

THE WULFF LAND CAVE, NORTH GREENLAND

by

GINA E. MOSELEY

ABSTRACT

Large solution caves in Silurian limestone are known throughout North Greenland with the earliest documented observations dating to the 1950s. In 1958, one large cave situated in Wulff Land was photographed during aerial reconnaissance. The image was sent to the University of Bristol and then eventually to members of the University of Bristol Spelæological Society (UBSS) where it set off a chain of events over decades that included many UBSS members, unimaginable research efforts, logistics planning and crucially, fundraising. This article presents the narrative of UBSS attempts to reach, enter and explore ‘the big cave in Wulff Land’, now known as ‘WUL-8’, which was finally achieved by a small team on 22nd July, 2023. Exploratory methods, observations, and the interdisciplinary research that was conducted during the 2023 expedition is presented.

UBSS HISTORICAL CONTEXT

In 1956, a large cave then considered to be the world’s farthest north solution cave was observed during geological investigations in Wulff Land, North Greenland (Figure 1; Davies, 1956; Davies, 1957). It was described as being situated near the top of a 1500 foot (c.460 m) cliff that borders the west side of a large finger lake and was said to be 40-50 feet (c.12-15 m) in diameter and from appearance extended for considerable distance from the face of the cliff. In 1958, Davies further photographed a large cave situated high up in a cliff face during geological aerial reconnaissance in Wulff Land (Figure 2) and based on multiple similar accounts, it is assumed that the photograph is of the same cave first observed in 1956. Davies and Krinsley (1960) went on to mention the large solution cave in Wulff Land again in their short paper on ‘Caves in Northern Greenland’. The reconnaissance photograph was sent to Prof. John W. Cowie of the Department of Geology, University of Bristol, UK (Figure 3), which at the time was a world-leading institution in cave and karst research. Cowie had vast experience of Greenland, having travelled to the East in 1949 to study the Cambrian and Ordovician rocks and fossils as part of his Ph.D. thesis (Cowie, 2012). Between 1949 and 1954, Cowie returned many times to Greenland, notably with the Lauge Koch expeditions (Adams and Cowie, 1953; Higgins, 2010) and in 1956, he received the Bruce Medal from the Royal Society of Edinburgh for his investigations into the stratigraphy and palaeontology of Greenland (Cowie, 2012). Cowie would also become a member of the Expeditions Committee of the Scott Polar Research Institute where he gave advice to polar explorers (Cowie, 2012). Additionally, it should be noted that another long-time UBSS member, Desmond T. Donovan, also joined the Lauge Koch expeditions between 1947 to 1957 (Donovan-Beerman and Mullan, 2020; Higgins, 2010). With Donovan appointed Lecturer at the University of Bristol in the Geology Department in 1950 (Donovan-Beerman and Mullan, 2020) and then Cowie in 1953 (Cowie, 2012), sending the image of ‘the big cave in Wulff Land’ to Bristol was a logical move.

Over time, the iconic photograph found its way into the hands of long-time UBSS member, Charlie Self. Years passed by with Self researching the area and logistical approaches, as well as sending typewritten letters via post to the geologists, often receiving replies many



Figure 1. Map highlighting key locations discussed in text. *Glacier and ice sheet extent (CEC, 2010).*

