any crashed drone lost for ever.

Under normal circumstances drone operators normally observe the Drone Code when planning missions; never fly above 120m above ground level or greater than 500m from the pilot, keep the drone in view at all times. But flying in the Melinau Gorge is far from normal.

The gorge is approximately 3.5km outside the Mulu airport Control Zone (CTR) but within the extended higher level Control Area (CTA). However, the risk of interfering with commercial flight operations to or from Mulu airport, when flying at relatively low levels within the confines of the gorge, was seen to be so low as to be not worth considering. If a commercial aircraft was in the gorge then there would be something very, very wrong. However, there is always the unexpected, a light aircraft or a helicopter passing through, but these are normally relatively slow moving, easy to see and can be heard long before they arrive so evasive action can be taken. The drone pilot must be aware of their surroundings and be prepared for the unexpected at all times. For future missions it is certainly worth considering the use of a spotter or assistant to keep an eye on the airspace whilst the operator concentrates on the drone.

In order to access cave entrances within the gorge the normal rule of 120m maximum altitude must be exceeded. With cliffs towering to over 500m, and higher entrances at least 350m above the heli pad, to gain access to remote sites the '500m or within visible range' rule must also be exceeded. As there is no risk to persons or property on the ground when flying beyond visual line of sight the only risk is the loss of the drone, which was accepted as a possibility. Each mission was considered on a risk based principal. Flights up to the Benarat Cliffs were relatively low risk and straightforward as the drone was visible. Flying to and from the Canopy Cave area was a higher risk due to the distance and the altitude required. The flight relied on the pilot being in full communication with the drone so that the camera view could be used to orientate the flight. The software does display the orientation but this is not easy to view in strong sunlight on a small iPhone screen. The important consideration for the Canopy Cave mission was to maintain communications at all times to ensure the drone did not enter a return-to-home mode.

Flying in the Yorkshire Dales one can normally expect to lock onto 17 to 19 satellites very quickly to establish an excellent GPS fix. Unfortunately the vertical nature of the Melinau Gorge reduces the availability of satellites and it was found that establishment of an adequate GPS lock took longer to establish than normal. On three occasions there were insufficient satellites available to allow the drone to fly, it rose to 4.3m and refused to go any higher. On other occasions the drone took off with less than 10 satellites only establishing a better lock with altitude. During twelve successful missions the maximum recorded satellites was 14. It must always be considered as a risk that the drone could lose a significant number of satellites during a flight if, for example, it is flown close to a cliff. Without knowing precisely where it is the drone may struggle to return to home in the event of loss of comms with the controller.

Suitable launch sites are in short supply in the gorge. The heli pad is ideal in that it provides a flat surface but also good views all round. Although it may be possible to take off and land from a much

smaller site, the surrounding trees would restrict the line of sight and radio communications with the drone with the risk of a premature return to home situation.

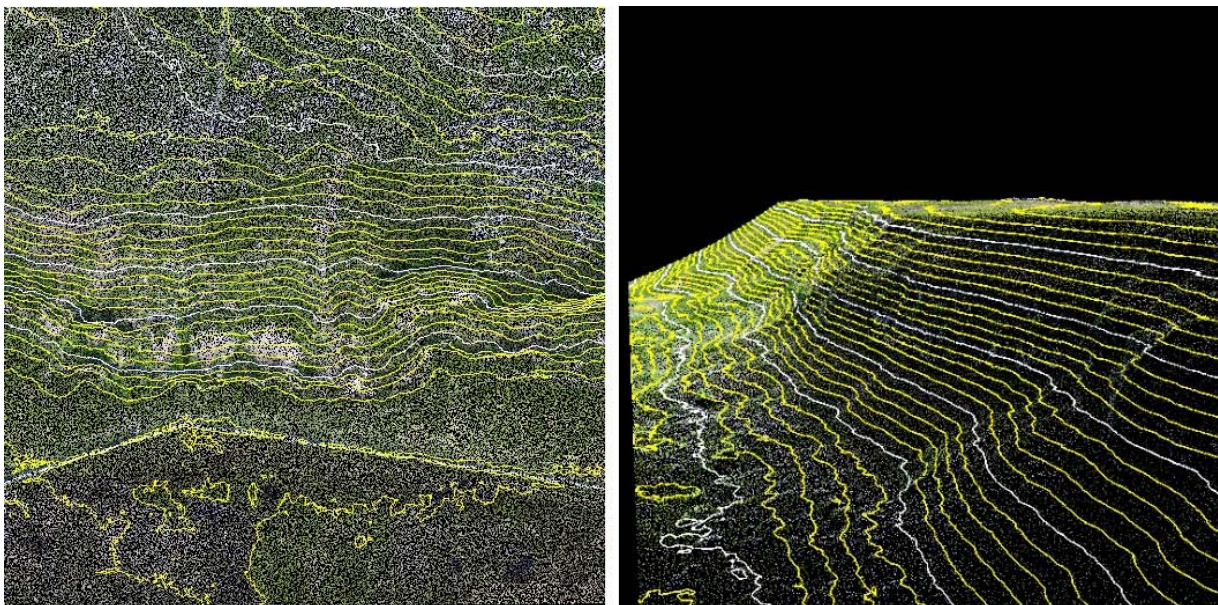
Electromagnetic interference is another consideration. Thunderstorms can affect communications and increase the risk of loss of communications. It is not advisable to fly when there is potential for electromagnetic interference, a high risk in Mulu.

The most challenging mission was the attempt to reach Canopy Cave. Two flights were made, one at a relatively low level then a later one much higher. With high ground en-route and the potential loss of signal it was not possible to get close to the entrance itself but a clear view was obtained from a distance of approximately 450m. This required that the drone flew up slope to a point 480m above the altitude of heli pad and 1150m away from it; far higher than would normally be required on a drone mission. The total flight time for the second there-and-back trip was 12.5 minutes with the drone landing with only 23% battery power remaining, alarms normally start at 30%. It took three minutes to bring the drone down from 450m.

Given the above experiences it is important to plan missions with care. Consideration should always be given to the potential for loss of comms and the return-to-home route. In the event of loss of signal the drone will head directly for its Home Point in an attempt to affect an autonomous landing. If there is high ground on this route then it could collide with the ground or a tall tree. With the Mavic Pro it is possible to set a return to home altitude but given the extreme height of the features surrounding the gorge the additional energy required may cause the batteries to expire before the drone reaches its home point.

On a lighter note its worth remembering that sand flies inhabit the heli pad and will make a bee line for any exposed flesh. Insects nipping at your ankles, when you are concentrating on keeping the drone safe, is a major distraction. Cover up when flying from here.

So what next? Drone technology is advancing at a considerable rate. Using specialist software autonomous pre-programmed flights are possible. Three dimensional models of land surface or structures can be captured with relative ease and these can be reproduced in hard form using a 3D printer. In addition digital terrain models can be created complete with contour lines, perhaps the gorge could be mapped in greater detail than Google Earth provides.



Example of a digital terrain model complete with contour lines (plan & elevation)

A secondary objective of the expedition was to try and establish a new survey centerline for the Cave of the Winds and Clearwater sections of the Clearwater System.

All the original survey data from the '78 and '80 expeditions for Clearwater Cave and Cave of the Winds (and also Benarat Caverns) has been lost. At that time the data was used solely to draw the surveys and, once completed, there was thought to be no further use for it. Indeed, there are stories from back then of such prodigious amounts of cave being found that the explorers ran out of survey paper – once the data had been used to draw a survey, it was erased from the paper which could then be re-used for new explorations!

Of course, times have changed. We now live in the 'digital' age with all its data collection and storage refinements and data manipulation techniques. Modern surveying methods input field data directly into computer based programmes or 'apps' which can produce line surveys onto which passage detail can be added in vector drawing software such as Adobe Illustrator.

During 2005 all available data for the Clearwater System was input to the 'Survex' programme to produce a master dataset. Unfortunately this did not include Clearwater, Cave of the Winds or Benarat Caverns, three of the most important caves in the park, for which data did not exist.

The 2005 Solution

Fortunately a solution was at hand - to reverse-engineer the original paper plans and elevations to produce Cartesian x, y and z coordinates which could be input to the Survex model. The downside of this process was that it produced a single cave file (named Clearwater Fake or Benarat Fake) for the whole of the three great caves, and which was in a different format to that of all the other data. Although a Cartesian file works well in Survex it is extremely difficult to connect new passages into it as there are no fixed stations or marker cairns in the cave; all stations are 'virtual'.

The 2018 Solution

The only long term solution to this was to resurvey all the '78 & '80 passages. The method would be to run centreline surveys through the main passages and install fixed survey markers at key junctions which could be used at a later date to continue the work.

Of course, resurveying 50+ kilometres of cave could be a lengthy task, and indeed it is seen as a long term project. The aim of this small expedition was to start the process, with the objective being to produce a 'backbone' centerline from the principle entrances through the main passages. It was thought that centerline surveys could be taken through Cave of the Winds and up Clearwater river, joining at Junction Cavern and then being taken on to the Volcano and possibly Scumring. We knew we had no chance of getting all the way to West Wall Chamber beyond Revival where we could hook up with survex guaranteed Blackrock data. But that is a future necessity.

Colin Boothroyd's 1990 hand-drawn survey of Clearwater and Blackrock was studied and fixed survey points were identified, mostly major junctions or interface points (like between Clearwater and Cave of the Winds.)

In the event this plan was too ambitious for a small team with other objectives, and inclement weather also conspired against us.

In **Cave of the Winds**, a survey line was recorded and fixed stations installed at:

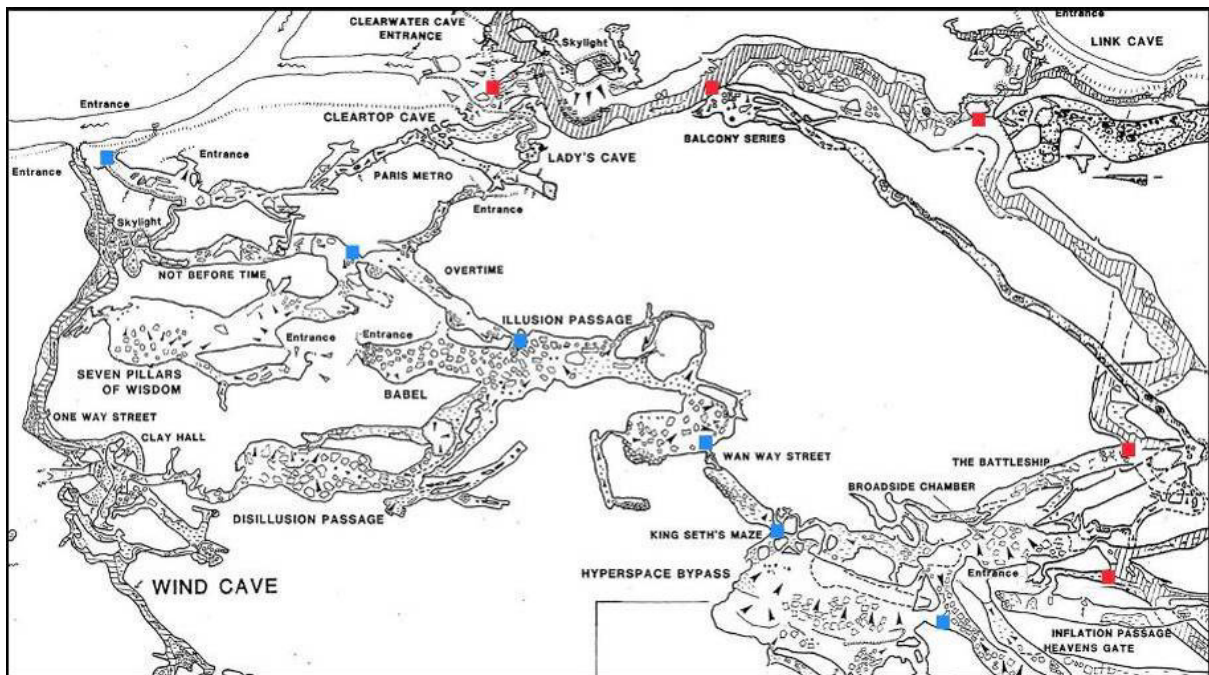
- Cave of the Winds upper entrance

- Seven Pillars of Wisdom Junction
- Babel Junction
- Top of Wan Way Street (Clearwater connection)

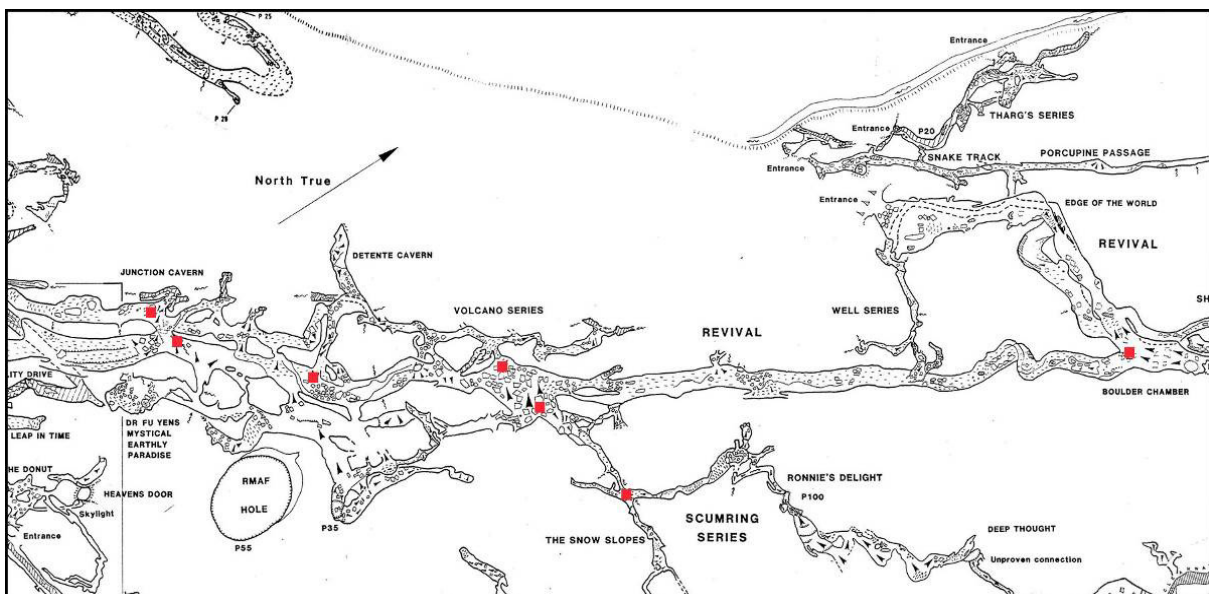
An attempt was made to run a survey line up the Clearwater river but owing to high water conditions this was abandoned at the second rope crossing and a survey marker was installed at the junction with the Balcony Series. This can easily be picked up at a later date.

In **Clearwater Cave**, a survey line was recorded and fixed stations installed at:

- Clearwater Cave main entrance (dripline)
- Clearwater river passage below the Balcony Series

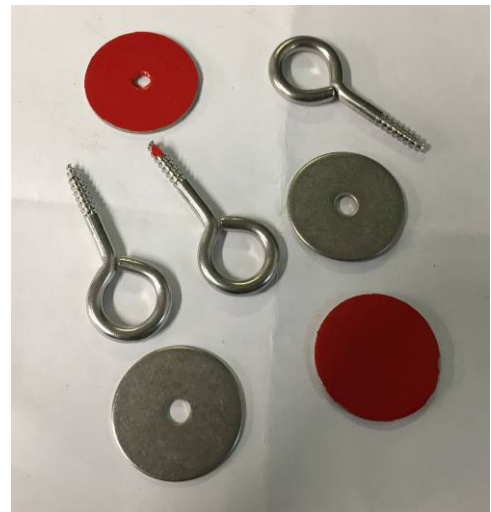


Planned stations; Cave of the Winds to Clearwater



I was asked to come up with a design for a station marker which would be permanent and easily identifiable. Having done some searching to find that there was nothing commercially available which was suitable, I identified a solution which consisted of a 7mm plastic Rawlplug, a 30mm dia. stainless steel washer covered on one side with red reflective tape, held in place by a stainless eye which could be screwed in by hand. To identify the station, a plastic tag with a printed label was attached to the eye with a cable tie.

It was decided to give the stations where these markers were placed unique numbers rather than try to integrate them into the exiting survey station numbers. This not only highlights



that they are easily identifiable stations which can be searched for in the cave (and easily found from a distance due to the reflective tape on the washer) but it also means that the labelling could be prepared back in the UK using a systems which should be durable for many years: the plastic tag is a durable cable marking label (Hellermann IT1-NAT) and the label itself is a waterproof, laminated thermal transfer label (Brother TZ tape). The result will stand complete and prolonged immersion and should be durable for the foreseeable future.

A stock of station markers (plug, screw eye, label tag and cable tie) has been left in the gear store at Park HQ.

Recent Survey Lines

Hugh St Lawrence

The expedition fully recognised that there have been recent survey lines put through some sections of the cave we intended to cover. In 2009, a re-survey line was put in all the way from Armistice down to Clearwater 2 river, to try and explain an anomaly in the fake survey data which suggested there was a 30m waterfall between Clearwater 5 and Clearwater 3! In 2014, Dave Nixon and crew put in a disto-x survey line from Scumring to Cave of the Winds upper entrance, tying in the new Creedence discoveries and helping to establish their true elevation in the mountain. Similarly, in 2017 Andy Farrant and others put a survey line up the Clearwater river to River Junction.

So why put in yet another survey line?

The problem with these lines is not with their accuracy, which is undoubted, but with their permanence in the cave – i.e. can their stations be easily relocated and referenced against a survey model. Such is the size of the Clearwater passages that small pink dots (nail varnish) or even cairns can easily be missed. Even if found, will they necessarily carry a station number? A look at the current survey model for the system shows numerous ‘duplicate’ lines in Clearwater – a confusing state of affairs with plenty of doubt about which survey line or stations to take as ‘de facto’; and, indeed, which ones contribute to the survey calculated length of the cave. (* see note 1)

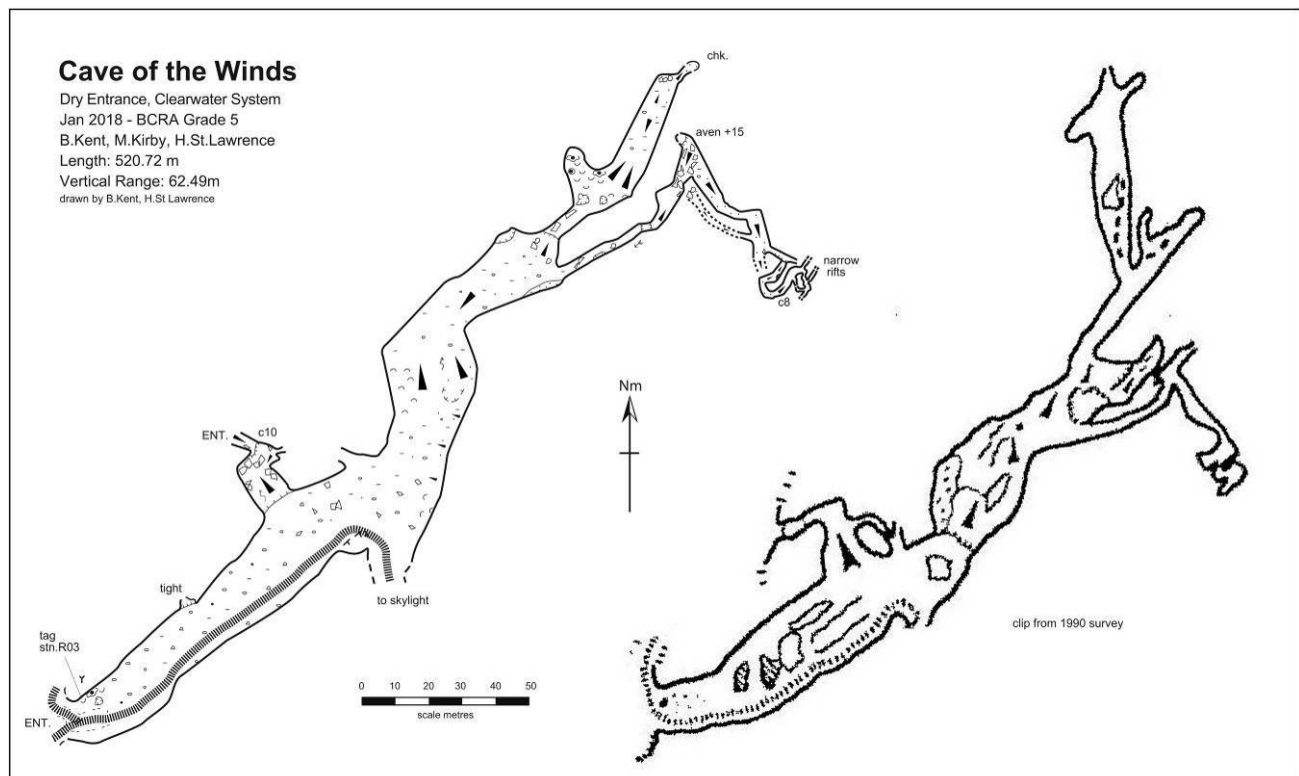
With new cave being found all the time, this confusion can only get worse. It was felt it was time to go back to square one and establish a new survey line for the main passages – a line which would have fixed survey markers installed at major junctions, to and from which new discoveries or re-surveys of existing passages could be tied in with confidence.

New Line or New Survey?

A full re-survey would imply re-recording all the passage detail. At this stage this is not our intention. The 1990 hand-drawn survey is a masterpiece of detail, at least at the scale at which is drawn. This fact was checked when, unable to push the survey up the river due to high water, the party decided to climb into the Balcony Series. There then ensued an hour's effort to find the way on, eventually concluding that we were still in the Clearwater river passage, albeit an obscure branch of the roof level bedding. If we'd had the survey with us we could have worked that out in five minutes!

So the existing hand-drawn survey is pretty accurate 'at the scale it is drawn'. The latter is emphasised because the scale of the hand-drawn survey is approximately 1:10000 – obviously a lot of detail has to be omitted at such a small scale.

Nevertheless, it is hoped that a confident centreline will encourage people to kick off re-surveys into side passages or branches at a more detailed scale. With half a day to spare during some anemometer calibrations, we decided to re-survey the Cave of the Winds upper entrance passage. The resulting survey was found to be fairly close to the original, although our detail differed a little. And in the process of surveying we walked into a small, draughting extension which we did not have time to conclude. Resurveying can have added benefits!