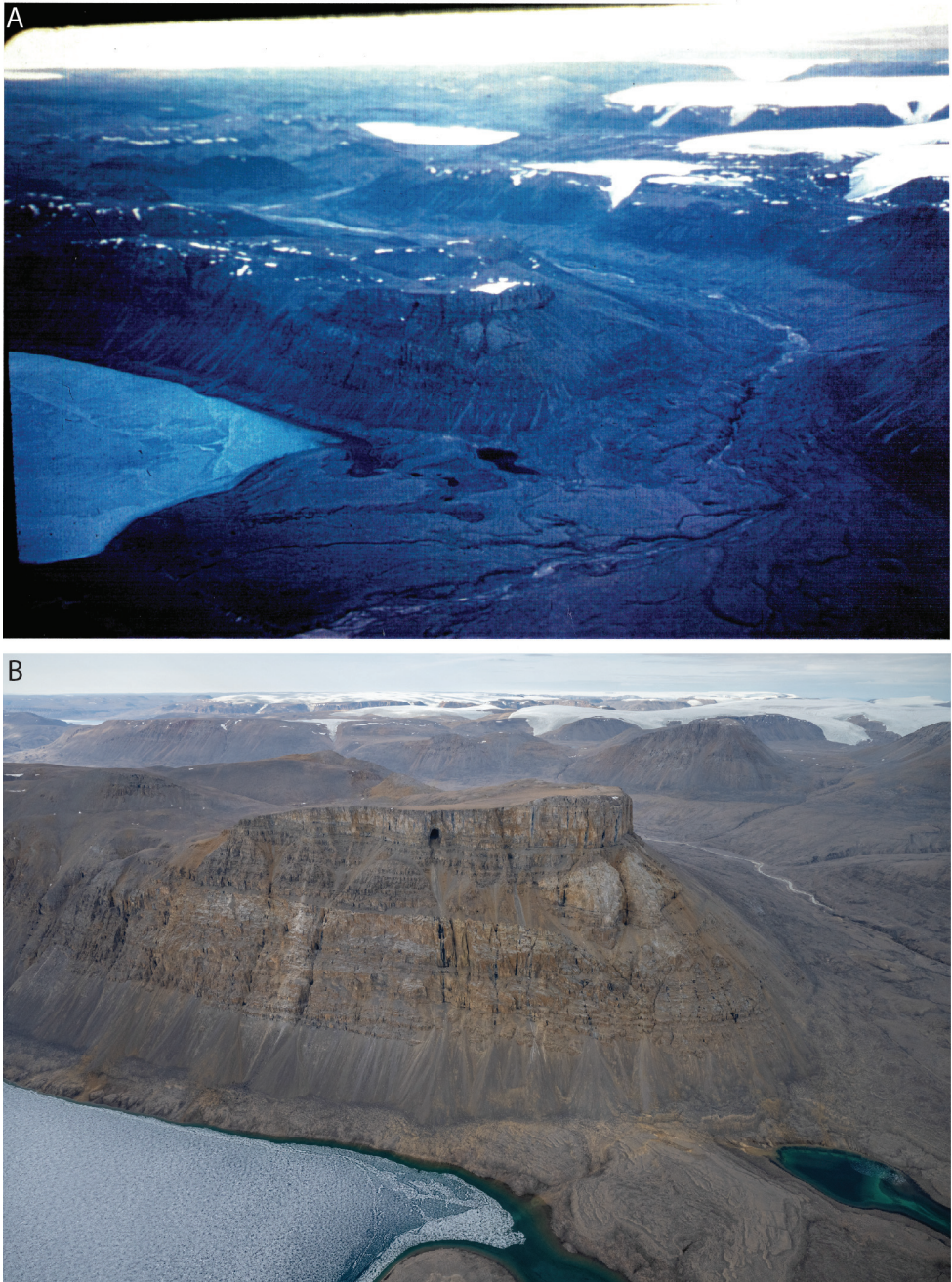
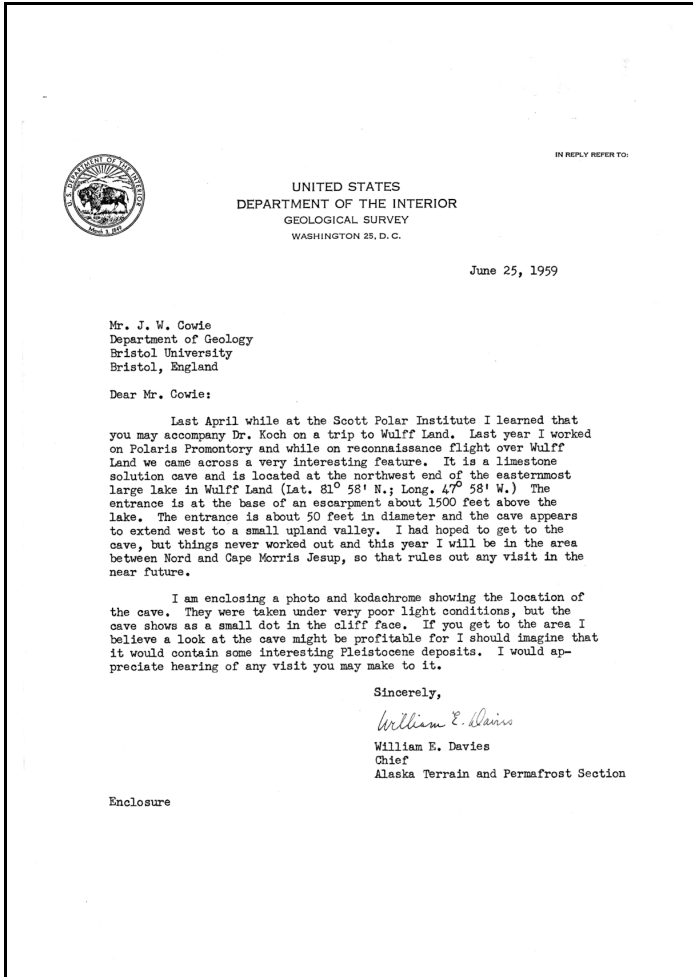


Figure 2. Photographs of WULF-8. (A) 1958 aerial reconnaissance by William E. Davies. (B) Similar image taken by Robbie Shone on 23.7.23 from a helicopter during the Northern Caves 2023 expedition.

All rights reserved by Robbie Shone and not included in CC BY licence.

months later. All the time, Self built up an extensive record of his research and correspondence that was kept in a folder in the hope that one day he would be leading an expedition to 'the big cave in Wulff Land'.

In the 1980s, Self approached another UBSS member, Bob Churcher, who had led a number of long climbing expeditions in the 70s and 80s in East Greenland. Through British



military connections, Self thought that Churcher might be able to organise a Royal Air Force Hercules for use in Greenland and the idea of a joint British services/UBSS expedition was proposed for 1987. It soon became apparent that a Hercules couldn't land near Wulff Land with Thule or Ellesmere Island (Figure 1) being the closest they could get. It was suggested that bulk supplies could be airdropped onto base camp but then a Twin Otter would still be needed to perform the necessary tundra landing. This severely limited the payload and in turn increased the costs. In correspondence dated to 1987, the cost of a Twin Otter from Resolute was quoted at £12,000. The expedition never happened, largely due to budget constraints. In 1991, the Oxford University Officers' Training Corps also began planning a Wulff Land expedition for the following year, but this met the same fate as those before it. Of note is that one person known to the British caving

Figure 3. A copy of the correspondence sent by William E. Davies to Prof. John W. Cowie at the University of Bristol in 1959.

scene, now Prof. M. Paul Smith, currently at the University of Oxford, UK, undertook many geological mapping campaigns in North Greenland in the 1990s as part of his post-doc. Smith observed and photographed the infamous Wulff Land cave as well as many other large caves in the region.

As the years went by, Self, Churcher and other UBSS members continued to talk about 'the big cave in Wulff Land' which, for the sake of clarity, will be referred to from now on as

WUL-8 (Figure, 1; Smith and Moseley, 2022). One evening at the weekly pub meeting in c.2008, which, if memory is correct, is believed to have been the Coach and Horses in Clifton, the topic came up in conversation once again. This time, Self was talking to Gina Moseley, a Ph.D. student in the School of Geographical Sciences, working on speleothem-based palaeoclimate and sea-level research in the Caribbean region. Moseley had joined UBSS on arrival in Bristol in 2005. Like those in the long line before her, Moseley was immediately hooked on the idea of limestone caves in Greenland. Self did a particularly good job in describing the large size of WUL-8, but was somewhat dismissive of some other caves that were known about in Grottedalen, Northeast Greenland (Figure 1; Davies and Krinsley, 1960) describing them as 'small scrott holes'. It was clear where Self's exploratory allegiances lay. Self mentioned that he had been trying for 30 years, on and off, to get a trip organised to the north coast of Greenland. He offered Moseley his folder of correspondence to copy, which he handed over in the pub the following week. Moseley used up the majority of her annual photocopying budget on reproducing the entire work and then duly returned the original folder to Self. More years passed with the copy of Self's folder moving from drawer to drawer in various different houses and the dream of exploring WUL-8 still deeply buried for the time being.