Resurvey of the Upper entrance area of Cave of the Winds

Future Work

Due to various circumstances we achieved less than we hoped for. But it should not be difficult to pick up where we left off and continue the ‘backbone’ re-survey up the Clearwater river and from Cave of the Winds through to Junction Cavern. From here the priority extension of the line should be along Revival and through the Dune Series to meet up with the Blackrock connection – all passages in Blackrock and Whiterock are recorded in survex data. This would enable a harmonised centreline along the whole length of the Clearwater system.

There will still be plenty of work to do replacing the rest of the fake data with ‘real’ survey data. But the process has started and may encourage parties to add a bit more to the new centreline each time Clearwater is visited. With modern disto-x surveying and a moderate amount of commitment, replacement survey could come together relatively quickly.

Lessons Learned

- A record of all fixed stations should be kept in a log, with description of location and photograph. Even if a station tag should go missing, the photograph will help locate the station point. A log has been created available to all future expeditions.
- Fixed stations can be placed independent of surveying operations – it may not be feasible to survey on every trip, but stopping to place a tag at a major junction need only take 5 minutes. As long as the station is recorded in the log, it can be surveyed to at any time.
- Some care should be taken over placing and recording intermediate stations, particularly those at significant junctions; also the last station of an unjoined or unfinished survey line.

Note 1. System Length:

Although the original survey data from '78 & '80 has been lost, records were kept at the time of the length of surveyed passages. These have been incrementally added to over the years, together with lengths derived from modern Survex data. The ‘fake data’ covering Clearwater and Cave of the Winds, which is not ‘real’ and would be inaccurate, is not included in the system length calculation. So it is believed that the Clearwater System length is in fact quite accurate.

Nevertheless, it would be preferable for a system length to be derivable from one source of data. Whether resurvey with modern electronic instruments will produce data which alters the system length, either up or down, remains to be seen.

Further details of the fixed stations are shown in Appendix 2.

SUMMARY OF UNDERGROUND EXPLORATION

Moonmilk Cave

Soup Dragon, length 184m - explored 12 Jan '18

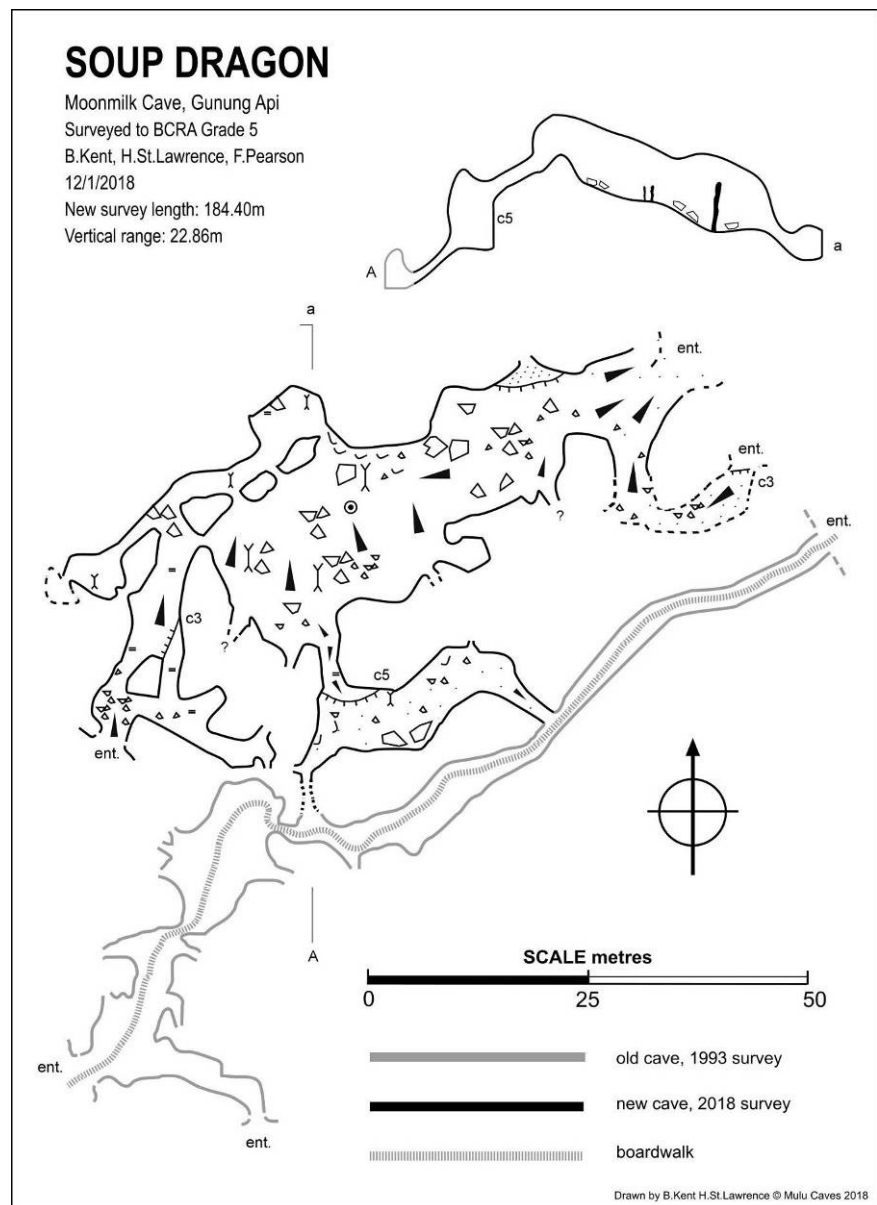
Explored by Ben Kent, **Hugh St.Lawrence**, Frank Pearson

Whilst recovering tackle from the Racer Cave area at the end of the 2017 easter expedition, HSL noticed a large entrance just to the side and below the north portal of Moonmilk Cave on the now defunct boardwalk (no boards!) With an afternoon to spend on our arrival in the park, we set off to look at it.

Just 20 metres from the portal the ground drops steeply away towards the river. A large entrance is visible and an easy 10m handline climb accesses the 15m x 8m entrance. To the left is a small passage and climb to a side exit avoiding the handline. Straight ahead the passage narrows and then breaks out into a much larger section of cave, dominated by the prospect of a tall, leaning stalagmite. An irregular shaped bedding chamber leads forward past the stal to a climb up to the

left, passing holes into a passage on the right. Up the bedding reaches a small hole in the corner which was not pursued, while following the top of the bedding back in the direction of the entrance passes several small rifts. One of these descends to a view of a larger passage below, and a free climb down to the left reaches known ground in the upper level of Moonmilk Cave.

Back in the chamber, holes down to the right of the stal lead into an easy passage with stal deposits to a junction. Right leads to a stal choked alcove, while left leads up to a loose exit onto steep forest ground above the river.

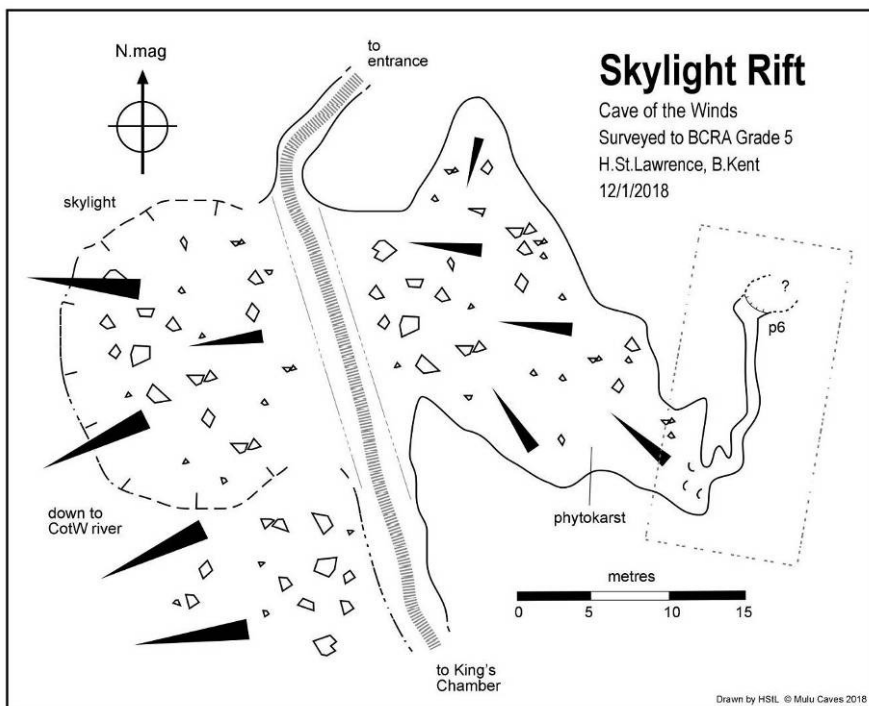


Cave of the Winds

Skylight Rift, length 38.26m - explored 14 Jan '18

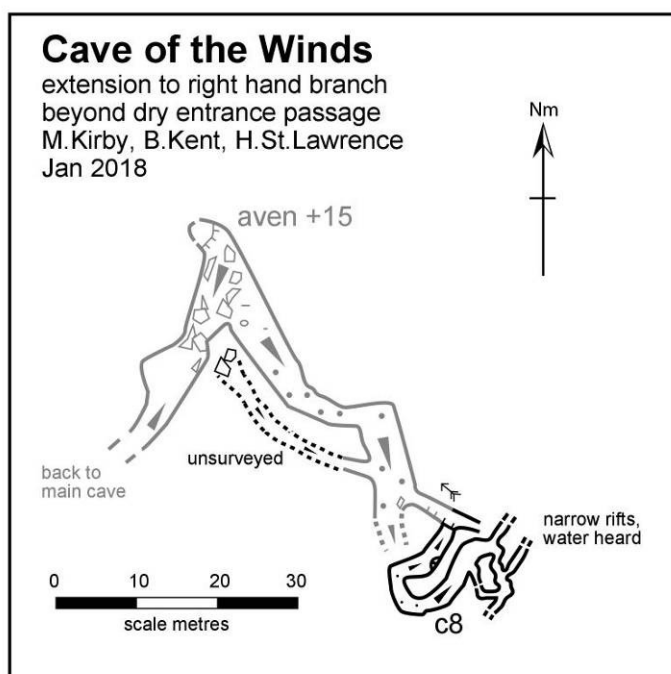
Explored by **Hugh St.Lawrence**, Ben Kent

As the Cave of the Winds boardwalk enters the skylight, a scree slope to the left leads up over lighting cables to several visible openings. A short climb amongst stal leads into a narrow rift passage which within a few metres reaches the edge of a drop of 6m or so into a passage below. The drop was not descended and needs 10m of rope for either a handline descent or short pitch into the as yet unexplored continuation.



Horseshoe Tube, length 36.51m - explored 14 Jan '18

Explored by Matt Kirby, **Hugh St.Lawrence**, Ben Kent



As the Cave of the Winds boardwalk swings right and away from daylight, the large entrance passage continues straight ahead. The whole entrance passage and left branch beyond the boardwalk was resurveyed (resurveyed length 520.72m incl. Horseshoe Tube) and found broadly to conform with the old survey from 1978. Beyond the boardwalk large passage continues a short way to a split; the larger left branch continues to a pinnacled descent to a chamber and choke, while the smaller right branch carries a draught and descends guano floored tubes to an apparent mud choke. This would appear to be the end of the old survey. A dip tube rises up a steep bedding but doesn't look very promising. However, a draught is noticeable and a traverse up and across the

bedding reveals a small hidden tube which takes a horseshoe shaped turn to the left before plunging steeply downhill. A 10m handline descent (stud in right wall) lands in a hading rift from which a complex of small interconnecting rifts can be entered which were not surveyed.

From one rift emanated the sound of a waterfall, but could not be reached without some digging. This extension appears to take the passage beneath the floor of Not Before Time near the rope climb up to the notch. The waterfall heard may be derived from showers and inlets in Not Before Time, and it's interesting to speculate where it might drain to.

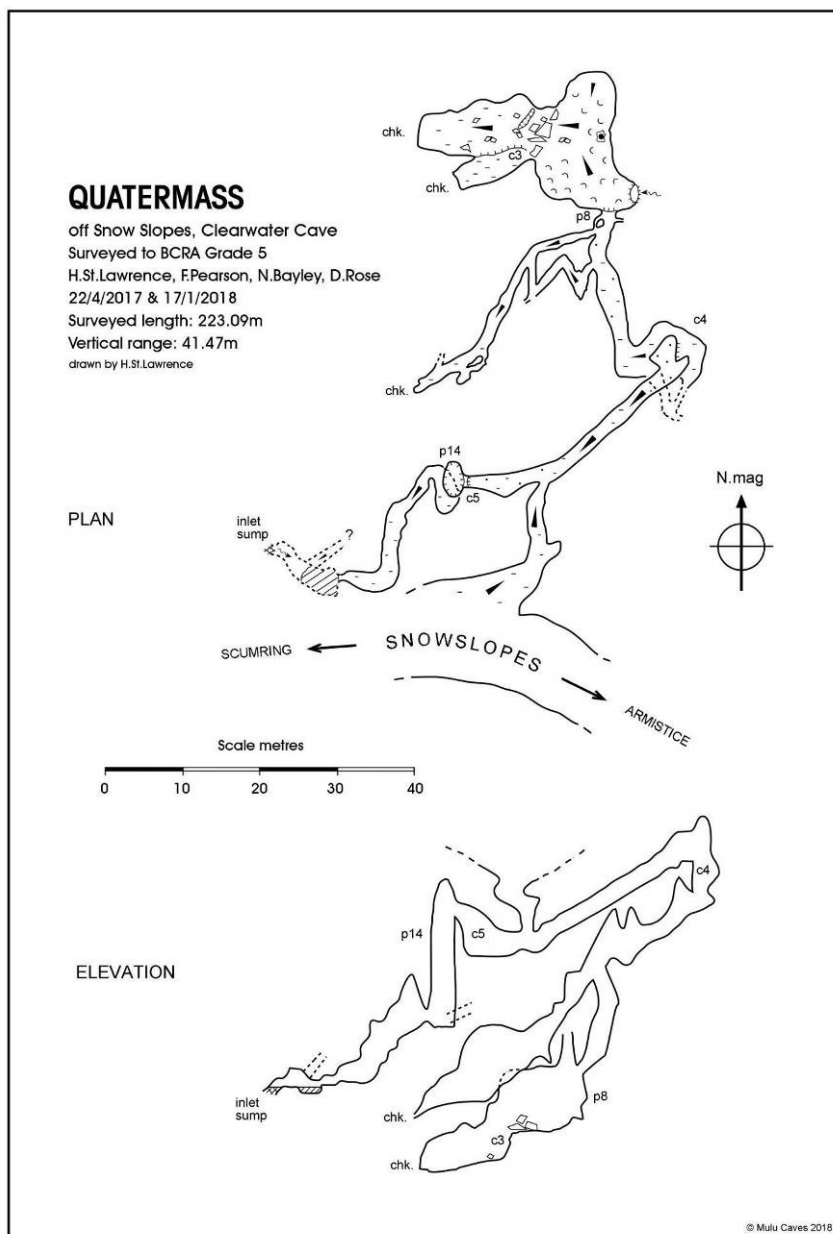
Clearwater Cave

Quatermass Series, length 223m, discovered 2014 - further explored 22 Jan '18

Explored by **Hugh St.Lawrence**, Frank Pearson

Early explorations in 2017 led to the edge of two climbs/pitches. FP descended one of these on a handline and reported several passages and a window into a large chamber. HSL climbed a short wall to a knife-edge arête looking down an estimated 20m pitch.

In 2018 Frank and Hugh revisited to continue exploration and survey. Below the 5m climb a slippery guano slope leads to a short walking passage descending past several small side passages to a window overlooking a chamber. The side passages are narrow rifts which join and descend to a larger section and a mud choke. A 10m pitch from the window (could be hand lined) lands in a chamber which descends to a lower level and chokes conclusively. Although there is a definite draught at the window, there appears to be no passable way on in the chamber below.



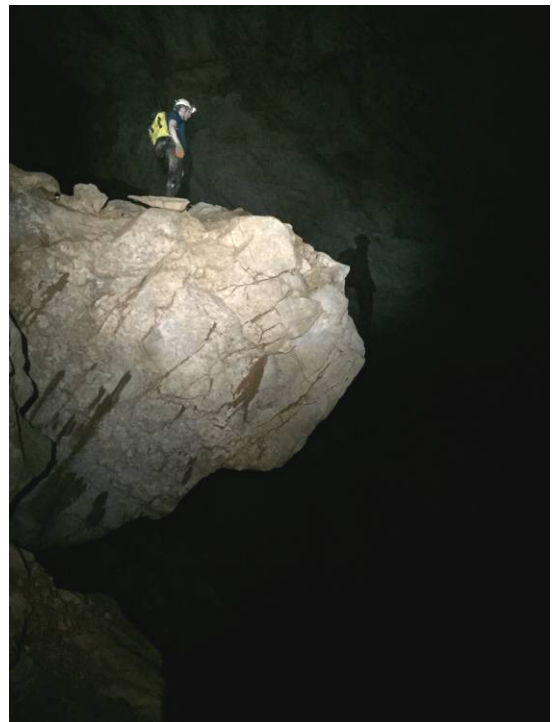
The other route, left at the first T-junction, quickly leads to an awkward 5m wall climb. At the top a knife-edge saddle is the take off for a 14m pitch (2 studs on left wall) to a mud floor and descending passage to a mud squeeze. The squeeze is straight into a thigh deep pool which is waded to a short continuation and an inlet sump. Above the pool is a steep tube which was not climbed.

An aven in this series, which FP remembered climbing to the base of in 2017, was not relocated.

Red Dwarf Chamber, explored 22 Jan '18

Re-visited by **Matt Kirby**, Rambli Ahmad, Ben Kent, Mark Jones

The explorations of the Armistice Series above Scumring Camp in 1989 had revealed 15km of new discoveries with only minor leads left to explore. During a return to the end point of the upper series in 1991 a new hole in the passage floor had revealed a previously unexplored series (Edwin's Long Cut) which connected with the Clearwater 5 upstream sump area. The end point was eventually checked out but no further passage was discovered. With the subsequent discovery of Api Chamber in Whiterock Cave lying only 790m north from here the gap between the two caves has become a frustratingly empty space. Attempts were made to follow the draughts and push southwards through the boulders of Api Chamber but without success, perhaps there was a similar area in the Armistice Series where we could push northwards? The only easily accessible point that fitted the bill was Red Dwarf Chamber, visited only once before, in 1989, at the end of a very long day by Matt Kirby and Pete Boyes.



The vastness of Armistice

Matt Kirby



Calcified Bat Skeleton in the Road to Hell

Ben Kent

This was a big boulder-filled chamber but there was no recollection of any draughts. However, could the original exploration have been carried out at a time when the draughts were at a

minimum; there was only one way to find out....have another look. With a camp at Scumring and an open book of things-to-do whilst the loggers were running this was the ideal opportunity to return to Red Dwarf Chamber.

The route up to Armistice a relatively straightforward with an easy handline climb (which is rigged) up out of the Snow Slopes and into the lower Armistice series. This eventually rises up into the main junction with Armistice running south and north from here. Following the passage northwards leads through enormous boulder filled passages to the 'Grin 'n Bear It' crawl. Up to the right before the crawl leads into the Road to Hell so named after a particularly nasty side passage which led to a boulder choke in 1989. What amazed us on this expedition was how beautiful the main Road to Hell passage is. Massive white stalagmite columns, delicate helictites, lots of red colouration and a crystal lake. The passage ends at a handline climb down into the approach to Red Dwarf Chamber (to the left here leads to the other side of the Grin 'n Bear it crawl).



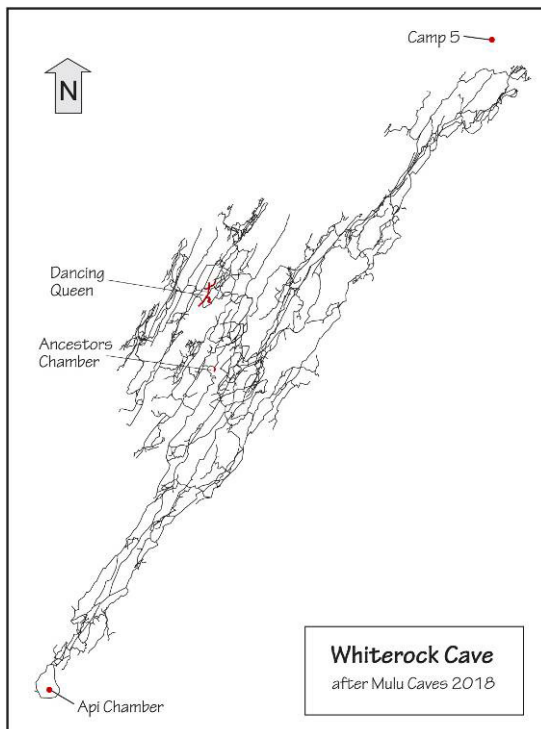
Red Dwarf Chamber

Ben Kent

The chamber itself is very impressive, filled with large boulders including one particularly massive flat slab which slopes down at 40°. A thorough search was made around the northern end of the chamber but without any obvious leads or draughts. One small side chamber was located on the eastern side but this revealed no further passages.

Unfortunately Red Dwarf Chamber drew a blank but it did give the explorers the opportunity of seeing one of the most beautiful passages in Mulu. Only five people have ever set eyes on this passage, owing to its remoteness and the fact that it goes nowhere there is a strong possibility that these may be the last eyes ever to see this passage and that light will never fall on these beautiful formations again. We all felt honoured to have been to this part of the cave.

Whiterock Cave



Three trips were made into Whiterock Cave. An initial day-trip was used to install the logger in the Midnight entrance and to revisit the magnificent Daydream Believer, which heads southward from Africa. Our logistics manager, Veno Enar, advised us that recent tree fall between the Headhunter's Trail and the entrance had rendered the old Whiterock track unusable. He had recently re-cut a new track so accompanied us to the cave entrance to ensure we found the new route.

A second, overnight visit, allowed a small team to make the round-trip through Into Out Of, Who's Cairn, Propeller Camp, Ancestors Passage and return via Daydream Believer to the bivi site in the Africa series.

The third trip was used to remove the loggers, investigate a lead off Africa (Dancing Queen) and to carry out photographic work in the entrance series.

Whiterock Cave continued to reveal new discoveries, even though only small ones.



Giant stalagmites in Daydream Believer

Ben Kent

Dancing Queen, length 505m - explored 24 Jan '18

Explored by **Hugh St.Lawrence**, Ben Kent

Just before the Africa passage descends to the Daydream Believer junction is a pit against the left wall.

A small hole amongst slabs leads on to a 10m rope descent, or alternatively a hop into a clean tube on the right; both descend and rejoin as the route enlarges, continuing down over weathered slabs and clay.