2015-2019 EXPEDITIONS

After taking up a postdoctoral position at the University of Innsbruck, Austria, Moseley once again browsed the folder and decided it wouldn't hurt to send a few emails inquiring about costs of expeditions to Greenland. Despite Self's indifference to the caves in Northeast Greenland, Moseley considered this a good place to start the project. Moseley was as much interested in the palaeoclimate research potential of the caves as the exploration potential. The Davies and Krinsley (1960) article had clearly stated that one of the caves in the Grottedalen region of Northeast Greenland (Figure 1) contained a layer of red silt about half a foot thick that was capped by a flowstone deposit 4 inches thick (c.10 cm) formed of coarsely crystalline calcite. Given that today the region is a polar desert with a mean annual precipitation of c.200 mm yr⁻¹ (Schuster *et al.*, 2021) and the ground is in the zone of continuous permafrost (Obu *et al.*, 2019), it is not possible for speleothems to form under present conditions. The documented presence of flowstone in one cave therefore clearly indicated that at some point in the geological past, the region had been both wetter and warmer than today. Since anthropogenic climate change is amplified in the Arctic, with Greenland warming up twice as fast as the global average, investigation of the geochemical record contained within the flowstone could therefore provide valuable insights into the palaeoclimate and palaeoenvironment of Northeast Greenland in a warmer world. Moseley hoped to collect a sample of this flowstone but also investigate whether other caves contained speleothems allowing for the possibility of a large-scale palaeoclimate project.

The first quote for the logistics for a 6-person team for a couple of weeks came back at c.£150,000. To Moseley, this seemed like an awful lot of money and without prior experience of raising such funds, or even leading a remote caving expedition, it was difficult to know where to start. Fate and luck somehow played their part when Moseley was introduced to polar explorer Clive Johnson, the brother-in-law of lifelong caver Mark Wright. The details of this first expedition are well documented elsewhere (Moseley, 2016) hence only a summary is given here. In short, Johnson devised a more cost-effective logistical plan that included logistical partners and replaced expensive helicopter operations with inflatable boats and days of hiking. The first expedition went ahead in July 2015 to Grottedalen (80 °N; Figure 1) in the Centrum

Sø region of Kronprins Christian Land, Northeast Greenland, with five people at a cost of £85,755 (Moseley, 2016).

The 2015 expedition was extremely successful (Moseley, 2016) thus in 2018 a second expedition, this time to the Wegener Halvø peninsula (Figure 1) on the east coast at 70 °N, took place (Moseley, 2018). For this expedition, Moseley largely took over the logistical organisation with Johnson providing permitting support. In order to reduce the environmental cost of the expedition, the **East Greenland 2018 (EAGRE18)** expedition teamed up with the Top-to-Top Global Climate Expedition (Zollinger, 2015). Top-to-Top had been communicating issues of climate change and sustainable living by sailing the world in a 15 m-yacht called Pachamama (the Incan word for ‘Mama Earth’) since 2002. Perhaps unique to this story is that Top-to-Top comprises the Schwoerer family from Switzerland with mum Sabine, dad Dario, and their six children aged c.18 months to 13 years at the time. Together, the Schwoerer family, a school teacher and three cavers sailed from Ólafsfjörður, Iceland to Nerlerit Inaat, Greenland (Figure 1) and back on the 2018 expedition (Moseley, 2018). EAGRE18 had a final budget of £38,696.

Finally, a third expedition in 2019 returned to the caves in Grottedalen, Northeast Greenland (Figure 1). The 2015 expedition had been so successful in terms of palaeoclimate potential that Moseley had managed to secure €1.2 million from the Austrian Science Fund in order to pursue a project lasting five years. In 2019, a major interdisciplinary expedition returned to the caves of Northeast Greenland with nine participants and lasting for about two weeks. The expedition and its scientific goals are documented in a special issue of *Cave and Karst Science* (e.g. Moseley, 2020a), but to give an idea of the scale of such an expedition, the final cost was £389,980 (Moseley, 2020b).