The insignificant entrance to Dancing Queen out of the Africa Series

Matt Kirby

A short slippery climb of 2m leads onto a slope into much larger passage and a junction. The obvious passage heads north and quickly divides, left descending to a sand choke, while right continues smaller through pleasant walking tubes to a junction with several passages radiating. On the day of discovery a waterfall fell from an open passage above – although it is possible to climb into this, it was not explored or surveyed, but appears quite open. The black slick flooring the waterfall inlet is not unlike that seen at the watering hole at the Africa-Daydream Believer junction, so it's possible the two are connected.



The unexplored waterfall passage

Ben Kent



Tube passage

Ben Kent

To the right, north, quickly divides again; the sand floored tube dips downhill to a constriction, beyond which rope would be needed to descend further and into a large passage seen at the bottom - this is almost certainly Zahara Dessert. Above the sand tube is a short slope up into level passage which crosses some flowstone traverses to join up with the Spectacle Pot area beneath Under Out Of.

The junction waterfall lands amongst black boulders and behind these the water runs off into a larger tube which curves away downhill until it steepens at a drop into the same large passage as seen before. Rope and most likely SRT gear would be needed to reach the floor, as the ramp appears to go vertical for the last drop into the passage (20m of rope estimated.) Nevertheless, this may be a quicker and easier route into Zahara Dessert than Spectacle Pot itself. Indeed, via Zahara Dessert and Shane Warne's it's probably one of the quickest and easiest routes into the Racer and Firecracker areas of Blackrock Cave.

Dancing Queen

Africa area, Whiterock Cave

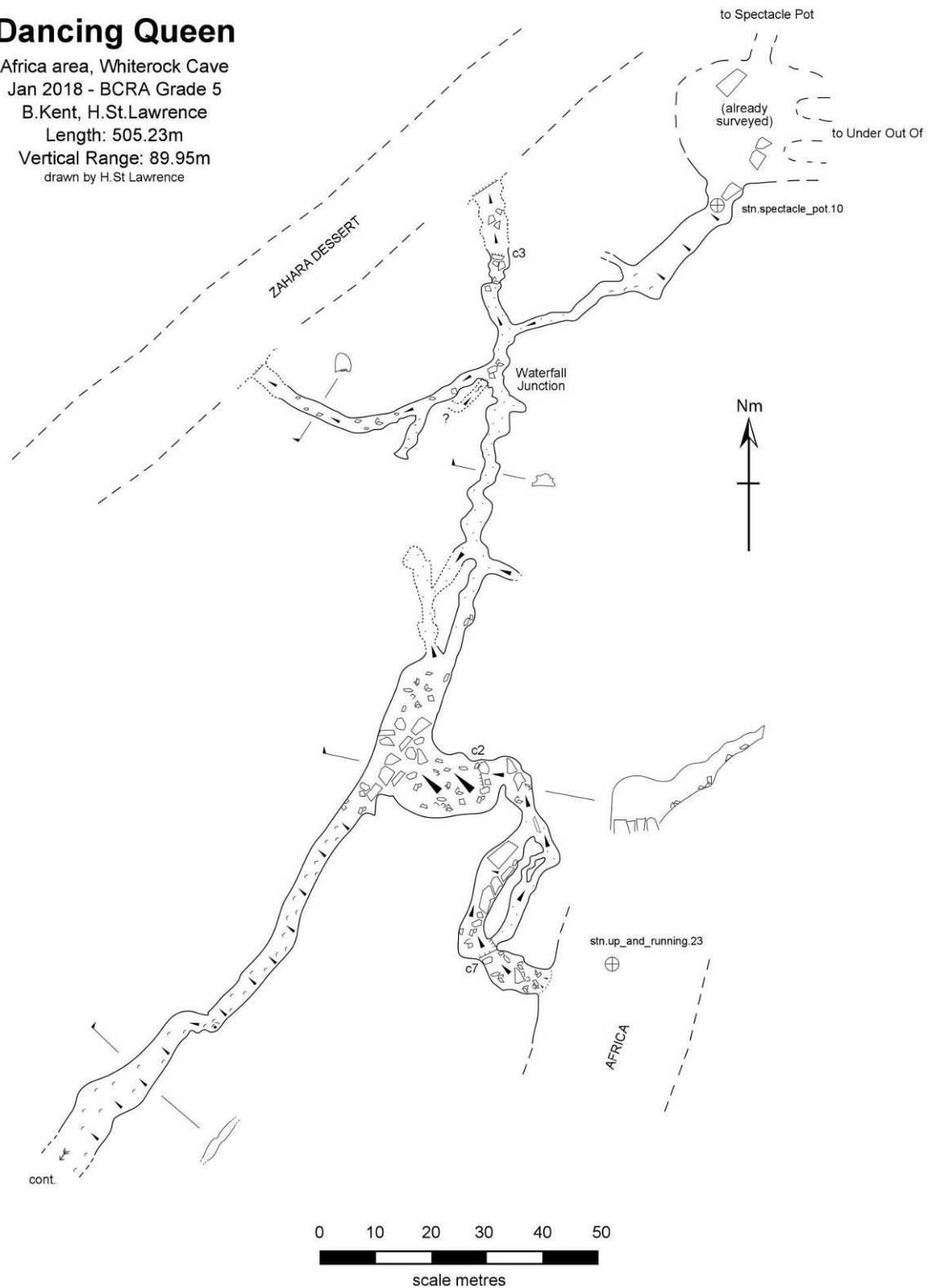
Jan 2018 - BCRA Grade 5

B.Kent, H.St.Lawrence

Length: 505.23m

Vertical Range: 89.95m

drawn by H.St.Lawrence



© Mulu Caves Project/HSL - Jan 2018



Dancing Queen at the bottom of the descent from Africa

Ben Kent

From the junction chamber at the bottom of the initial descent, crossing large boulders leads into a passage heading south and carrying a slight draught. The passage is an inclined bedding along the strike and makes for awkward going with tippy-toe traverses on steep calcite and route-finding of the best level to progress at. After 100m the survey was suspended with the passage still continuing.

Ben's Loop, *unsurveyed, est. 50m - explored 24 Jan '18

Explored by Ben Kent (**Hugh St.Lawrence**)

Opposite Dancing Queen and immediately before the Daydream Believer junction in the Africa Passage is a steep ramp above a short wall of calcite flow. An awkward 5m climb with no protection leads onto a steep but fairly wide ramp which tops out with no upward continuation and only a passage descending to the left which quickly reaches a window pitch (undescended) into the Africa/Daydream Believer junction.

Ancestor's Chamber, length 111m est. grade 2 survey – discovered 2005, surveyed 24 Jan '18
Explored by **Hugh St.Lawrence**, Ben Kent

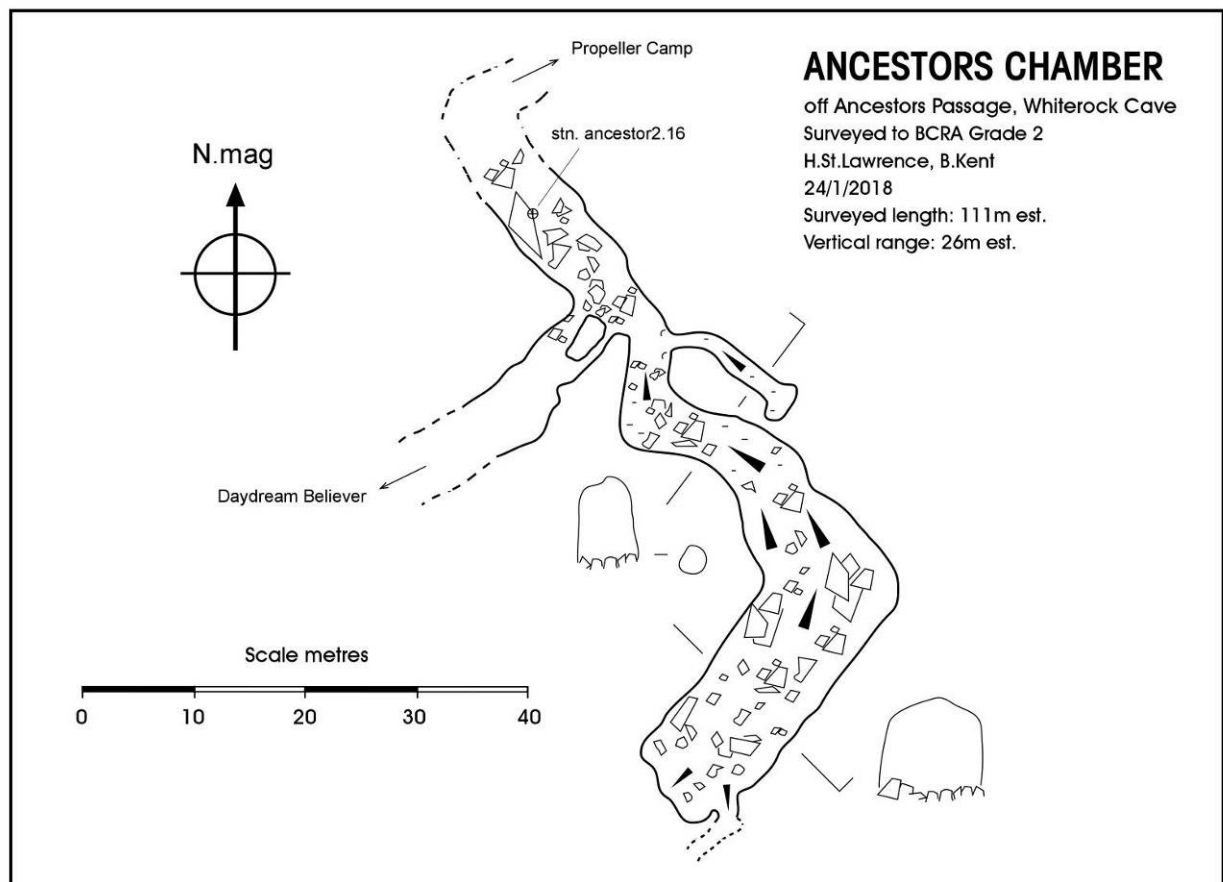
Ancestors Passage was named after the discovery of a monkey skeleton apparently far from any known entrance, deep inside the cave

From station 16 in Ancestors Passage (ancestors2.16) the main route towards Daydream Believer turns right and passes through a small hole. Straight ahead is a much larger passage rising steeply up a slope to a chamber with no continuation, save for a miserable short draughtless crawl beneath the far left wall. At the start of the slope up a ramp on the left can be ascended with difficulty to a level platform with some impassable inlet tubes.



Monkey skeleton

Ben Kent



SURFACE SEARCHING

Searching on Benarat

22 Jan '18

Frank Pearson & Ben Kent

Whilst others slacked in camp, Ben and Frank, full of energy, set off for a morning jaunt to investigate Benarat Caverns. Unfortunately the objective was never reached. With instructions from Veno the track was successfully followed to a 'durian camp' where plentiful fruit lay rotting on the floor. Further durian dumps were encountered a little way beyond before the track was intentionally barred by crossed logs and branches – definitely a 'keep out' sign! Retracing their footsteps the duo attempted to forge an alternative route, but eventually gave up under assault from treefall, rattan and the midday heat. It is worth bearing in mind that the trail to the cliffs, seemingly a mere stones throw from Camp 5, is not necessarily a simple undertaking! It also appears to be a busy area with nesters and locals, especially during the durian harvest. Future explorers to this area should be aware that access may not be straightforward.

Searching On Api

As with all expeditions based at Camp 5 the temptation to venture up the Gorge to find something new is always there.

Above No Country for Old Men, explored 22 Jan '18

Explored by Ben Kent & **Hugh St.Lawrence**

On the afternoon of the Benarat outing (above), Ben and Hugh took an anemometer up to place in No Country for Old Men. They passed the swamp feature and moved easily into the shallow valley, where the draughting holes from previous expeditions were inspected, not draughting much on this day. Just beyond the bat shelters they struck upslope toward NCfOM, Hugh on line for the cave, Ben further right.

Ben called that he felt a cool draught and leaf movement, so we investigated. A climb up a series of ledges and gullies some 50m to the west of NCfOM reached a point where climbing gear would be needed to proceed. A definite cool draught could be felt falling down the cliff, but whether this is from a cave entrance or is simply a katabatic wind falling down the mountain slope is uncertain. We resolved to return with a rope and continued on our mission to place the anemometer in NCfOM.



Climb above NCfOM

Hugh St.Lawrence

Four days later, on a trip to retrieve the anemometer, we returned to the previous high point with rope. An altimeter suggested we were at an altitude of 200m, with the end of 1954 in Whiterock being generally at around 235m. Matt flew his drone up from the helipad to see if our location could be pinpointed, but we were well hidden behind tree cover. Harnesses were donned and Ben tackled a short rock corner and climbed up on to a ledge with a tree runner. Unfortunately, a full rack of gear and most likely bolting gear will be needed to continue any further up a face of wet rock beneath overhanging corners. It was thought that some old stal features were just visible 20m or so above, but it was difficult to see clearly. The cool draught was again present, suggesting that the climb may be worth an assault with hardware; properly equipped, the next 20-30m should be achievable in a day's outing.

Below No Country for Old Men (NCfOM), explored 27 Jan '18

Explored by Ben Kent & **Hugh St.Lawrence**



Rift Pot

Hugh St.Lawrence

After retrieving the anemometer from NCfOM, the duo headed downhill for a quick look in the valley containing Cairn Pot. Just beyond the bat shelters is a large isolated boulder, below which the valley becomes deeper against the slope. In the first major set of clints against the slope a short rift leads to several small, sharp holes with hints of cave below and rocks falling and rattling with interest. A noticeable outward draught was felt here (circa. 4pm) and the new site, **Rift Pot**, may repay attention with a lumphammer and protective clothing.

A little further down the valley **Cairn Pot** was located – curiously, this had little draught compared to the rift just visited, although it had a noticeable draught when it was discovered and explored in 2011.

At the bottom of the valley **Bouldery Sink** was relocated and Hugh entered for some re-familiarisation.

A light touch is required as some of the entrance boulders appear a little precarious, a situation best appreciated on exiting! Further in, the cave improves amongst large blocks of shiny black limestone coated with a white calcareous matrix, with floors of water washed cobbles and gravel. Several chokes offer opportunity for digging, and there was a view of 8m or so along a low but open crawl heading into the hill – this wasn't entered as the caver was solo and required moral support amongst the uncertainty! The cave is sufficiently long to warrant a survey.

Although there wasn't much in the way of draught (4.30pm) Ben, who was outside, observed quite a few bats flying into the cave. As bats are also seen at Pointless Junction in Whiterock

Cave, one is left to speculate. Bouldery Sink is at the end of the valley and is a sink for several small streams in wet weather; correspondingly, several small inlets enter the Pointless passages. Draughts have been noticed in many of the features and small holes in the valley below the swamp feature, and their proximity to the Pointless Junction area suggests that this is almost certainly Whiterock air. Whether a northern entrance to the system can be found amidst this difficult ground remains to be seen.

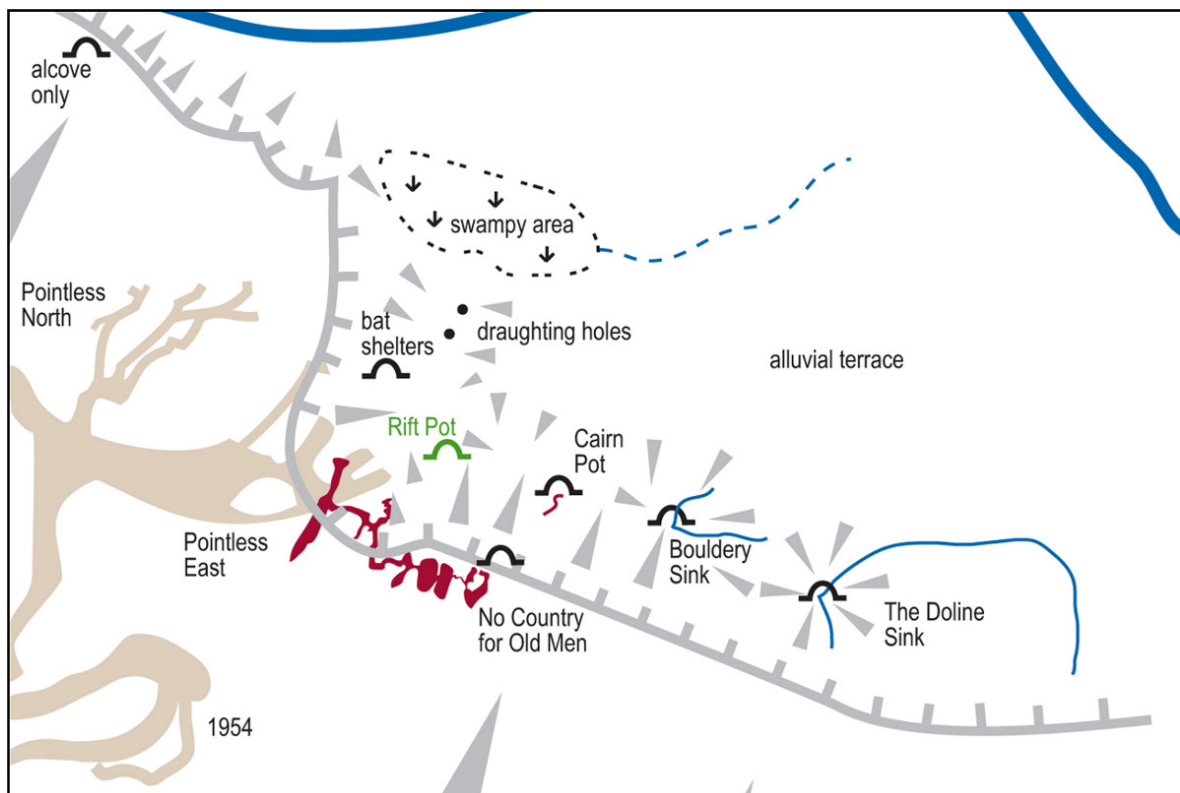
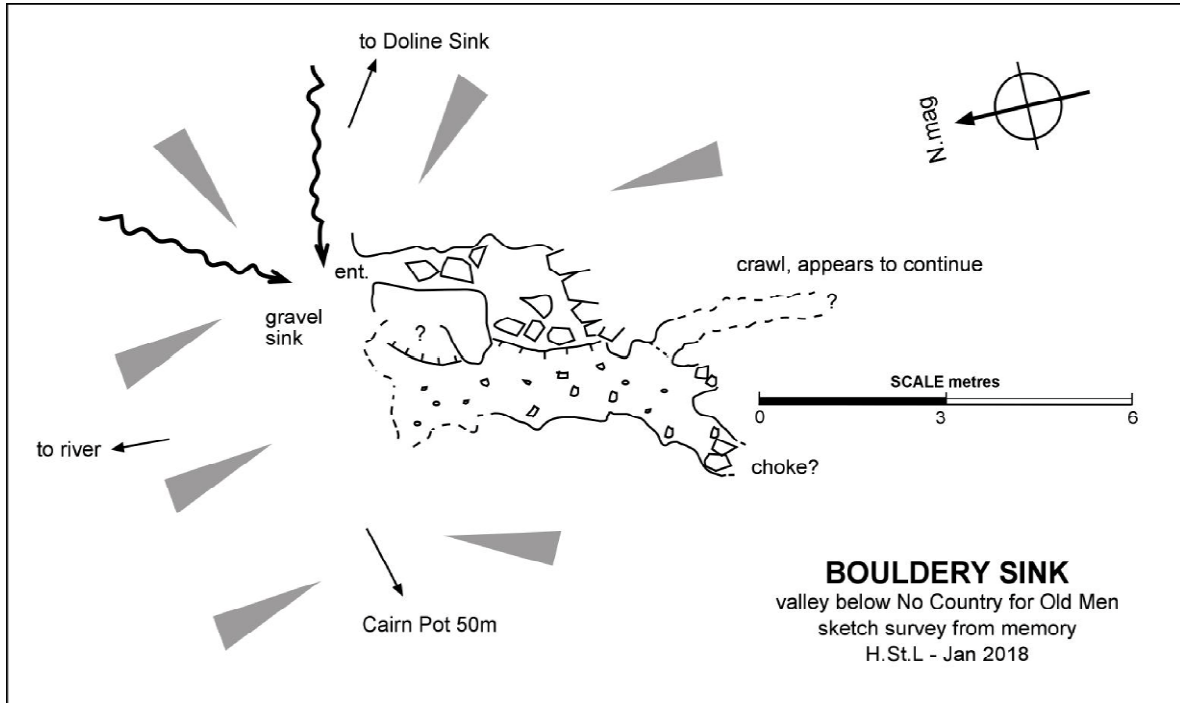


Figure 5: Surface features around Camp 5

FINANCIAL REPORT

Dick Willis

During the preparation for the expedition, a budget was prepared based on the prior experience of recent expeditions with a cost estimate, excluding flights, of £600. All members of the team were asked to pay a £200 non-refundable deposit and bring with them a further £400 to be available to the expedition as required. In the event, the per capita cost worked out at £541 for this team of 7.

A record was kept of all expenditure with a comparison against the budget (see below). In the event the budget was slightly underspent and team members were not required to use the entire sum they had allocated to the expedition. Individuals then chose whether they wanted a refund or to donate their surplus to the Mulu Caves Project.

The underspend would have been greater had there not been some miscalculation of various supplies. An estimate of requirements was produced using a standardised spreadsheet that had been prepared for previous expeditions and which had proved very accurate. This spreadsheet was based on the number of days in the field in toto (calculating general requirements, snacks and items for lunches) and the number of days camping underground (calculating underground rations in addition to lunches and snacks). Using the results as guidance, shopping was carried out in Miri, with the freight accompanying the team up to the Park, and additional requirements were purchased later as necessary and shipped up to Mulu.

Due to illness, two members of the expedition did not, as had been anticipated, accompany the others to Camp 5. In addition, the overall number of days spent camping underground was lower than had been anticipated. These factors reduced the overall requirement for food and snacks, particularly during the second half of the trip. The situation was compounded when it was found that the expedition gear store held a number of food items which were about to go out of date. Had this been known in advance, it would have further reduced the shopping bill at the outset.

These almost out of date items were taken out of the store and used in preference to equivalents that had been recently purchased and, at the end of the expedition, surplus items suitable for storage were placed in the tackle store for use by the next team: an inventory of these items and their best-before dates was produced.

Any short life food items were left for use by Park staff.

Summary of expenditure:

	Budget	Actual
Food & drink	1645.00	1216.00
Accommodation	784.00	855.00
Transport	409.00	534.00
Labour	315.00	437.00
Staff fees	756.00	669.00
Miscellaneous	177.00	75.00
	4086.00	3786.00

Notes:

Food and drink: when based at Park HQ, breakfast and evening meals were purchased on account at the canteen. Food and drink supplies for Camp 5 were purchased in Miri and taken up to Camp 5 by porters.

Accommodation: For the duration of the expedition, the Park staff kindly allocated a 7 bed-chalet for use by the team which was charged at RM33 per person/day of occupancy. For staying at Camp 5, RM22 was charged per person/day of occupancy.

Transport: boat transport was used to transport cavers to Cave of the Winds/Clearwater and cavers and porters to the Long Berar drop-off at the start of the track to Camp 5. Capacity of the largest boats is 7 persons but that is reduced to accommodate gear. 4 boats were used at a rate of RM312

per return journey to take cavers, equipment and porters to and from Long Berar. 5 day-boat trips were used for journeys to Cave of the Winds/Clearwater, at RM150. Other transport costs were the use of taxis in Miri.

Labour costs relate to porters required to transport supplies and equipment to Camp 5.

Staff fees relate to the services of Venio Enar, who handled our logistics and provided support at Camp 5, cutting new track to the entrance to Whiterock, and to the services of our Camp 5 cook, Steven.

Miscellaneous: a small number of hardware items and some stationery were purchased for use.



The towering cliffs of Benarat. Looking up the gorge from Camp 5

Hugh St.Lawrence

MEDICAL REPORT

Frank Pearson

There were no major issues to report on health and medicine on this expedition. The small team stayed fit and well for the duration of the trip. Good and plentiful food, water and diligent hygiene ensured basic health needs. The application of foot powder at base and in underground camps secured everyone's feet from 'Mulu foot.' The usual hygiene at underground camps with washing, hand-gels and the handling of food secured against stomach up-sets. The use of antiseptic cream, iodine or betadine on unavoidable insect bites and shallow cuts and lacerations secured expedition members from infection. The essential way of dealing with insects and leeches was cover up wherever possible. One member suffered a troublesome blood blister from a boot rub-point, though at an underground camp he dealt with it hygienically and strapped it up. The basics were quietly stressed by the team and done well.

There did occur two minor accidents on the trip. One member of the team tripped and fell awkwardly on his left fore-arm on a trip in Cave of the Winds. The arm was lightly cut and grazed, and soon was subject to swelling. This was not bad enough to stop him from progressing through the cave to the Scumring Camp, though he did take the following day off caving to rest his arm. The day after this he had no trouble exiting the cave with the rest of the team through the Snake Track entrance.

A second minor accident occurred in Whiterock Cave when a small slab of rock twisted up when stood on by a member of the team, causing an edge of it to strike his shin. A cut on the shin does not need to be deep to expose bone. This one appeared to do so. Although the injury was painful there was no thought that it had broken skin. He left the wound covered by his long seal skin socks whilst in the cave, the injury did not impede the return to Camp 5. The wound was only inspected once back at Camp 5, where it was cleaned and then left exposed to heal. He then rested his leg for a day so it would dry and scab over. He was necessarily cautious of further any scrambling and climbing that would cause it to open again.



Damaged shin

Matt Kirby

The sole issue that caused problems is one that will potentially affect all expeditions: the timely and affective communication of information from one expedition to another. Getting an inventory of medical supplies left at Park HQ from the last expedition was problematic. No inventory was available, though a late email informed us that all the Tramadol and Ibuprofen had been used or was out of date, and two courses of Flucloxacillin had also been used. We replaced the ibuprofen in a base camp medical kit, an underground camp medical kit and a day-use medical kit. We could not get any Tramadol or Flucloxacillin without a prescription. One of the expedition had some spare Co-Codamol which we included in the kits, however, this is now out-of-date (end of January). All that was used by our expedition in the medical kits was iodine, swabs, cotton wool and plasters. The next expedition needs to fully restock with Tramadol, ibuprofen and add two courses of Flucloxacillin, as well as stock up with basic wound treatment items.

EXPEDITION MEMBERS

From the UK

Hugh St.Lawrence
Matt Kirby
Dick Willis
Nick Williams
Ben Kent
Frank Pearson

From the USA

Mark Jones (Cave Research Foundation)

From Sarawak

Rambli Ahmad (Sarawak Forestry Corporation)
Veno Enar, (logistical support)
Steve Lian (Camp 5 cook)
Jimmy (boatman)



The 2018 Team

**Back Row: Nick Williams, Ben Kent, Mark Jones, Dick Willis, Matt Kirby, Rambli Ahmad
Front Row: Hugh St.Lawrence, Frank Pearson**

ACKNOWLEDGEMENTS

Members of the Mulu Caves 2018 expedition are grateful for the support of the following.

In Sarawak

The Chief Minister of Sarawak

The Sarawak Secretary of State

The Director of Forests, Sarawak

Protected Areas & Biodiversity Conservation Unit, Sarawak Forestry Corporation

The Sarawak Ministry of Planning and Resource Management

The Resident, Miri Division

The Sarawak Immigration Department

The Sarawak Police Department

Gunung Mulu National Park Management & Staff

Hein & Andia Gerstner

Dave & Liz Clucas for their support and hospitality

Veno Enar and his team for logistical support

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Gill Instruments Ltd for the Windsonic anemometer

Richard Paul Russell Ltd. For W10 Spaceloggers

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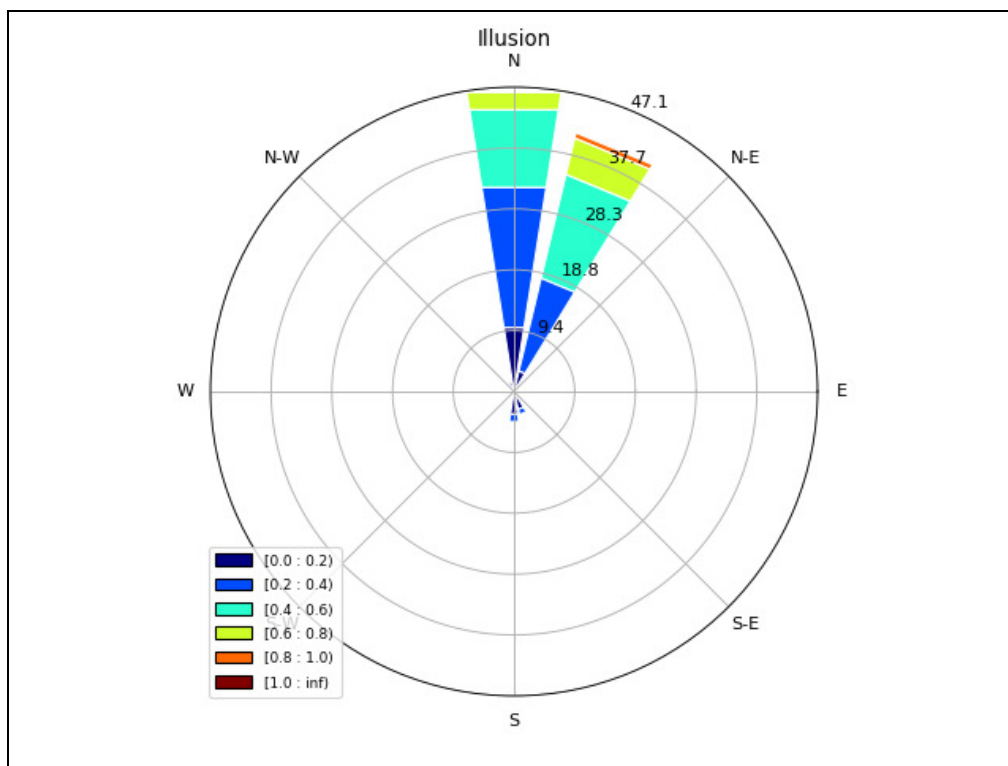
APPENDICES



Frank Pearson descends the Horseshoe Tube in Cave of the Winds

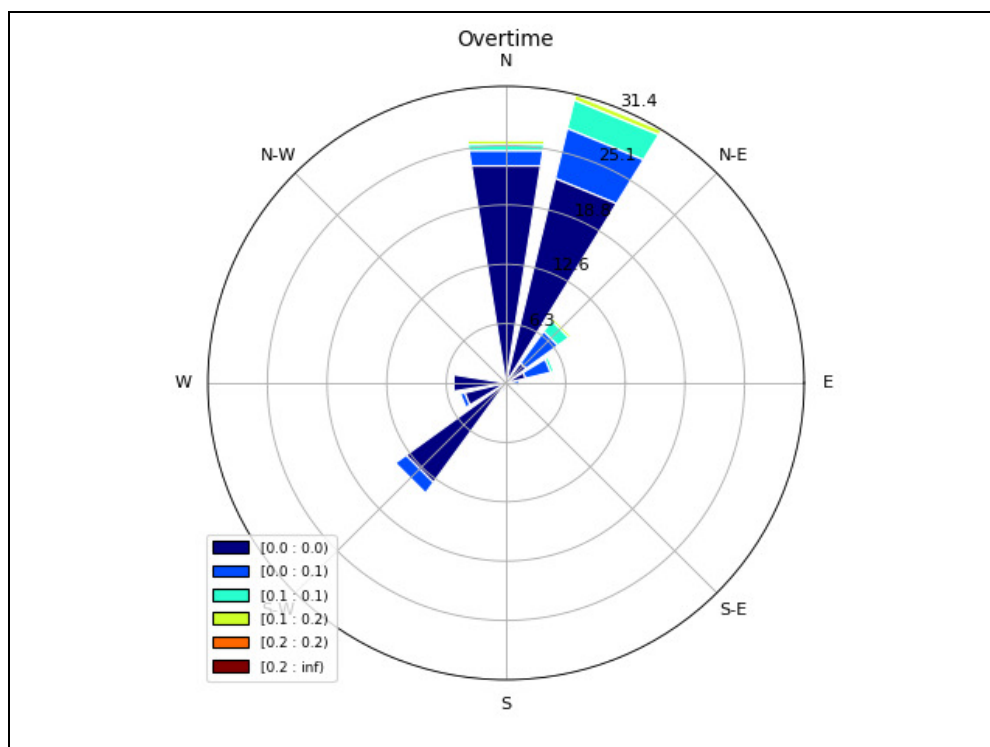
Matt Kirby

Illusion Passage



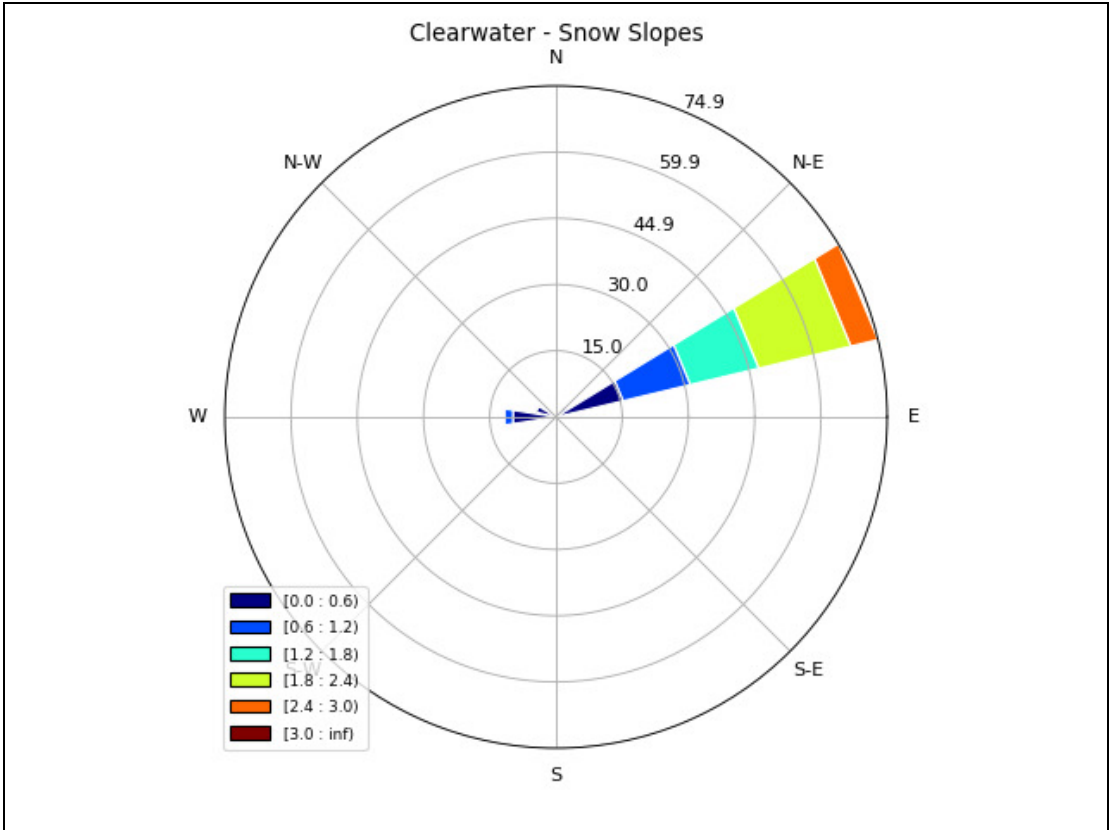
Illusion Passage polar plot showing the predominant airflow

Overtime

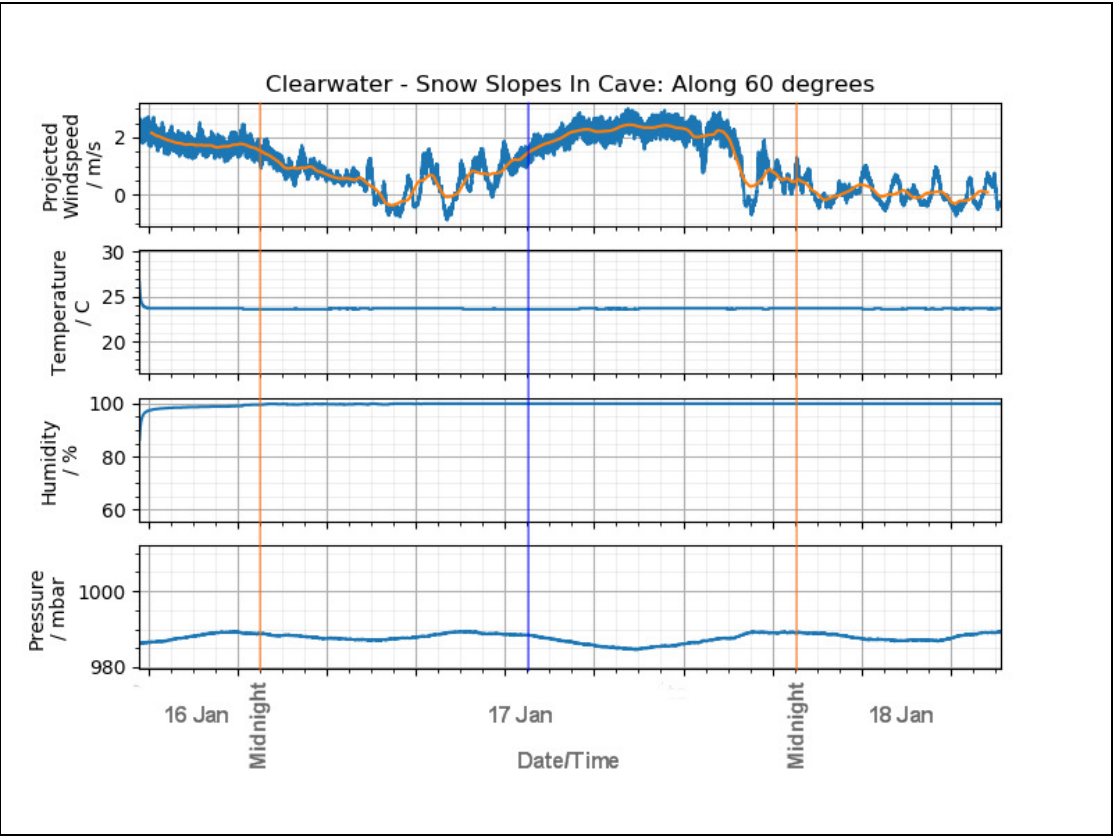


Overtime Passage polar plot showing the predominant airflow

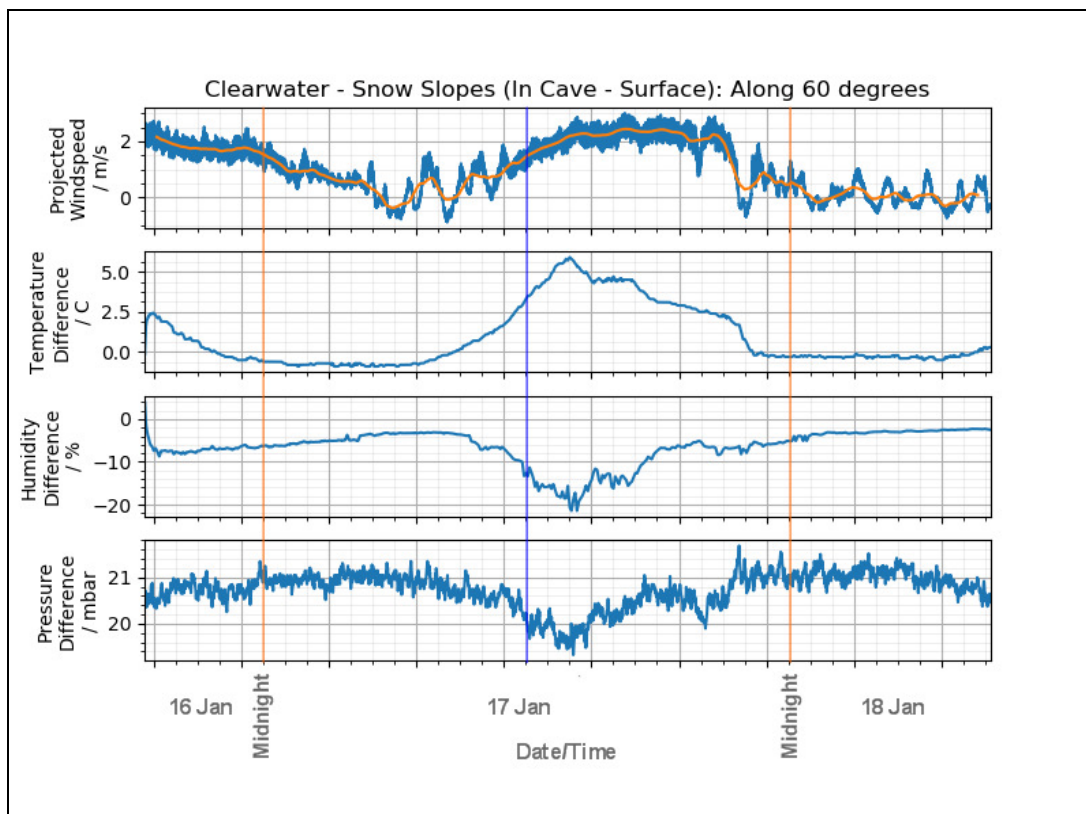
The Snowslopes



The Snow Slopes polar plot showing the predominant airflow

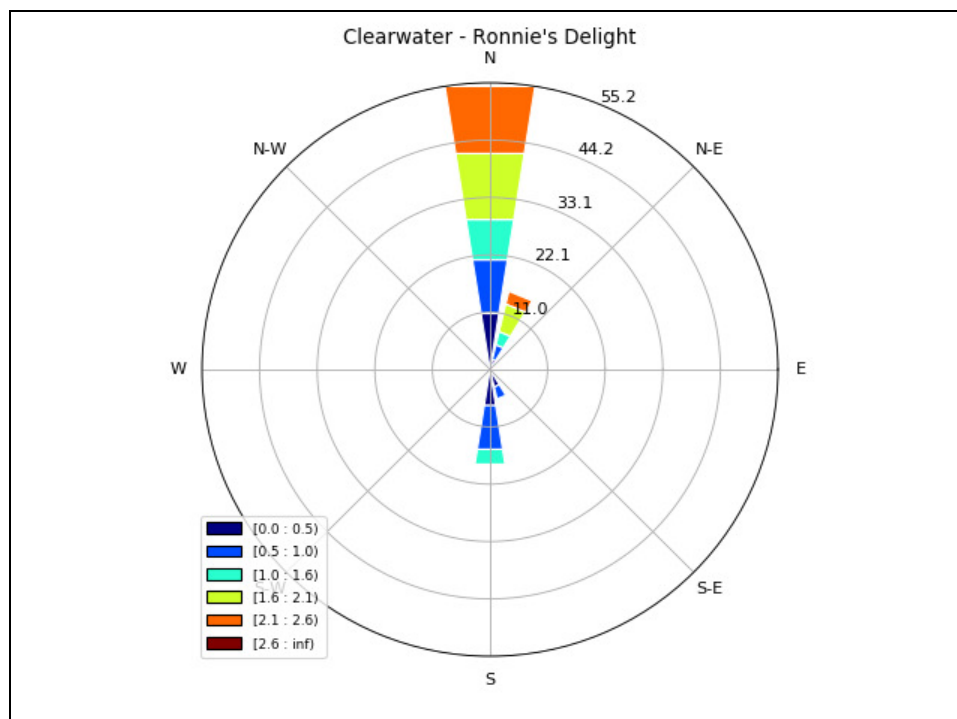


The Snow Slopes airflow compared with 'In Cave' atmospheric sensor

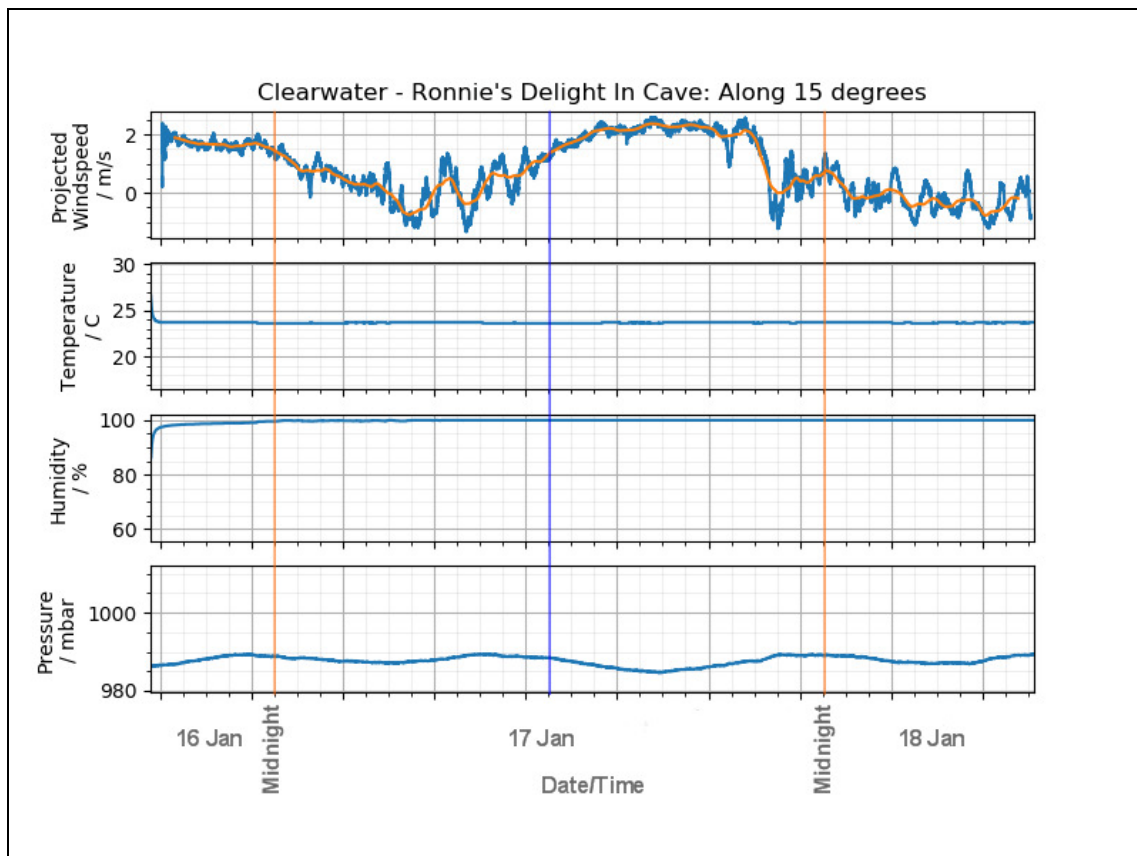


The Snow Slopes plot comparing airflow with the difference between in cave and surface sensors

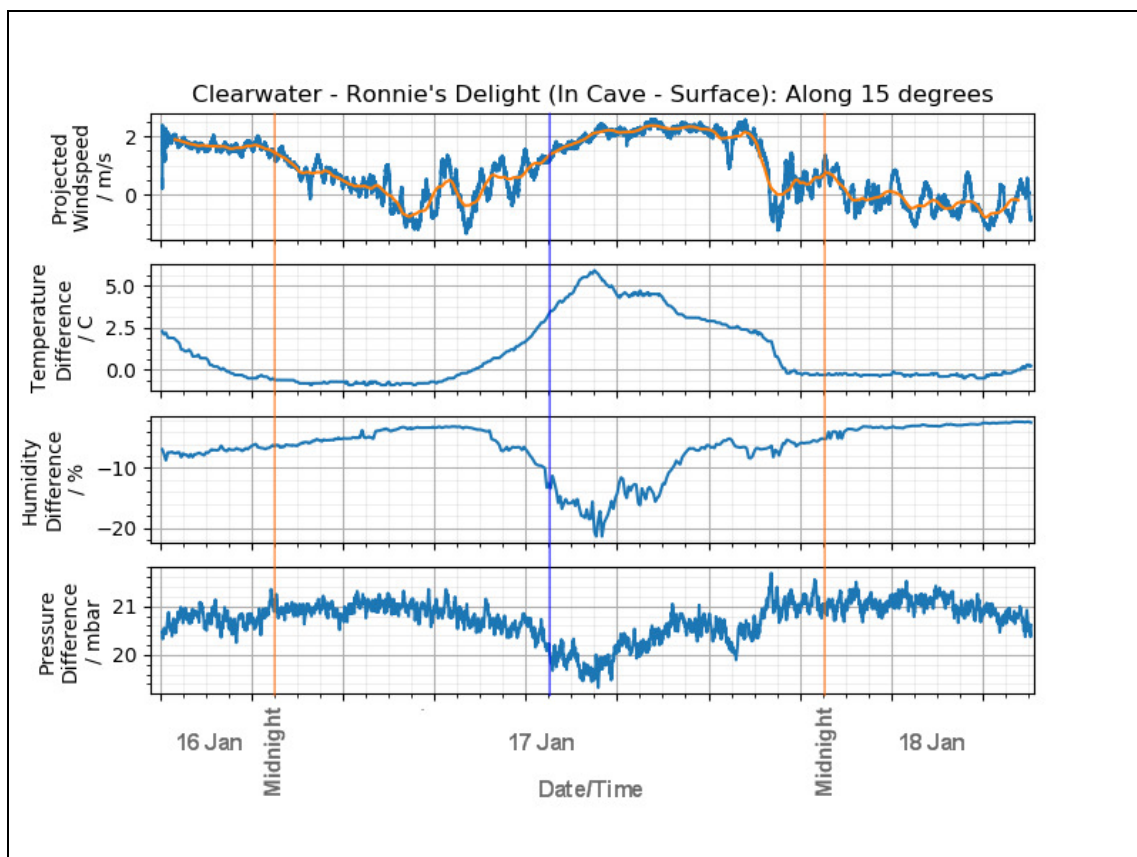
Ronnie's Delight



Ronnie's Delight polar plot showing the predominant airflow

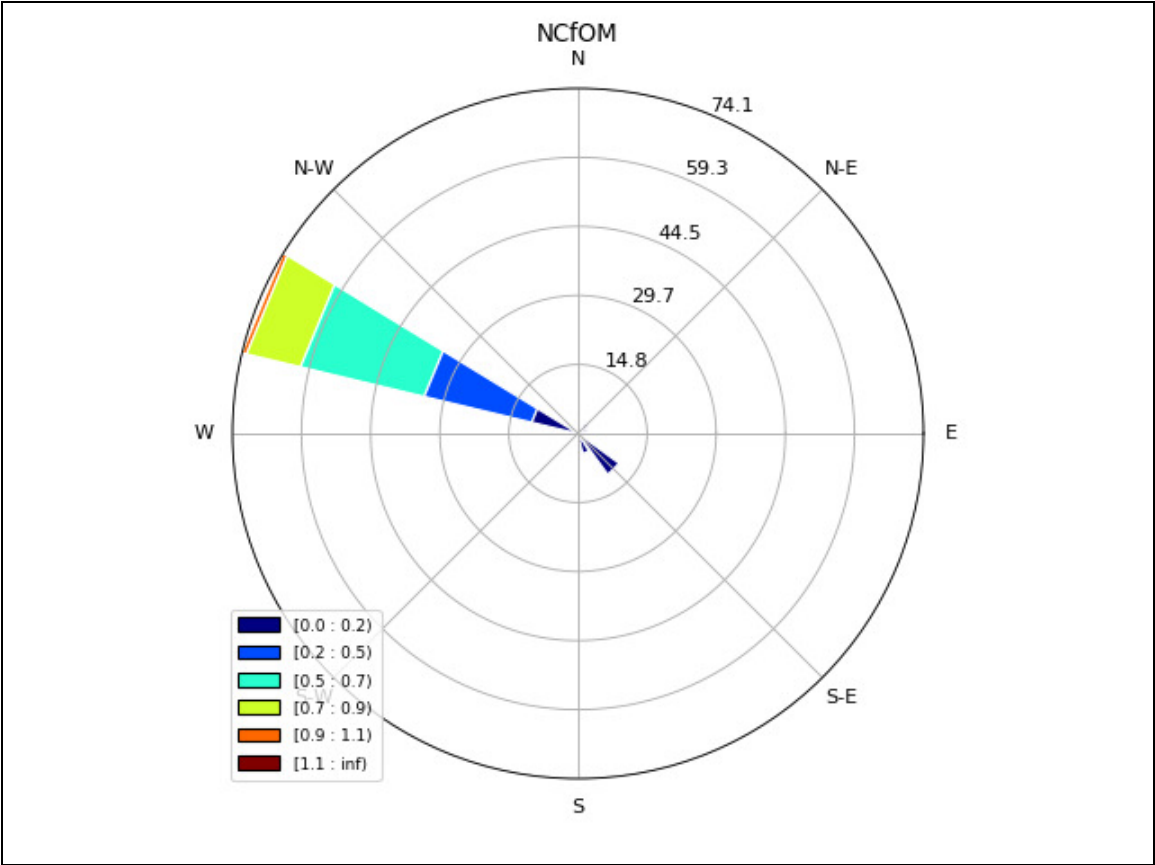


Ronnie's Delight airflow compared with 'In Cave' atmospheric sensor

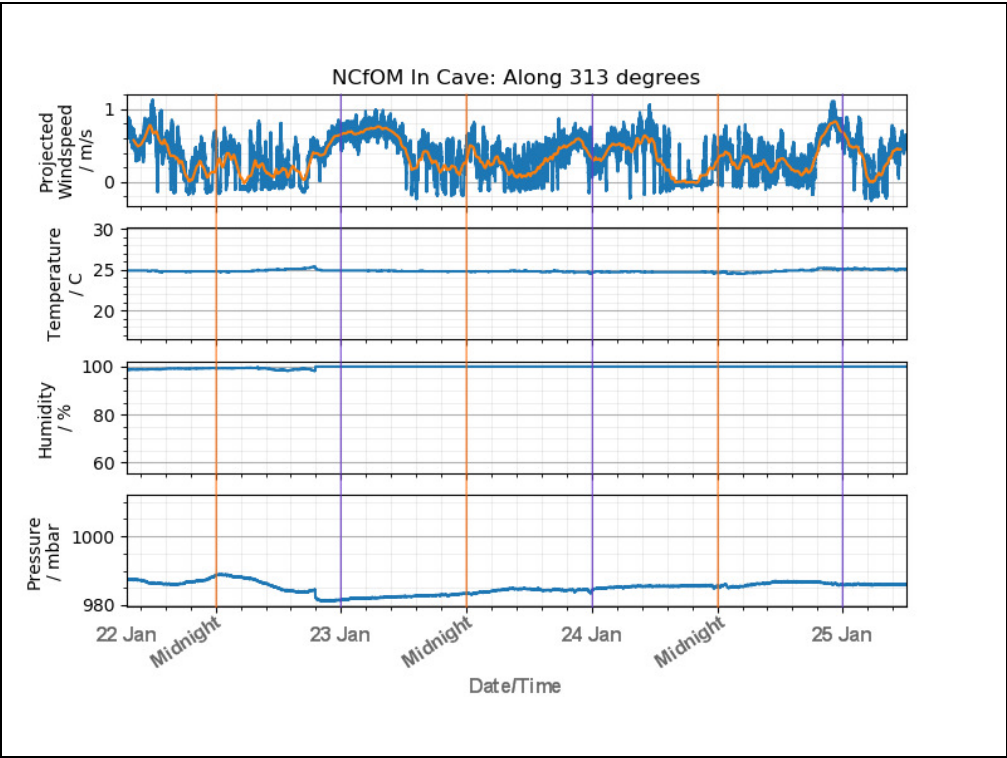


Ronnie's Delight plot comparing airflow with the difference between in cave and surface sensors

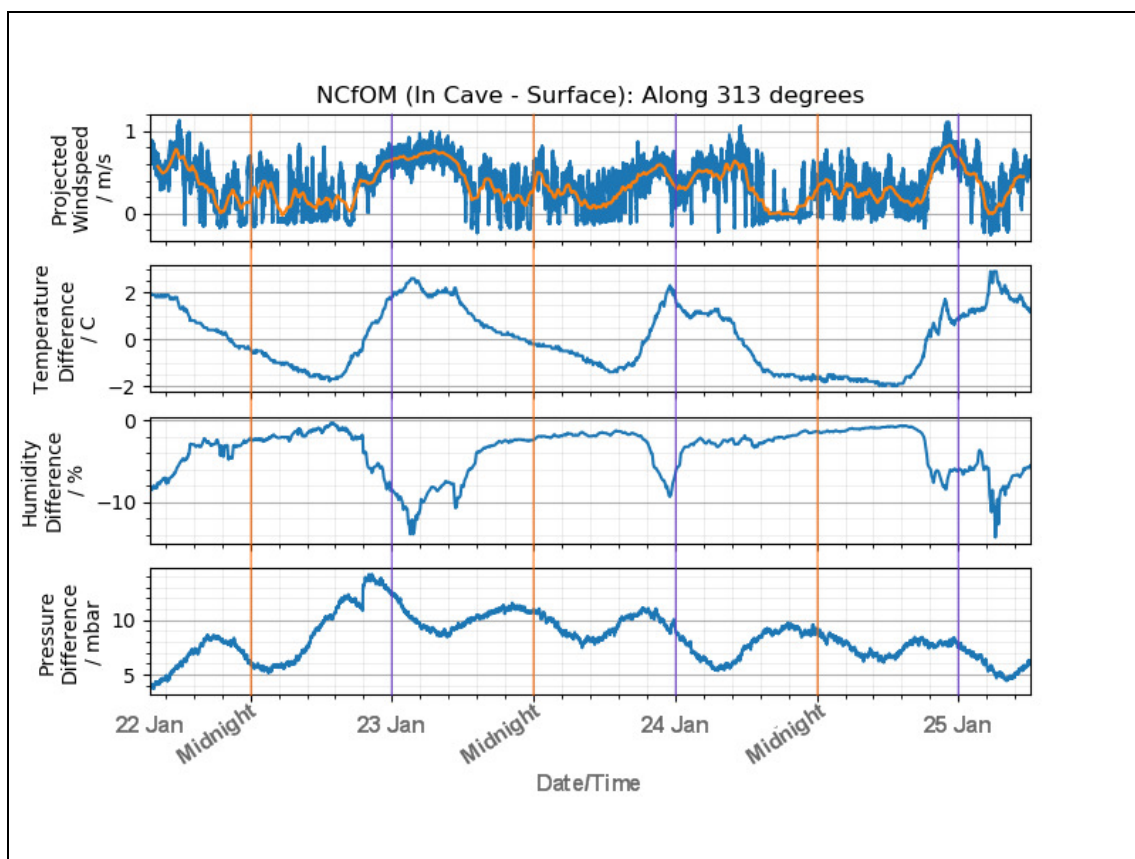
No Country for Old Men



No Country for Old Men polar plot showing the predominant airflow



No Country for Old Men airflow compared with ‘In Cave’ atmospheric sensor



NCfOM plot comparing airflow with the difference between in cave and surface sensors

The resurveying work installed fixed survey stations in Cave of the Winds and Clearwater Cave. These are detailed below:

Cave of the Winds Upper (Dry) Entrance: Fixed Station. No. R003

On the left wall of the entrance looking in, behind the left hand seating area.



Seven Pillars of Wisdom Junction: Fixed Station. No. R004

80m past the last rope Climb in Not Before Time, on left wall on the wall notch just before passage goes into Overtime.



Babel Junction: Fixed Station. No. R005

After climbing up through the choke from Overtime, on left wall of the window looking out into Babel.



Wan Way Street: Fixed Station. No. R006

On the wall of Illusion Passage immediately above the climb down into the connection choke.



Clearwater Main Entrance: Fixed Stn. No. R007

3m south of the viewing platform railing at the top of the steps from the boat landing stage.
Tag in flat-topped bedrock/boulder at ground level beneath drip line.



Balcony Series Junction: Fixed Station. No. R008

On ledge on right wall going upstream, immediately above the second river crossing, just after coming out of the boulder route, and immediately beneath climb into Balcony Series.



Note: 001 & 002 markers were not used during this expedition.

Appendix 3:

The Caves of Mulu

English Name	Malay Name	RGS '78	Mulu '80	S'wak '84	Mulu '88	Mulu '89	Api '90	Mulu '91	Api '91	DWG '92	Recce '93	DWG '93	Api '94	DWG '94	DWG '95	Buda '95	Buda '96
Gunung Api Caves																	
Clearwater Cave	<i>Gua Air Jernih</i>	26330.00	11255.00	14015.00	212.00	15048.50	922.00	2837.80			893.10		160.90				
Cleartop Cave	-	-	-	0.00													
Lady's Cave	-	-	-	0.00		323.80											
Cave of the Winds	<i>Gua Angin</i>	2300.00	4250.00	960.00	59.50			133.70					85.00				
Drunk Forest Cave	-			1300.00													
Blackrock Cave	<i>Gua Batu Hitam</i>				14445.40	6695.00		1207.60									
Leopard Cave	<i>Gua Harimau Bintang</i>		3375.00										344.10				
Watercock Cave	<i>Gua Batu Putih</i>																
Nilong's Cave	<i>Lubang Nilong</i>			0.00													
Lagang's Cave	<i>Lubang Lagang</i>			3900.00													
Water Polo Cave	-		0.00														
Solo	<i>Sendirian</i>	259.00															
Cobra Cave	<i>Lubang Lipah Stileh</i>			3400.00													
Good Luck Cave	<i>Lubang Nasib Bagus</i>		2900.00														
Prediction Cave	<i>Lubang Ramalan</i>	610.00															
Wonder Cave	<i>Gua Ajaib</i>	4770.00															
Conviction Cave	-																
Imperial Cave	<i>Gua Imperial</i>		705.00														
Birthday Cave	<i>Gua Harijadi</i>				200.00												
Noah's Cave	<i>Lubang Noah</i>				425.00												
Python Eat	-				80.00												
Racer Cave (formerly Simons Cave)	-																
Metric Cave	<i>Gua Metric</i>					1072.70	3412.00	320.50	398.00	104.00							
Snail Cave	<i>Gua Supit</i>			80.00		1085.30											
Ipo's Cave	<i>Lubang Ipoi</i>					281.00											
Palm Cave	<i>Gua Sago</i>							233.80									
Damocles Cave	<i>Gua Damocles</i>							686.50	163.00								
No Name Cave	-																
Yellow Viper's Pit	-																
Arch Cave	<i>Gua Gerbang</i>																
Perseverance Cave	<i>Gua Ketabahan</i>																
Bridge Cave	<i>Gua Jambatan</i>																
Cloud Cave	<i>Gua Awan</i>																
Invader Streamway	-																
Tiger Back Cave	<i>Gua Hartau</i>																
Tiger Water Cave	<i>Gua Hartau</i>																
Highest Cave in Mulu	-																
Helicopter Cave	-																
Western Front Cave	-																
Moonmilk Cave	<i>Gua Bulan Susa</i>										115.00						
Snail Shell Cave	-																
Tree Cave	-																
Pinnacle Cave	-																
Bat Cave	-																
Rat Cave	-																
Frog Cave	-																
Penan Pot Cave	-																
Pinnacle Cave No. 2	-																
Pre Repast Cave	-																
Rock Shelter	-																
Lakoh Cave	-																
Shatterbox	-																
White Rift Cave	-																
No County for Old Men	-																
Red Tip Racer Cave	-																
Caim Pot	-																
Moon Rising (Surprisingly Obvious)	-																
Red Leaf Monkey Cave 1	-																
Red Leaf Monkey Cave 2	-																
Gift Horse Cave	-																
Train Cave	-																
Consolation Cave	-																
Doline Sink	-																
Maypole Hole	-																
Easter Cave	-																
Gunung Benarat Caves																	
Moon Cave	<i>Gua Bulan</i>																
Benarat Cavems	<i>Lubang Benarat</i>	1355.00	4870.00	2095.00													
Hurricane Hole	<i>Lubang Taufan</i>																
Cobweb Cave	<i>Lubang Sarang Laba-Laba</i>			15185.00													
Sakai's Cave	<i>Lubang Sakai</i>		1120.00	1525.00													
Tiger Cave	<i>Gua Harimau</i>			3800.00													
David's Cave	<i>Lubang David</i>			439.00													
Deception Cave	<i>Lubang Tipu</i>			1510.00													
Nenagene Cave	<i>Lubang Kumpulan Binatang</i>			1875.00													
Tenkan Rising Cave	<i>Gua Sungai Terikan</i>	775.00															
Tenkan River Cave West	<i>Gua Sungai Terikan Barat</i>	2270.00															
Tenkan River Cave East	<i>Gua Sungai Terikan Timur</i>	3840.00															
Blue Moonlight Bay Cave	<i>Gua Teluk Cahaya Bulan Yang</i>		9400.00														
Deliverance Cave*	<i>Gua Pembebasan</i>																
Gawai Cave*	<i>Gua Gawai</i>			500.00													
Buda Overlook Cave	-																
Hole of the Moon	-																
Paradise	-																
Gardener's World	-																
Little Deliverance	-																
Half Moon Penguin Cave	-																
Batu Terikan Caves																	
Tobichi Cave	<i>Gua Tobichi</i>																
Red River East 1	<i>Gua Sungai Merah</i>																
Red River East 3	<i>Gua Sungai Merah</i>																
Red River East 4	<i>Gua Sungai Merah</i>																
Red River West 2	<i>Gua Sungai Merah</i>																
Red River West 3	<i>Gua Sungai Merah</i>																
Red River West 4	<i>Gua Sungai Merah</i>																
Red River West 5	<i>Gua Sungai Merah</i>																
Red River North	<i>Gua Sungai Merah</i>																
Red River South	<i>Gua Sungai Merah</i>																
Red River S-E 1	<i>Gua Sungai Merah</i>																
Red River S-E 2	<i>Gua Sungai Merah</i>																
Expedition Totals		48949.00	39900.13	52784.00	15421.90	24225.30	4615.00	8083.90	1406.00	1305.00	893.10	1136.00	1405.00	300.00	310.00	25267.00	4979.00
Mulu Area Running Total		48949.00	88849.13	141633.13	157055.03	181280.33	185895.33	193979.23	195385.23	196690.23	197583.33	198719.33	200124.33	200424.33	200734.33	226001.33	230980.33
Clearwater Cave System																	
Benarat Cavems System																	
Tenkan System																	
Cobra - Bridge - Cloud System																	

Mulu '96	Buda '97	DWG '97	Mulu '98	Buda '00	B'rat '00	B'rat '03	B'rat '05	Mulu '07	Mulu '09	Mulu '10	Mulu '11	Mulu '12	Mulu '13	Mulu '14	Mulu '15	Mulu '17	Mulu '17	Mulu '18	Total Lengths
			1476.40											9607.91		5271.45		168.64	88,198.70
																			0.00
																			323.80
														190.90	380.89	1491.05		74.77	9,925.81
																			1,300.00
									93.30										22,441.30
																			3,719.10
						3707.72	17272.96	21986.14	24075.14		13365.11		7947.44		8079.29		4237.47	616.27	101,287.54
													1660.00		1545.35	767.30	1794.38		0.00
																			9,667.03
																			0.00
																			259.00
																			3,400.00
																			2,900.00
42.10																			652.10
																1607.03	12435.58		18,812.61
																467.24			467.24
																			705.00
																			200.00
																			425.00
																			80.00
																	234.05		5,541.25
																			1,085.30
																			361.00
																			233.80
																			849.50
244.90																			244.90
70.00																			70.00
124.00																			124.00
980.50																			980.50
953.10																			1,578.80
6053.30			625.70																9,891.90
2192.50			3838.60																2,209.90
			17.40																618.60
			618.60																296.70
			296.70																1,285.80
			1285.80																280.00
			280.00																30.00
			30.00																30.00
			30.00																184.40
																			112.30
																			27.70
																			316.20
																			219.90
																			266.30
																			76.50
																			0.00
																			185.30
																			26.59
																			0.00
																			0.00
																			83.90
																			381.59
																			556.13
																			16.53
																			279.00
																			1262.00
																			850.00
																			104.00
																			5130.47
																			117.00
																			47.41
																			8.50
																			4127.29
																			781.81
																			4,909.10
																			Api Total
																			305,869.93
																			6635.00
																			3787.77
																			10,422.77
																			8,320.00
																			1,580.30
																			10747.00
																			4414.00
																			102.30
																			2,645.00
																			3,800.00
																			788.00
																			349.00
																			1,510.00
																			1,875.00
																			13,307.00
																			12532.00
																			20.00
																			40.00
																			257.00
																			53.00
																			9,710.00
																			4,954.01
																			596.37
																			2,075.00
																			1775.00
																			20.50
																			2553.00
																			1192.87
																			33.75
																			7.40
																			0.00
																			Benarat Total
																			101,310.60
																			1146.00
																			532.00
																			234.00
																			129.00
																			400.00
																			155.00
																			177.00
																			582.00
																			105.00
																			865.00
																			2,775.00
																			80.00
																			Batu Terikan Total
																			7,180.00
10660.40	26001.67	8955.00	8499.20	23114.47	12246.70	22638.51	24020.96	25857.81	27281.83	2417.58	15157.25	9691.54	8640.87	15471.45	11419.66	22008.32	4237.47	1044.08	510,345.10
241640.73	267642.40	276597.40	285096.60	308211.07	320457.77	343096.28	367117.24	392975.05	420256.88	422674.46	437831.71	447533.25	456164.12	471635.57	483055.23	505063.55	509301.02	510345.10	
																			227,196.25
																			50,669.07
																			32,572.00
																			20,632.27

English Name	Malay Name	RGS '78	Mulu '80	S'wak '84	Mulu '88	Mulu '89	Api '90	Mulu '91	Api '91	DWG '92	Reece '93	DWG '93	Api '94	DWG '94	DWG '95	Buda '95	Buda '96
Southern Hills Caves																	
Bat Cave		0.00															
Daniels Cave	<i>Gua Daniel</i>			900.00													
Deer Cave	<i>Gua Payau</i>	1760.00	400.00														
Deer Water Cave	<i>Lubang Sungai Payau</i>	885.00															
Fat Frog Cave	<i>Gua Katak</i>											1136.00					
Peter's Cave	<i>Gua Peter</i>													300.00			
Fern Rock Cave	<i>Gua Batu Paku</i>								845.00				815.00		310.00		
Green Cave	<i>Gua Hijau</i>	2895.00	550.00														
Langs Cave	<i>Gua Lang</i>	0.00															
Mayday Cave	<i>Lubang Darurat</i>	900.00															
Paris Cave	<i>Gua Paris</i>									658.00							
Porcupine Cave			295.13														
Snake Cave	<i>Lubang Ular</i>		780.00														
Stone Horse Cave	<i>Gua Batu Kuda</i>							2664.00		428.00							
Surface Cave	<i>Gua Permukaan</i>			1500.00													
Pendant Cave																	
Big Cave																	
Wild Boar Cave	<i>Gua Babi Hutan</i>																
Fruit Bat Cave																	
Kervalang Cave																	
Caves in Isolated Batus																	
Campfire Cave	<i>Gua Camp Api</i>																
Gunung Buda Caves																	
Green Cathedral Cave																11800.00	
Lower Turtle Cave																552.00	
Tardis Cave																2541.00	
Loris Cave																	
Roly Poly Cave																2193.00	
Graffiti Cave																422.00	
Snailshell Cave																5830.00	2080.00
Waterworks Cave																	
Twilight Cave																	
Fruitbat Cave																	823.00
Pirate Cave																	2076.00
Buda River Cave																	
Spirit River Cave																	
Biocyclone Cave															1450.00		
Hornbill Cave																	
Babylon Cave																	
Thunder Cave																	
Compendium Cave																	
Bukit Assam																	
Spirit of the Jungle																260.00	
Monkeys in the Mist																159.00	
Sea Breeze																60.00	
Expedition Totals		48949.00	39900.13	52784.00	15421.90	24225.30	4615.00	8083.90	1406.00	1305.00	893.10	1136.00	1405.00	300.00	310.00	25267.00	4979.00
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Clearwater Cave System																	
Benarat Cavems System																	
Tenkan System																	
Cobra - Bridge - Cloud System																	

[illegible]

New Discoveries		
Clearwater Cave		
	quatermass2	129.44
	quatermass_shaft	39.20
	Total	168.64
	Clearwater Cave after Oct '17	88030.06
	Clearwater Cave total after Mulu '18	88198.70
Cave of the Winds		
	horseshoe_tube	36.51
	skylight_rift	38.26
	Total	74.77
	Cave of the Winds after Oct '17	9851.04
	Cave of the Winds after Mulu '18	9925.81
Whiterock Cave		
	dancing_queen	505.27
	ancestor_chamber	111.00
	Total	616.27
	Whiterock total after Oct '17	100671.27
	Whiterock total after Mulu '18	101287.54
Moonmilk Cave		
	soup_dragon	184.40
	Expedition new discoveries	1044.08
	Clearwater System Total October 2017	226336.57
	Clearwater System Total January 2018	227196.25
Resurvey Work		
Clearwater resurvey		
	cotw_entrance_redraw	484.21
	cotw_centreline	1466.28
	cotw_surface_tie_in	6.65
	clearwater_centreline	691.43
Whiterock		
	dr_disto_tie_in	67.03
	Expedition total re-survey work	2715.60
	Expedition total survey work	3759.68

Scumring is probably the best underground camp site in Mulu. With its expanse of flat sediment floor and constant water supply it has been the setting-off point for explorations in Armistice, Creedence, Ronnie's Delight and many other Clearwater sites. The camp is known as a peaceful site with occasional swifts flying past, a light breeze and a trickle of water flowing into a large depression at the eastern side.



The normally dry camp site

Matt Kirby

The name Scumring was chosen as a result of the thin lines of debris which clearly mark the high-tide line of past flood events. These are made-up of small black insect husks derived from swift guano. Although the camp site is clear of guano a mound of this lies to the east on slightly higher ground below an obvious swift roost. Many explorers had enquired about the name; why 'Scumring'? Although on arrival at the camp the scum ring was always present, in the 38 years since the area was discovered, nobody had witnessed its formation. That was to change on 17th January 2018.

Owing to high water levels in the Clearwater Streamway the team had entered the cave via Cave of the Winds; a rather arduous trip of seven hours. The first night was peaceful as normal, aching limbs gained a well-earned rest and everyone slept well. Two of us Mulu veterans suggested it would be great to exit the cave via Snake Track to make a proper through trip, but this was soon kicked into touch. It was hoped that water levels in the streamway would have subsided by the time we exited so there wouldn't be any need to fight our way back out via Cave of the Winds, in fact our boatman was to meet us at the Clearwater entrance in two days time.

The following day the team split up with two heading for Quatermass and the others making the first return to Red Dwarf Chamber for 29 years. A great time was had by all and the groups returned to Scumring after a long day's exploration. Brews of tea were made, food was prepared and the evening meal consumed. There was another brief discussion about heading out via the streamway, "the river level will have dropped by now" said our optimistic leader. The Snaketrack idea was briefly floated again but fell on deaf ears. Everyone retired to their beds for another well-earned sleep.

At 10.30 the group was awakened by a watery roaring noise which filled the chamber. Upon investigation it was found that the normally dry calcite cascade to the north of the site, which leads up to the Ronnie's Delight passages, was a raging torrent of water and two big cascades were entering the pool from above. Scumring was flooding!



The flood starts to fill the pool with water cascading in from the east and north

Ben Kent

The immediate concern was for the instruments which were placed above the cascade. Hugh donned his wellies and not much else and climbed up into the narrow passage, getting a soaking on the way. The news was good but he reported two water spouts entering from above and the tripod was stood in a couple of inches of water; great relief. The Snow Slopes logger was in a similar situation with water cascading down the passage but the tripod was doing its job.

Water continued to pour in for the next hour or so and the pool began to grow. It was soon evident that the camp site could be overwhelmed. So sleep mats were gathered up and moved to the higher ground under the swift roost, not the best site to spend the night. Matt & Mark decided to take their chances and pulled their mats back a few metres in the hope that they could succeed where King Canute had failed.

The pool continued to rise and soon an overflow channel started to run with water, directed to the deep pit to the south of the site where it fell as a waterfall. As time went on this channel became overwhelmed and the overflow split and started to flow down the passage towards the Volcano where it cascaded into another deep pit.



Camp site inundated and the pool overflows, 2m higher than normal

Ben Kent

At about 11.00 our leader said “I guess we’re going out via Snake Track”....yessss! With this much water the streamway would once again be impassable and nobody fancied fighting their way back up through the ‘connection’ to Cave of the Winds.

Fortunately for Matt & Mark their plan worked and they enjoyed a great deal of smugness and a pleasant night on what was left of the flat sediment floor. Unfortunately for the rest of the team a rather uncomfortable night was spent on the rough surface and guano under the swift roost! Dick punctured his sleep mat!

So it came to pass that next morning instead of heading south the team headed north and out via the grandeur of Revival and the Snake Track entrance. There was a slight hiccup at the stal forest near the entrance where neither Dick nor Matt could remember the fine detail of how to negotiate this three dimensional maze but eventually Hugh and Ben found the way and we reached the surface. The track back to the river is on the high ground at the far side of the river. Once found this is relatively easy to follow.

There followed a strength-sapping trek through the forest back to the river but after an hour or so we made it unscathed if not rather dehydrated. Unfortunately our boatman was waiting for us 1km downstream. An attempt was made to follow the river bank but this proved impassable with dense vegetation and much rattan. A passing boat was hailed but just continued on downstream without acknowledging our shouts. The river was still a raging torrent after the previous night’s rain so

swimming downstream was quickly ruled out. Could we back track and find a way over the swampy ground direct to Clearwater? Fortunately just as we were about to set off Jimmy appeared with the boat, the passing boat had alerted him and he guessed what had happened: we were free.



The group exit via the Snake Track entrance series

Matt Kirby

This was indeed a fantastic trip. Not only the return to Red Dwarf Chamber and all the beautiful formations en route but having the chance to cave with a great group of people and to make the seldom-used through trip from Cave of the Winds to Snake Track.

I consider this one of my best Mulu experiences.

With the key expedition objective focusing on cave wind measurement, we were fortunate to be supplied by two of the leading UK companies in environmental monitoring equipment. The cost of mounting an expedition to Mulu is always high, and the extra cost of specialised scientific equipment could have been a heavy burden. The expedition is grateful for our sponsors provision of key items of equipment, and for their support with software and device configuration.



Gill Instruments Ltd. kindly provided one of their WindSonic ultrasonic wind sensors.

The Gill WindSonic is a 2-axis ultrasonic anemometer, providing wind speed (0-60m/s) and direction data in a robust housing. This anemometer has no moving parts, offering maintenance-free wind speed and direction monitoring for true ‘fit and forget’ wind sensing.

The Gill WindSonic is a genuine low cost alternative to conventional cup and vane or propeller wind sensors, with all of the advantages of solid-state ultrasonic technology. With no moving parts to jam, break or wear out, this ultrasonic wind sensor is ideal for use in harsh weather conditions.

WindSonic is a 2-axis ultrasonic wind sensor, providing wind speed and direction data via one serial or two analogue outputs. To confirm correct operation, wind sensor outputs are transmitted together with an instrumentation status code.



In practice the WindSonic was found to be the almost perfect instrument for wind measurement in the Mulu caves. Small, lightweight yet robust, the WindSonic perfectly fitted the Mulu creed of ‘minimal weight’ - only 500g and with dimensions of 142mm x 163mm, one is unlikely to get the same combination of high performance and robust portability with any other device. Perhaps it was a touch of good fortune, but we found that the WindSonic fitted snugly in a BDH container, with room for cables, battery pack, and logger device (see below). This meant a very neat and waterproof package could be carried into the caves, the only external item being a lightweight tripod.

Configuration of the device, specifically setting its sampling rate, is done before any monitoring activity by connecting the WindSonic to a computer and using the provided software. Once completed, the device is ready for transport and use.

We deployed the WindSonic for 9 days in total, the longest fixed location being in the Whiterock entrance where the device operated continuously for 5 days. Performance was faultless, despite the

very high humidity. We were unable to test the waterproofing properties, although the device is rated to IP66. We nearly tested it when the Snow Slopes and Ronnie's Delight locations flooded, and the tripod supporting the anemometer suddenly found itself in 4 inches of rushing water! Fortunately the tripod was sufficiently weighted and didn't capsize. The WindSonic was also found to be swift-proof; on recovering the Whiterock entrance device it was found to be covered in small feathers where swiftlets had collided with the device. But there was no evidence that racer snakes had inspected the instrument!

All in all, the WindSonic proved to be the ideal device for our studies, with perfect performance in Mulu's extreme climate and environment, and hardy enough to withstand all the knocks and scrapes of cave transport and usage.

<http://gillinstruments.com/products/anemometer/windsonic.htm>



R-P-R Ltd. supplied two of their Space Logger S10 logging devices to use in conjunction with the WindSonic anemometers.

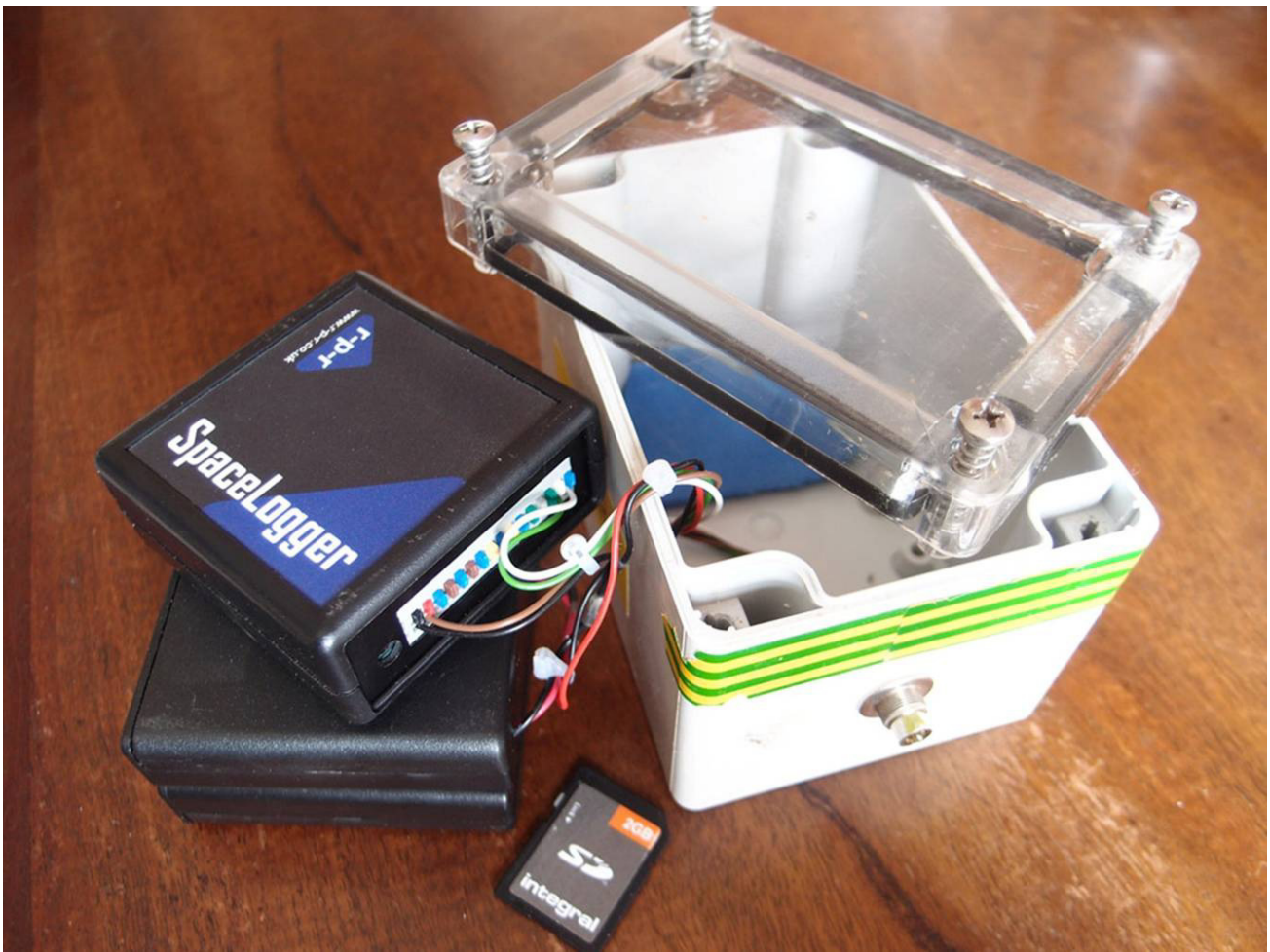
The SpaceLogger S10 is a versatile serial data logger for sampling RS232 data from up to two devices.

Data is stored on a removable memory card (included), enabling remote data logging without the need for direct connection to a PC. After logging, the memory card can be simply inserted in a card reader, to view and analyse the data on a PC; no special software is required.

Each data record combines the data from the two devices or from the two samples from one device. This record is date and time-stamped when it is stored. A new file is generated for each day's data. The default file format is .CSV; other file extensions may be specified.

As with the WindSonic anemometer, the Space Logger perfectly fitted our needs. Small and simple to use, this was another 'fit and forget' device whose only concern for us was that it wouldn't run out of power – drawing only 10mA at 12v, this was unlikely to happen – a simple homemade battery pack comprising 8x 1.5v AA batteries was sufficient to power both anemometer and logger for several days.

The only drawback of the Space Logger is that it is not inherently waterproof. R-P-R can provide a waterproof enclosure, but in the event we decided to source these ourselves – these were designed to house both the Space Logger and the batteries which would power both logger and anemometer.



One nice touch of the Space Logger is that data is recorded to a standard SD card, which can simply be inserted into a computer for download of the data for analysis. Our loggers were supplied with 2gb Integral SD cards – in the event this was rather overkill; 24 hours worth of logging at a 4 second sampling rate output a CSV file under 1mb in size. The Space Logger can collect a lot of data! Nevertheless, the SD card facility makes it very easy to transfer data to computer.

Sealed in their waterproof housings, the Space Loggers performed faultlessly for the duration of the expedition. At 65mm x 65mm x 25mm, the Space Logger is a very compact device and, although not waterproof itself, is easily built in to a ‘cave proof’ enclosure. Full details on the Space Logger’s capabilities can be found on the R-P-R web site. But suffice to say that for our monitoring needs in the Mulu caves, the Space Logger does exactly what it says on the tin.

<https://r-p-r.co.uk/spacelogger/s10.php>

USA caver Mark Jones was invited to join the expedition after Hugh & Matt had made his acquaintance during a visit to the Mammoth Cave System in Kentucky in 2016. Whilst in Mulu, Mark kept a detailed diary which provides a fascinating insight into a first experience of caving in Mulu. It's something all Mulu explorers have experienced but never put into writing. Follow Mark's journey into some of the most wonderful caves on earth.

Borneo

January 2018

Back during the 2016 July Cave Research Foundation (C.R.F.) Mammoth Cave Expedition I met two British cavers, Matt Kirby and Hugh St. Lawrence. We hit it off during the week being assigned to several of the same trips in the park. During our discussions they said that they have done quite a bit of expedition work in Borneo over the past forty years in Gunung Mulu National Park. They talked at length about the fantastic caves as well as the other aspects of the island. I casually mentioned that if they ever had an opening for one of their trips that I'd sure like to have an opportunity to go. Fast forward to the fall of 2017 when I get an e-mail from Matt asking if I would be interested in participating in an upcoming expedition! It didn't take long to respond with an enthusiastic "yes". For the next two months they kept me informed about the trip with updates and recommendations. Soon the framework developed for the January 2018 Mulu Caves Expedition under the auspices of the Mulu Cave Project. Our team would consist of six Brits (Ben Kent, Matt Kirby, Frank Pearson, Hugh St. Lawrence, Nick Williams, Dick Willis), myself as well as Rambli Ahmad of the Sarawak Forestry Department and Veno Enar, our fixer. Andy Eavis of the Union of International Speleology would be in the park during our stay with a group from the Singapore Zoo to do research for a multi-million dollar cave replica.

My adventure began on January 8th at 10:30 a.m. at Chicago's O'Hare International Airport with a fourteen hour flight on All Nippon Airways to Tokyo. From there it was an additional eight hours on ANA to Kuala Lumpur in Malaysia. The trip would extend over the International Date Line so I picked up another thirteen hours on the flight. Needless to say I was very tired when I arrived in Kuala Lumpur at 12:30 a.m. on the 10th. Luckily I had another sixteen hours until the flight over to Miri on Borneo so I checked into the Sama Sama Hotel for a fitful night's rest. At 9:00 a.m. I met up with Frank and spent the next eight hours in the airport waiting for the rest of the team. During this time we solved many world problems, unfortunately we didn't write them down. Nick and Ben soon appeared and took an early flight over to Borneo. It wasn't until after 4:00 p.m. that Dick, Hugh and Matt joined us for the two hour flight to Miri. Everything went off like clockwork and we arrived at the Dynasty Hotel by 9:00 p.m. A quick meal of satay (a sort of shish kabob) at a local establishment and we were ready for bed.

January 11, 2018

The day started with breakfast at a local eatery before Veno took Dick, Ben and me to the Hypermarket to do the grocery shopping. A two week expedition for seven people takes a lot of food and supplies so we grabbed three shopping carts to transport all of the goods. I was amazed at the variety of foodstuffs available and not available. Not surprisingly much of the food originated in the nearby Pacific Rim area but items from the E.U. and the U.S.A. were also for sale. The cost of shipping made buying the U.S. goods out of the range of most consumers in Malaysia – dried cranberries for \$15/pound, a box of cereal for \$10, etc. The entire grocery bill totalled out at 2,241.20 RM (\$600 US). Everything was boxed up for Veno to deliver to the airport to be

transported by airfreight to Mulu. The remainder of the day was spent doing some personal shopping and making plans.

January 12, 2018

A 9:30 a.m. flight had us up and about at seven to check out of the Dynasty Hotel in downtown Miri. Check-in was a breeze and we sailed through security to the departure lounge where Andy and Rambli were already there with the delegation from Singapore. When we were called we hustled down a long corridor and down to the tarmac and onto a turboprop. It would only be a half hour trip so it wasn't quite as formal of a boarding as the other flights. Our stewardess had us seated and we were soon ascending over acres of palm plantations that looked strangely like rows of cornfields in the Midwest. Much of the rainforest in Sarawak has been timbered resulting in ugly scars on the hillside while across the border in Brunei swaths of primary rainforests still remain. Low-lying clouds obscured much of the scenery and resulted in the captain waving off on the landing for another go-around. This attempt was also foiled so we headed back to Miri to await better conditions. With hopes of a later flight we sat down in the departure lounge for a quick snack and soon we were harkened back to the tarmac. The crew had been changed and once again we were back in the air. Our steward was a very animated fellow who was confident that the pilot, a local flyer, would have no issue with delivering us to Mulu. Indeed we were on the ground in no time and grabbing our luggage and boxes of food to load in a truck that whisked us down the road to the roundabout at the entrance to the park.



Arrival in Mulu

Matt Kirby

After unloading gear at our chalet (a modern two-bedroom bungalow) and having lunch at the Mulu Café we stopped by the research centre where we sorted out equipment needed for our expedition.

By three o'clock two teams had plans for the day – Hugh, Frank and Ben would nip on up to Moonmilk Cave to investigate a nearby entrance lead and survey the passage while Matt would initiate me to Mulu with a hike up to Deer Cave. Dick and Nick would stay behind to prepare equipment for later in the expedition.

Deer Cave, a popular attraction in Gunung Mulu National Park with the general public, is a four kilometre hike on a wooden boardwalk from the park headquarters. The boardwalk is elevated a meter over the swamp giving a good vantage point into the dense mass of greenery. Insects abounded as well as a fair number of skinks and even a chameleon. After crossing the Melinau Paku (a river) we immediately arrived at the base of the limestone mountains. Further up the trail we detoured up a steep staircase a hundred meters to see Stone Horse Cave. As often happens, this cave was discovered by chance rather than on purpose. A cool breeze emanating from the fifteen-meter diameter entrance wafted down the valley prompting a curious visitor to inquire about its source. When an intrepid climber pushed up the nearly-vertical slope he was rewarded with this hidden gem. We only popped under the dripline for a quick peek, but it extends for quite a ways.

Returning to the main boardwalk we ambled up past Deer Water Cave, a flood resurgence for Deer Cave that does not humanly connect. Winding along the trail we eventually reach a clearing with seating for the evening bat flights. Several people were milling about waiting for the show. The awe-inspiring southern entrance is in a sheer limestone mountain that abruptly rises out of the jungle. Actually there are two jaw-dropping entrances separated by a significant pillar, the upper entrance on the right and the stream level off to the left. As we grew closer the first cave swifts darted around navigating by loud clicks. This form of echolocation serves them well in the massive caverns on the island. Under the dripline we were surprised to find a red postal box to mail postcards. Unfortunately we weren't aware of this service so I couldn't send a postcard from this cave. (I have sent postcards from the Big Room in Carlsbad Caverns in New Mexico.) Hiking along the stream it became obvious I was in for a treat. The width of the passage is more than the length of 99% of the Iowa caves on record. The dimensions of the caves in Mulu are irrelevant when compared with nearly every other cave I've had the pleasure to explore. Suffice it to say that the leads here are often time borehole with no end in sight.

Shining our lights into the water we spooked several small carp that quickly swam away. The unmistakable odour of guano wafted in the breeze and soon we were climbing an impressive slope covered in guano. The pile was alive with cockroaches that scurried under our headlamps beam. Flies of all sorts swarmed to the light resulting in my ingestion of same. Matt pointed out a feature from a balcony looking back at the upper entrance that was a perfect profile of the 16th president of the United States. I normally would poo poo such a claim but it was indeed an uncanny likeness of Abraham Lincoln. For the next several hundred meters we followed the undulating boardwalk past vast guano piles to an overlook of the northern entrance five hundred meters away. With plenty of time we decided to scramble down the slope to follow the stream up to that entrance. Once again we were traveling among huge guano deposits that offended my senses. It was here that we spotted the biggest earwig I'd ever seen. Normally these parasites cling to the seldom-seen naked bat (*Cheiromeles torquatus*) but occasionally they fall to the ground and attempt to get back up the ceiling. Often times you don't know they're present until you feel them climbing up your neck. Thankfully this was the only one that we noticed. To make the journey more entertaining the floor was covered in sizable breakdown blocks in the stream that we had to weave through. As we approached the daylight the Garden of Eden, a limestone bowl several hectares in area, beckoned to hearty explorers. The park offers day trips to this natural wonder for the more adventurous visitors. We finished at a cobble-strewn beach a hundred meters wide at the edge of the water. All of the stories about Deer Cave can't describe the enormity of the passage in one of the world's largest

caves. Can a cave be too big? That's for somewhere else to decide, I'll just remember this as my first cave of 2018!

On the return trip we heard the roar of the rain falling indicating that the bats wouldn't be flying and that we'd be slogging four kilometres back to park headquarters. That's the price you pay for caving in Borneo.

January 13, 2018

Cave of the Winds

The second day of the Mulu Cave Project began with a nice breakfast at the Mulu Café before loading our gear in a longboat for a four-kilometre journey upstream. Since the rain hadn't stopped since yesterday afternoon the Sungai Melinau was running very high and very brown. The longboat is just what the name implies – a seven meter long boat that is wide enough for one person that can accommodate up to eight adults. After a brief safety lecture (Don't fall in.) we donned our life vests and were off. We passed the Penan settlement of Batu Bungan in addition to several scattered buildings on the left while the Gunung Mulu National Park was on the right. The Penan people were an indigenous tribe of nomads that wandered the area until the park was created. Since then they have lived along the banks of the river and working in the park. Many of the park personnel and guides were Penan. Above Batu Bungan the river hugs the base of the limestone cliffs adding to the already spectacular scenery. We whisked by the river-level entrance to Cave of the Winds and soon were pulling up to the jetty for the Cave of the Winds trail. Waving farewell to our boatman we hiked up the boardwalk to the upper entrance of Cave of the Winds.



Heading upstream to Cave of the Winds, first longboat trip

Matt Kirby

For today's objectives we split into two groups of three – Hugh, Matt and Frank would be setting permanent stations and erecting two anemometers while Ben, Dick and I would be using the Disto-X to establish a line plot of the cave. Once the particulars were sorted out we were off to the races. Dick set stations, Ben recorded data with a PDA and I would be shooting the Disto-X. Using a Bluetooth connection Ben was able to sync the two devices and download the three readings from each station for greater accuracy and efficiency. From the dripline we followed the tourist trail to the King's Chamber being careful to avoid the magnetism of the railing. There were many nice formations along the route but a fifty-meter high skylight before the King's Chamber was the most impressive to that point. At the beginning of the King's Chamber we detoured off the balcony to start of the Adventure Caving experience in The Not Before Time passage. The size and scale of the passage is simply indescribable so I won't even try. Suffice it to say that often times the walls and ceiling were at the limits of our lights. For the next four hundred meters we were scrambling up and down boulder slopes using an occasional handline until reaching a balcony ledge on the left. We stayed at this level (Overtime Passage) for another four hundred meters passing many formations that reminded me of the grotesqueries on Isla de Mona in Puerto Rico. A surprising breakdown slope actually forced us to remove our packs and wiggle up into the Illusion Passage. I was not prepared to be overwhelmed when I popped into this massive room – a hundred meters floor to ceiling, wall to wall! Off to the right was the gigantic Babel Room with kilometres of cave beyond. After a lunch break we turned left and crossed an expansive breakdown field for the next four hundred meters on the way to Wan Way Street. This entire section was decorated with a dense forest of the most interesting columns and totem poles I've had the pleasure to see. With time running out we tied off the survey and retraced our steps to the jetty.

Arriving a bit early for the boat Matt, Hugh, Ben, Frank and I hiked three hundred meters on the catwalk above the Sungai Melanau over to Clearwater Cave. In spite of its name the recent precipitation had Clearwater Branch running deep and dirty out of the spring entrance. We ascended the nearly two hundred steps to the top of backslope entrance to Clearwater Cave. An equal number of steps descended on the other side so Frank and I opted to stay up top while the others nipped on down to reconnoitre the water level for tomorrow's trip. We returned to the dock at 5:30 p.m. to find our boatman ready to depart so we hopped on board for the fifteen minute ride back to park headquarters. We dined at the Mulu Café that evening to celebrate Frank's birthday with ice cream and big plans for the morning.

January 14, 2018

Clearwater Cave

The past few years I've been celebrating my birthday caving with Cave Research Foundation (C.R.F.) in Missouri but for my 58th birthday I would be breaking that streak since I was with the Mulu Cave Project in Gunung Mulu National Park on the island of Borneo. The day's objective was to continue the line survey from the Clearwater entrance and connect to yesterday's survey and collect the anemometers as well as putting in some additional permanent stations. After a late breakfast we packed up our gear and met the longboat at the dock at 10:30 a.m. Once again we'd be going upstream but today we would be dropped off at the Clearwater Cave jetty. The river was running a bit clearer and lower with an occasional boulder or gravel bar visible. In no time we were deposited at the dock with a return trip scheduled for 5:00 p.m.

Scaling two hundred steps we topped the rise where I marvelled at the floral-covered stalactites stretching over a hundred meters wide. Over the years I've seen untold algae-coated stalactites at entrances but never this much greenery. Of course this is one of the most expansive entrances I've ever encountered. Today Ben and Hugh would be surveying the line plot while Matt, Frank and I would be sinking permanent stations and route finding. We dropped back down the stairs to stream level in what has now become "standard" passage in the park. By standard I mean from twenty to

forty meter diameter borehole with significant balconies scattered along the walls with an impressive skylight thrown in for good measure. A swath of interesting phytokarst on the wall had been formed by the sunlight focused through the entrance opening in the twilight zone. The new twist was that we would be weaving in and out of a respectable river in flood for several hundred meters. Over the years the water has scoured the bedrock razor sharp forcing us to move cautiously. Handlines were set along the route in several places making it safer on some of the trickier terrain. At the first water crossing the river was running chest deep which didn't bode well for the next crossing. When we reached the Balcony Series it was obvious that it would be unwise to attempt fording the river since the water was running both deep and swift.

A route through the Balcony Series to connect with yesterday's survey was indicated on the map but alas after ninety minutes of fruitless searching we were stymied. The most amazing aspect of these balconies was the deep conglomerated river cobble far above the streambed below. Regrouping we decided to abandon from this direction and hike back out and to retrieve the anemometers from the Cave of the Winds entrance. Ben and Frank volunteered to pick up the equipment while Matt and Hugh would show me the King's Chamber. This roundabout at the end of the tourist trail circles around a photogenic collection of grotesqueries and totem poles along with some nice stalactites. It was only a short while before Ben and Frank rejoined us for the trip back to the dock. We met our longboat at 5:00 p.m. and were ferried back to park headquarters to clean gear and shower. Once again we dined at the Mulu Café followed by birthday ice cream. What a wonderful way to spend your birthday!

January 15, 2018

Canopy Walkway

Rambli Ahmad of the Sarawak Forestry Department took the time to give a small group a guided tour of the canopy walk in Gunung Mulu National Park. This four hundred meter loop starts at a wooden tower and runs from tree to tree in a series of suspension bridges. We had a nice morning to wander but very few creatures were stirring. The view from ten meters up gave a great vantage point of the jungle below. Signage provided good information about the trees and some of the wildlife found in the park. We spent ninety minutes enjoying the casual pace of the tour.

Deer Cave

Having missed the evening bat flight earlier in the trip I took the opportunity to hike back out to Deer Cave in Gunung Mulu National Park accompanied by Rambli and Dick. A lively discussion made the four-kilometer boardwalk hike go quickly. We arrived at the viewing area at 5:00 p.m. as the sun began setting behind the mountains. Half an hour later the first few of over two million bats appeared as "wisps of smoke" against the blue sky much to the appreciation of the thirty people below. Small clusters of bats, perhaps five hundred to several thousand, trickled out building up for the grand finale of a stream of untold bats. We weren't the only ones interested in the spectacle as two bat-hawks weaved through the throngs of wrinkled-lipped bat (*Chaerephon plicata*) to snatch a meal. Certainly this rivals the bat flight at Carlsbad Caverns in New Mexico.

January 16, 2018

Cave of the Winds

Gunung Mulu National Park

The plans for the next three days was to push deep into the Clearwater Cave system to establish a base at the Scumring camp and explore and survey in the Red Dwarf Chamber before leaving through the Clearwater entrance. The return trip would be dependent on the water level in two days as high water would preclude exiting through Clearwater. Each of us would be lugging eleven to fifteen kilo packs filled with personal gear, food, vertical gear and anemometers. Rambli Ahmad, Ben Kent, Matt Kirby, Frank Pearson, Hugh St. Lawrence, Dick Willis and myself arrived at the longboat at 9:30 a.m. for the fifteen minute ride up to the Cave of the Winds landing where we

disembarked for the short hike up the boardwalk to the entrance. Having visited the cave twice in the past few days we were well-acquainted with the boardwalk out to the King's Chamber. From here we followed the Adventure Caving trail through The Not Before Time Passage, Overtime Passage, Illusion Passage and Wan Way Street. A huge breakdown pile appears to be the end of the line but back in 1989 a group of British cavers spent two days poking around this chamber before finding a squeeze along the left wall that slalomed down twenty seven meters to join Clearwater Cave. It took us quite some time to pass packs down through the Connection Choke to the rope ladder at the very bottom and the beginning of King Seth's Maze. When this passage was discovered a British cave biologist was chased by a particularly aggressive cave racer snake and so was named after a snake character from a comic book (AD2000) of that era. Soon we were in the undulating mud mounds of Hyperspace Bypass and on through Infinite Improbability Drive.



Mark and Rambli in the Snow Slopes above Scumring Camp

Matt Kirby

I'd soldiered along quite nicely until this point but the extensive boulder fields sapped my energy rather quickly. The most frustrating aspect of caving in Mulu is the fact that we're often in gigantic passage but are relegated to caroming among never-ending mountains of rock. Thirty meter diameter passage isn't any better than a Missouri bellycrawl if you have fight for every step. Needle-sharp rocks tore at our boots, slick mud slopes challenged our footfalls and loose scree disappeared underfoot. Another downside is the fact that it takes so much energy to deviate off-trail to investigate any lead. Even on Isla de Mona I never sweated as much as in the caves of Mulu. With a mean temperature of 23.7 Celsius and a 100% humidity I was drenched from head to foot whenever on the move. At this point I was questioning the sanity of these British cavers. Slogging away for the next hour we eventually reached Junction Cavern. This is a significant point where one can choose to exit through the Cave of the Winds entrance, Clearwater entrance or take Revival

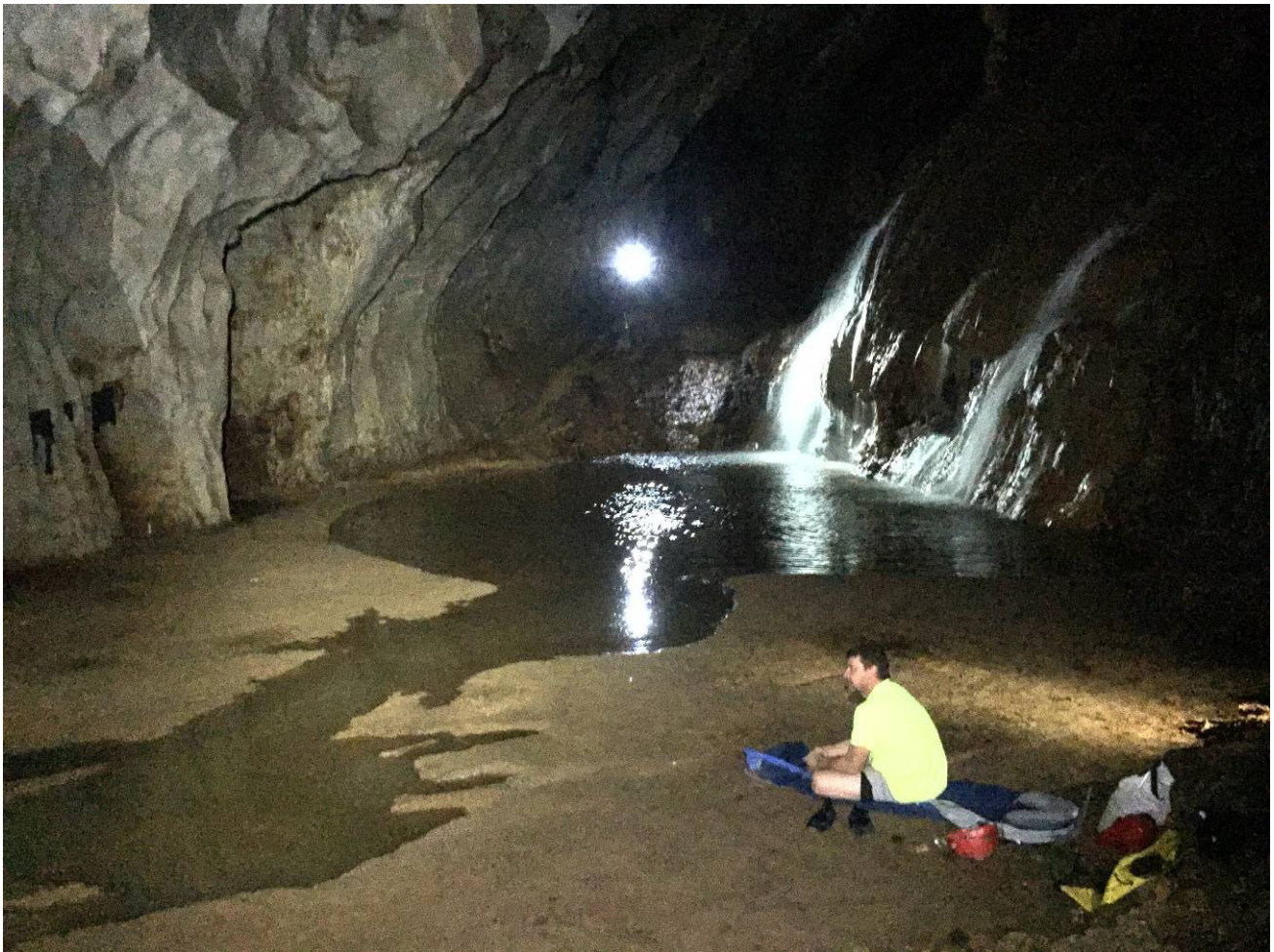
Passage out to the Snake Track entrance. In this area was an impressive flowstone mound perched on a five-meter high rimstone terrace covered in a thick, brown mud. We picked up the Revival Passage on the way to the Volcano Series where we negotiated up the largest breakdown slope of boulders that I've ever seen in a cave. At over a hundred meters high and at an acute angle it seemed to take forever to ascend. Thankfully we were almost to our objective of Scumring camp. Just fifteen minutes around a corner was the unusual mudflat of Scumring where we'd be based out of for the next couple days. The room itself was forty meters long by ten meters wide with a twenty meter ceiling. Off to the right a trickle of water dribbled down a flowstone wall into a two-meter deep pit 10 meters long by 2.5 meters wide that disappeared down a small drain. During heavy rains the pool overflows leaving a bathtub ring of debris, hence the name. Everyone staked out a site for their sleeping bag and personal space with a common kitchen area in the middle. Cave swifts darted about overhead constantly chirping their presence. These birds use a form of echolocation to navigate through the caves often building nests far from any entrance as is the case here. An evening meal of ramen noodles and tuna was taken at 8:00 p.m. before people began drifting off to sleep. After three kilometers of energy-draining caving it didn't take me long to fall fast asleep.

January 17, 2018

Clearwater Cave

Gunung Mulu National Park

Camp began to stir at 8:00 a.m. with a hot meal cooked up before heading out to the objectives. Dick would be staying in camp, Frank and Hugh were going to continue some exploration from 2017, while Rambli, Ben, Matt and I would be pushing on toward the Red Dwarf Chamber. From Scumring we ascended a handline ten meters to the aptly Snow Slopes. Actually the huge white mounds were not snow but fluffy piles of cave swift guano. The soft slope reminded me of the gypsum crystal floor in the Talcum Passage in Carlsbad Caverns. From the massive mounds it's obvious the cave swifts have been utilizing this passage for many centuries. Eventually we got to a vertical climb that we were belayed up to access the upper levels. Very few formations were noted in the Snow Slopes but that all changed now. A nice variety of columns, drapery, stalactites and stalagmites pulsed down the passage until we scramble up a hundred meter breakdown slope into Armistice Passage. Words cannot describe the length and breadth of the boulder field from this balcony overlook. It took an hour to navigate through the jumble of rock littering the floor. The boulder fields continued for another two hundred meters to the "Y" Frontier. The story goes that to drop a thirty meter pit fifteen meters in diameter sections of rope formed a "Y" for the climb down to the Cairn Farm. Currently this is the only known route to this portion of the cave. Standing there on the lip of the pit it is unthinkable the amount of planning, hauling, rigging and de-rigging just to check this one lead. More boulder field lay ahead until we reached the Road To Hell. For the life of me I can't understand why it was given that name because it was the most decorated part of the cave that I've seen. According to Matt there has only been one other group to this part of the cave on the discovery and survey trip in 1989. Stalactites, stalagmites, columns, totem poles, drapery, helictites, gypsum needles, popcorn, soda straws, flowstone, pool crystals and more were everywhere in a rainbow of colours. The beauty in this area certainly puts it in a league of its own. I opted out of dropping down a handline to the Red Dwarf Chamber while the others forged on to look for leads. I spent the time photographing some of the fabulous formations surrounding me. An hour later they returned with news that no new discoveries were made. We retraced our steps back to Scumring for a well-deserved meal after a three kilometre roundtrip. The rest of the party was already in camp with hot water on the stove for drinks and dinner.



Camping beside the rising waters at Scumring

Matt Kirby

Following a quick cleanup I was off to bed with high hopes of exiting through the Clearwater entrance rather than hefting our packs back up through the Connection Choke on the way to the Cave of the Winds entrance. I was soundly asleep when I saw the lights of the others waving around a substantial pool that an hour before was empty. Removing my ear plugs I heard a waterfall rumbling that had replaced the tinkling dribble. Evidently a substantial rainstorm had set in giving us a rare view of the Scumring pool overflowing. Numerous photos were taken of this impressive event. Unfortunately we had to move our bedding and kitchen to avoid being drowned. Matt and I challenged the water by remaining at a lower, muddy level while the others took to higher, rocky ground. In hindsight we made the right choice since the water crested just shy of our sleeping bags while the others endured the rocky ground under the cave swift nests (and their droppings).

January 18, 2018

Clearwater Cave

Gunung Mulu National Park

After the deluge the previous evening it was obvious that the Clearwater entrance would not be an option and the Connection Choke would be too taxing so it was decided to use the Snake Track entrance. Although an unfamiliar route it would be substantially easier than wrestling packs through squeezes. But the drawback was the fact that there would be a three-kilometre trek through the jungle back to the Sungai Melinau to meet the longboat. We broke down the Scumring camp at 9:00 a.m. and were on our way out by 10:00 a.m. It was a slow and tedious process descending the steep hundred meter boulder slope to the Revival Passage. Unlike the boulder-strewn Infinite Improbability Drive we were strolling down a relatively easy muddy floor for much of the way in Revival Passage.



Arrival back at the Melinau River after a long, hard trip

Matt Kirby

Not that we didn't have plenty of climbing and scrambling but it all seemed a bit too easy until we reached the Edge of the World. A very steep scree slope forced us to move singularly down the incline to the Snake Track Passage. After fifty-two hours underground I was getting entrance fever and ready to get back to the bungalow at park headquarter. Up ahead Matt spotted a shaft of light high above from a skylight indicating that we were close. Unfortunately no one had been in this area for quite some time and the final hundred meters to the entrance was well disguised. Finally Hugh was able to find the pinch and we were out into the jungle.

Since Rambli had a park radio we called to inform them of our plans and scurried down to the floodplain below. By this time I had figured the hardest work was behind us but how wrong I was. It seemed like we walked forever in a hot, humid green maze of spiky rattan and fetid undergrowth over slick swampy ground being pursued by all sorts of biting bugs. I'd run out of water but the others shared what they had left to keep me going. At one point I felt a little like Humphrey Bogart in *The African Queen*. By the time we reached the river I was completely spent and collapsed on the bank. I drank the last of Matt's Tang before washing up in the water. About this time Ben announced that he had a leech which caused me to scan my body for the same. I didn't see any of these parasites so felt pretty smug. Luckily a passing longboat notified our boat where we were and soon we were onboard. Just before docking at park headquarters I discover I was dripping blood from my shin, a sure sign of leech activity. I didn't feel a thing. When I got back to the bungalow I found another leech had just detached from my other shin! I quickly dispatched him but still bled for another half hour. Dang these guys are stealthy! This was an epic trip in every sense of the word. Thankfully tomorrow we'll be preparing for the week at Camp 5 so I'll have a chance to recuperate.

January 19, 2018

Gunung Mulu National Park

A day of rest was in order to prepare for our second week in Gunung Mulu National Park at Camp 5. I caught up on trip reports and photo editing before stuffing my packs for the seven days upriver. Veno had the porters carry the food and bulky supplies up ahead to be waiting at Camp 5. There's a lot of preplanning that goes into an expedition of this type and over the past forty years the Brits have refined their trips to be more efficient with their time and talent.

January 20, 2018

Gunung Mulu National Park

Breakfast at the Mulu Café was followed by a final check of our gear before handing off the bags to our porters. Besides the obvious benefit of not having to carry a heavy load by using porters we were supporting the local economy and providing them with a good cardiovascular workout. The day before they had lugged our food and other staples up in preparation for our week in the bush. Six healthy young Penan men grabbed our packs and set off for the longboats for the sixteen kilometre journey up the Sungai Melinau to the trailhead to Camp 5. Veno Enar, Ben Kent, Matt Kirby, Frank Pearson, Hugh St. Lawrence and me jumped in one boat while the porters with our gear piled into a second craft. As we were heading upstream several boats were returning with tourists from their two-day adventure to the Pinnacles. More about that later. Our boat beached on a steep mudbank where we disembarked and Veno hopped into the other longboat. Veno's knowledge of the river allowed him to push deeper into the jungle where they'd catch up to us with our gear. Immediately we were immersed in the rainforest on a well-worn but basic trail for the next nine kilometres. A pace that would impress an Olympic sprinter was set as we covered ground at quick clip. Most of the trail was covered in rounded river cobble, tree roots, decaying leaves and a thin soil. Occasionally wooden planks were laid in some of the muddier sections. I was very smug in the fact that I was wearing my rubber knee boots as we hustled through this swampy ground. Two suspended cable bridges spanned the river where fording could be dangerous during high water. I was flagging by the sixth kilometre but managed to keep the others in sight. Every time I saw a beam of sunlight in a break in the canopy I was convinced we were at Camp 5 but eventually I was resign to the fact that we'd never arrive. Finally a building popped into view and I knew that I wouldn't have to survive on my wits. (Like THAT could happen!) A time check with Frank's 30 ringgit (\$10) Rolex revealed that we zipped through at an amazing three kilometres per hour! That's comparable to a saunter in the city but slightly more difficult in the jungle. Unfortunately unlike a saunter in the city we were easy prey for the leeches and horseflies that pestered us throughout our trek. Ben was the most popular with the parasites today while I picked up just one leech on my wrist. I am still at a loss as to how they can attach without so much as a tingle. In fact if it wasn't for the blood gushing from the wound I wouldn't even know that my corpuscles had been stolen.

The Royal Geographical Society conducted the largest scientific expedition to leave the U.K. in a fifteen-month period in 1977-78 establishing a series of camps in Gunung Mulu National Park with Camp 5 being one of them. From that time it has grown and now consists of a main building with sleeping facilities, kitchen, dining room and bathrooms, a gazebo and a maintenance shed. Camp 5 serves as the basecamp for those visiting the exquisite limestone formations that are the Pinnacles. Considered by United Nations Environmental and Science Committee Organization (U.N.E.S.C.O.) to be a World Heritage Area of outstanding scenic value this is a popular attraction for the more adventuresome visitors to the park. People hike in the first day and stay the night at Camp 5. Climbers must leave early in the morning for the nine hour, fourteen hundred meters ascent with the final four hundred meters up eighteen ladders. Not for the faint of heart. But those who brave the climb are rewarded with a spectacular view of this eerie landscape. Knives of limestone jut up thirty meters with few options of navigating through the maze. The return trip has you back at Camp 5 by

mid-afternoon for a second evening before trekking nine kilometres back down the trail to meet a longboat.

The accommodations in each of five bedrooms consisted of raised platforms with ten to twenty sleeping mats in a $\frac{3}{4}$ high walled room. The open-air at the eaves allowed good ventilation but poor protection from bugs. Once I'd rested a bit I set up my sleeping bag and mosquito netting in Room 5 along with the rest of the party. Gear was unpacked and the remainder of the day was spent around camp with tales of past expeditions being bantered about. Across the river in a sheer limestone cliff one can easily see Hole in the Moon Cave, Lower Tiger and Upper Tiger which are all connected. Frank regaled us in the story of climbing above Hole in the Moon Cave, rigging, dropping down thirty meters to the entrance and then continuing down another three hundred meters to the forest floor! Similar stories flowed for much of the afternoon into the evening.

While sitting around Veno brought over some fruit that was in season - rambutan and durian. Of the two I can declare that rambutan is better. In fact my love of this tropical fruit earned me the nickname of "The King of The Rambutan."



King of the Rambutans

Matt Kirby

Related to lychee this fruit grows on a medium-sized tree and is about the size of an apricot with a hull similar in appearance to a cocklebur. This delicious fruit has the texture of Gummi Bears with a mellow flavour of melon/grape. To access the fruit you twist the soft hull and bit into the soft flesh being careful to not crack the pit.

On the other hand the durian grows on large trees and is a grapefruit-sized seed pod covered in sharp spikes surrounding walnut-sized seeds. A thick white inedible coating encompasses a gooey layer

of slime around the seeds. The slime has a texture of pudding and is eaten off the seed. With most people it is a love/hate relationship, either you love it or hate it. I was indifferent to it but many of the locals can't get enough of it. The real issue is the stench that it can emit. To give an indication of its dreadful smell it is banned from the Singapore Rapid Mass Transit and the hotels on Borneo prohibit it on their premises. According to an article in Smithsonian.com it inhibits the liver from breaking down alcohol so it is wise not to imbibe if you eat this fruit. Another issue is the fact that when they fall to the ground they reach terminal velocity and could impale the unsuspecting just like a medieval mace.



Mark at Camp 5 with the Benarat cliffs behind

Mark Jones

Since we'd be staying around Camp 5 for a week Veno had arranged a chef for our benefit and comfort. I can heartily endorse having a chef at all expedition and am going to insist that we institute this immediately in the U.S. Following a fine meal in the dining area we retired to our room where I collapsed under my mosquito netting for a good night's sleep. Whiterock Cave awaits us tomorrow.

January 21, 2018

Whiterock Cave

Gunung Mulu National Park

Steve, our chef for the week, had crepes and eggs prepared at 8:00 a.m. for our dining pleasure. At 9:30 a.m. our bags were packed and Veno led us four kilometres and one hour back down the trail to a footpath off toward the limestone escarpment. Bushwhacking for the next two kilometres through dense undergrowth he deftly wove a path across the swampy ground to the base of the climb. Here Veno departed for Camp 5 while we continued up the slope. The weathering of the hillside had

resulted in gnarly, sharp, nasty limestone that ripped at flesh and tore at our clothing. Adding to this was the rotting vegetation that camouflaged these dangers. Up, up, up for the next 115 meters rising high above the floodplain below. Frank zigzagged up to the nominally ten meter opening of the Midnight Entrance to Whiterock Cave of the Clearwater System. An hour had passed since leaving the main trail. This is a very special cave to Matt since he and Richard Chambers discovered this cave back in 2003. At over a hundred kilometres it is currently the longest component of the Clearwater System. The first objective was reached when Hugh deployed the anemometer in a passage choke to monitor wind data for the next four days. This area is well-visited by the cave racer snakes that pluck the cave swifts out of the air as they negotiate through the constriction deeper into the cave to nest. The only detectable breeze we found in the cave was here. The next several hundred meters we scrambled over mountains of ceiling breakdown in expansive chambers. Climbing down a flowstone mound we continued down to the Keel Passage, so named for the numerous draperies resembling boat keels poking down from the ceiling.



Mark with keel-shaped formations in Keel Passage

Matt Kirby

While Frank did some photography work the rest of us settled down to grab a bit to eat. About this time I noticed a large bloodstain on my pants indicating that I had been had by a leech. When I removed my boots an engorged leech plopped out, rather than dispatch him I left him to fend for itself in the dark recesses of the cave. Ben also found a few small ones crawling around his ankles but Matt had six of the little buggers around the top of his socks. In spite of all my precautions I was still attacked but take a bit of comfort in the fact that it wasn't as bad as others.

Further down the line the Zebra Ramp, a sixty meter slope down to the Lower Entrance, beckoned to those brave enough make the climb. We stayed in the upper level for several hundred more meters traversing over undulating mudslopes past the Up and Running Junction and into Africa. On a map this section of cave roughly resembles said continent hence the name. It was here that the formations blossomed into the Crown of Thorns. The ceiling exploded with a profusion of helictites, stalactites and drapery of exquisite beauty. Many photographs were taken in this area. Deeper into Africa we passed numerous flowstone mounds and massive columns before reaching a small waterfall cascading down manganese-coated flowstone. We went a short distance beyond here to reconnoitre a campsite for later in the week. On the rebound we detoured down the Daydream Believer Junction and another several hundred meters in huge passage over dissolving flowstone and piles of breakdown to Daydream Believer Passage. This huge chamber is dominated by beautiful totem pole columns and towering stalagmite mounds.

Ben set a nice pace for the exit out with hopes of spotting a cave racer perched on a ledge at the constriction. No snakes were found until Frank spotted two of them on rock outcroppings in the twilight zone. Several photos were snapped before they became irritated and we moved on. This was a nice four hours introduction to Whiterock Cave.

The descent required less energy but proved more dangerous than the climb. Back in the floodplain Ben led us down the footpath and directly to the main trail with little fanfare. By this time I was wiped out and my feet were aching so the four kilometres to Camp 5 proved to be a challenge. When I finally stumbled into the clearing it was with considerable relief that I sat down in the Melinau to cool down. In one day we'd trekked thirteen kilometres of jungle trails plus another couple of kilometres in the cave. Revived after fifteen minutes I took a long, cold shower before joining the others around the dining table for a fine meal. Veno brought everyone over a warm Tiger Asian lager and we celebrated the day. Ten minutes later I was fast asleep.

January 22, 2018

Gunung Mulu National Park

Thankfully we took the day off to recuperate from yesterday's trip. I spent the day writing trip reports and editing photos while taking it easy and nursing my sore feet.

January 23, 2018

Whiterock Cave

Gunung Mulu National Park

While Matt stayed in camp to nurse a nasty gash Ben, Hugh, Frank and I headed back to Whiterock Cave to give Ben and myself another peek at the cave and further orientate ourselves to this section of Clearwater Cave. Our plan was to set up camp in the Africa Passage and make a loop through the Ancestor Passage and return via Daydream Believer Passage. Our packs were quite a bit heavier with camping gear than two days ago but we scooted right down the Camp 5 Trail. Four kilometres later we cut off toward the limestone bluff crossing two kilometres of swamp. The ascent hadn't become any easier and I was winded by the time I'd reached the Midnight Entrance. When we passed the anemometer tripod the small pressure/humidity sensor had been dislodged indicating that either a swift had hit it avoiding being eaten by a cave racer or a cave racer had slithered up to await and eat a swift. We replaced it back on the tripod before moving on. Ben made a beeline for the Keel Passage followed by the Zebra Ramp, the Crown of Thorns, beyond the small waterfall and into the Africa Camp. Our campsite wasn't much to speak of, a fairly level, muddy floor just wide enough to stretch out a bedroll and enough room for the stove. Certainly not as spacious as Scumring in Clearwater Cave last week but there was very little chance that we'd be flooded out here.

Once gear was unloaded we struck off to the south deeper into Africa. Once again it is hard to describe passage so big other than to focus on the immediate area. With massive shattered ceiling breakdown covering the floor that wasn't too difficult. In places the rock was coated in thick layers of popcorn or calcite needles leaning in the direction of the wind flow. Soon the floor changed into a never-ending cobble expanse. The stones range from pebbles to soccer ball sized loosely cemented together. Since we were in an upper level this rock would have been deposited well before any of the lower cave was formed. In several spots drains had formed deep pits revealing the true depth of the cobble. At over ten meters thick the cobble was laid down by a river that must have been truly magnificent. When we reached a steep slope that spanned the width we rigged a rope for a handline to descend the frail cobble wall. No sooner than we'd gotten to the bottom than we were scaling back up the other side.

Continuing on for several hundred meters at ceiling level we eventually reached Propeller Camp. This is an important site during push trips into the unknown northern reaches of the cave. A quick inventory of supplies was taken before climbing up and around a scree slope that we promptly climbed down into the Ancestor Passage. Delicate calcite crystals decorated much of the breakdown in this area. Hugging the left wall we slowly zigzagged down to a narrow canyon with clusters of stalactites dotting the walls. Looking closely I discovered to my surprise that they were being deposited on the same cobbly conglomerate floor that we'd been walking on. Further down the line a ramp split up into the darkness. Hugh and Ben decided to survey this area while Frank and I opted to sit tight and discuss rock-n-roll. An hour later we were back on our way. Almost immediately the floor dropped off steeply down a rocky chute. Obviously this is a conduit for the water down to lower levels. At the top of the chute an interesting narrow three-meter tall column caught my eye. It looks like a soda straw that has been cut vertically leaving just a thin outer layer. On the opposite wall were a series of mud/flowstone clusters that stair stepped up the wall with each "step" smaller than the last. The wonders never end in Mulu.

Dropping the chute we were up and down steep, undulating flowstone/breakdown slopes coated in a broccoli-shaped flowstone with no end in sight when the passage finally mellowed out. Ahead Hugh pointed out the most amazing biological find and the passage name – a calcite-coated monkey skeleton! I was flabbergasted to even think that a potentially distant relative was here a very long time ago. In a few minutes we'd reached an impressive seven-meter column called Long Tall Sally. This is an important landmark at the intersection of the Ancestor Passage and Daydream Believer Passage. Turning right we entered the surreal world of Daydream Believer. Although I really can't do justice in words I will make a feeble attempt. A fifty meter wide, twenty meter high tube with an intermittent sandy floor covering massive breakdown extends for over a thousand of meters. Formations were randomly scattered throughout but nothing truly spectacular until we reached the forest of columns and totem poles that we'd seen on our first visit. We'd just completed a 2.2 kilometre loop in one of the grandest cave in the world in five hours. Within fifteen minutes we were back at the Africa Camp having a spot of tea along with ramen noodles and tuna. Reflecting on the day I realized that the 226 kilometres (140 miles) of surveyed cave passages of the Clearwater System is more than all of the known caves in Iowa!

January 24, 2018

Whiterock Cave

Gunung Mulu National Park

I got a respectable sleep at the Africa Camp and although mighty sore ready to have some breakfast before ambling out the Midnight Entrance. Another ramen and tuna meal was on the menu along with a drink and some snacks. The first objective was to tie in a survey near camp. The survey team consisted of Hugh, Ben and Frank while I dawdled along with my camera to photograph some of the formations. A flock of cave swifts chattered away in a nearby chamber as the survey began.

At one point Ben found a solitary bat low on the ceiling so I rushed over to snap its picture. This long-eared fellow was of blocky build and an interesting face. When we get back to park HQ I'll ask Rambli about the identity of this little guy. On the way out Hugh and Ben dropped down to a mid-level passage to record two hundred fifty meters of new survey with going passage. Meanwhile Frank and I went up to the Crown of Thorns Ceiling where I got some additional pictures. We regrouped at 2:00 p.m. for a nice saunter to the entrance passing by the anemometer where once again the pressure/humidity sensor had fallen off the tripod. Approaching the entrance I realized that during this expedition I had travelled twenty-five kilometres of the system seeing sixteen kilometres of passages but had crawled less than fifty meters!

A break was taken at the entrance followed by the 115 meter climb down to the floodplain. An afternoon shower had increased the sportiness of the descent as well as the two kilometre slog across the swamp. Back on the Camp 5 Trail I set a slower pace for the hike to camp arriving fifteen minutes after the others. I immediately jumped into the river to rinse the mud off the gear and knock the grime and sweat from my clothes. A long, cool shower rejuvenated my spirits followed by a tasty hot meal that nourished my body. Around dusk a drenching rain set in that pounded on the tin roof and raised the river over a meter in two hours. Hugh had left his boots on the beach and it was too late by that time. The Melinau raged a dirty brown all night long.



Writing up trip reports at Camp 5

Matt Kirby

January 25, 2018

Gunung Mulu National Park

By morning the river had dropped back down and was clearing up by the time we'd finished breakfast. I spent the day recuperating from the previous two days of caving and hiking by lounging around, writing trip reports and engaging in idle conversation with the rest of the party. During the afternoon Dave the Lizard made an appearance and stayed for a photo shoot. We celebrated Ben's 24th birthday at Camp 5 that evening with a tepid Tiger Asian lager. Life is very good.

January 26, 2018

Gunung Mulu National Park

Rather than go a third time to the Midnight Entrance of Whiterock Cave with the others to do a bit of surveying, photography and collect the anemometer I opted to stay alone in camp for the day. I whiled away the time relaxing and writing trip reports. An afternoon deluge soaked the intrepid cavers on their hike back to camp but hadn't damped their spirits. Another evening of fellowship was spent with yarns of caving exploits while analyzing pictures, survey and data.

January 27, 2018

Gunung Mulu National Park

Most of the day was spent preparing for the trek back down the Camp 5 trail on Sunday. I did take some time in the midmorning to wander upstream to cross the river at a suspension bridge and follow the Headhunter's Trail for a couple kilometres. A blast of hot air hit me as I broke out from under the canopy to the helipad. Without the buffering of the trees the canyon floor heats up quickly. This was a reminder that the tropical rainforests serve an important function in temperature moderation. Back under the canopy the sickening-sweet aroma of the day was durian permeated the air indicating that the guides had been feasting on the gooey treat(?). I was going to make the Lubang Cina loop but the trail was underwater so I simply retraced my steps back to Camp 5.

In the afternoon Hugh and Ben trekked up to No Country For Old Men Cave to retrieve the anemometer and investigate a cool breeze dropping down from the hillside. Meanwhile Matt would be doing his best to monitor them with the drone flying from the helipad. It should be noted that the helipad is a clearing that has a slab of concrete large enough to accommodate a small helicopter for dire emergencies. Frank and I would be safely absconded under the awning of the Camp 5 cantina watching Matt operate the drone across the Melinau. The heavy canopy prevented Matt from finding the others but he was able to fine-tune his drone flying along the Benarat cliffs. That evening we talked at length with a group of three Netherlander hikers who were going to the Pinnacles tomorrow.

January 28, 2018

Gunung Mulu National Park

With our gear all packed up for the porters I decided to amble ahead of the group to set my own pace for the nine kilometre walk back to meet the longboats. For the next two hours I enjoyed the sights and sounds while sauntering through the rainforest. At the first bridge I thought that it would be just a short distance to the second bridge but I think that the trail expanded during our stay. Finally I reached the bridge and knew that it was only one more kilometre to the boats. It wasn't until the last four hundred meters that Ben caught up to me. The others soon arrived although Hugh was slowed down by wellies that were chaffing his feet. He lost his surly attitude once the boats arrived and we were on board. As we moved downstream it occurred to me that the sixteen kilometres to park headquarters was comparable to the same distance that I'd seen underground during the expedition. Wow!

Dick and Nick had cold Tiger Asian lagers waiting for us at the bungalow after which a hot shower felt mighty nice. Gear was sorted and inventoried that afternoon before a small soiree with Hein and Andia Gerstner. Hein is the manager of the Borsa Mulu company which operates the commercial side of the park. Two hours later we excused ourselves for a farewell barbeque with Rambli and some of the staff. What a way to cap off an expedition!

January 29, 2018

While Frank and Ben remained in the park an additional day the rest of the troops loaded up their duffle bags and headed to the airport. It was a quick flight back to Miri where we were once again lodged at the Dynasty Hotel. The remainder of the day was spent wandering the streets followed by

a wonderful Chinese dinner with Dave and Liz Clucas. The evening was spent discussing a variety of topics.

January 30, 2018

The expedition was reunited for one last time when Frank and Ben arrived at the airport in the late morning. With our flight from Miri to Kuala Lumpur delayed an hour we checked in our baggage and spent the last couple hours on Borneo relaxing at Dave and Liz's home before grabbing a bite to eat. The gang separated when Hugh, Matt, Dick, Frank and I boarded the plane in the early afternoon while Nick and Ben hung around for an evening flight. We arrived in Kuala Lumpur in mid-afternoon where we spent six hours in caver fellowship before Hugh, Matt and Dick departed for their 1:00 a.m. boarding. There were no rooms to be had at the hotel so Frank and I claimed a long bench where we spread out for the next six hours.



Mark & Frank wave the rest of the team off at KL airport

Matt Kirby

January 31, 2018

At 5:00 a.m. I was the first in line at the All Nippon Airways check-in and soon had my luggage tagged and boarding pass in hand. I bid a fond farewell to Frank and headed to the international terminal. Everything went like clockwork and after a short layover in Tokyo and another ten hours I was back at O'Hare Field in Chicago, the end of a most memorable trip.