NORTHERN CAVES 2023 EXPEDITION PREPARATION

Though it had not been intended this way, the three expeditions to Northeast and East Greenland had proved to be a successful training ground (politically, logistically, financially) for a much bigger project. In 2020, at the start of the COVID crisis, Moseley decided to turn her attention to Wulff Land. Rolex had just opened the preliminary round of the Rolex Award for Enterprise and Moseley thought the time might be right to attempt a Wulff Land expedition. She was successful in being awarded the 2021 Rolex Award for Enterprise (Rolex, 2021) but still needed significantly more money for the expedition to go ahead. To complicate matters a little further, Moseley’s daughter Madeline was born in February, 2021. Navigating this new stage in life whilst also planning the biggest expedition yet to one of the remotest regions of the planet was certainly a challenge. It was clear that the expedition (and Moseley as a new mother) would not be ready for a 2022 campaign but summer 2023 looked feasible. Even without all the funding in place, Moseley had to commit in summer 2022 to sending 20 drums of A1 jet fuel by ship to Qaanaaq in northwest Greenland (Figure 1) at a cost of over £15,000. The race was then on to find the extra funding. By the end of the year, most of the funding that would be found was committed and options for other funding from elsewhere seemed to run dry. The final sum that was raised was too little for a stand-alone project. In order for the expedition to go ahead logistical partners were needed. Working with logistical partners is quite common in Greenland. For instance, if a Twin Otter is chartered to take a team from Iceland to North Greenland, it will be returning empty at a cost to the expedition. There may, however, be a team already in place that will purchase this empty leg, thus reducing costs for both projects. For such logistical shares to work, all parties have to be flexible with timing in order to

accommodate the many different requirements and schedules. For the 2019 campaign, Moseley had brought onboard Sebastian Rasmussen of Polog as the logistics organiser. Rasmussen's background at the time included 10 years of experience in the Danish military of which two years was spent in the Arctic special unit known as the Sirius Sledge Patrol. The Sirius patrol travel Greenland by dog sledge in teams of two through the harshest conditions of the winter. Rasmussen had a hugely impressive network that he could utilise as well as substantial experience with logistical planning. Thankfully, the harder the logistics the more he seemed to thrive at the challenge, hence he was the obvious choice once again for the expedition to Wulff Land.

Rasmussen worked tirelessly on devising a logistical plan to get 5-6 people and a helicopter to Wulff Land. He often described it as a logistical death zone. The initial plan included sending the fuel to Qaanaaq in the summer of 2022, where it would be stored until winter. In winter 2023, a large ski-equipped plane would then collect the fuel and take it to a fuel dump in North Greenland. In the summer of 2023, the much smaller Twin Otter, which is the only plane available that is capable of landing in wild terrain, would then do shuttle runs to bring the fuel to base camp in Wulff Land (Figure 1). Hence as stated, the fuel was shipped in summer 2022. By winter 2023, the regulations in Qaanaaq had changed, and the large ski-equipped plane was no longer permitted to land. Without the winter fuel dump, the entire plan had to change. Rasmussen worked tremendously hard to devise a new plan. He sourced a smaller, more fuel-efficient helicopter than had originally been planned, which meant that less fuel was needed at base camp. Due to this development, a new plan was put in operation that would involve using the Twin Otter to do shuttle runs with the fuel to base camp in Wulff Land at the start of the expedition.

The first six months of 2023 were the most intense of the preparation phase. The various permits were applied for first, including the preliminary registration of the expedition to a remote area, scientific research permit, genetic resources permit, mineral collection permit, plus a radio licence and a weapons licence. In addition, insurance covering search and rescue for the whole expedition without any policy clauses was required for 1,000,000 DKK (c.£114,000 at present) plus medical evacuation transport for each individual participant, also without any policy clauses, was required for 600,000 DKK (c.£68,000 at present). Sourcing such an insurance policy that also covers people resident in different countries was extremely challenging and after months of research, only one company based in Greenland that is used to offering such insurance policies could be sourced. The policy just covered the three weeks of the expedition and was specifically for the search and rescue and medical evacuation only (i.e. it was not a travel insurance policy) costing 37,609 DKK (c.£4,250 at present). Only once all these permits and the insurance were in place could the final remote expedition permit be applied for. Unfortunately, due to continuing uncertainties that will be explained below, the final dates of the expedition could not be finalised until very late, hence the application for the final expedition permit was severely delayed as well as issuance of the permit. In fact, it was so delayed that all members of the expedition left home and travelled to Iceland without the permit in hand. They had two nights in Iceland before flying to Greenland. The stress for Moseley at this late stage was quite horrendous. Without the permit, the expedition couldn't go ahead and with the fine details of all the interconnected logistics, it wasn't a case of simply catching the next flight. No permit meant no expedition. Eventually the final permission did arrive at c.19.30 whilst at dinner in Akureyri (Figure 1) the night before flying to Greenland.

The narrative has now jumped ahead quite far, hence let's rewind back to April, 2023, when Moseley started preparing the freight. It was a huge amount of kit to prepare, spending hours in the garage with a two-year-old who took great enjoyment in emptying the boxes that had been packed (Figure 4). The attention span of a two-year old doesn't last long though, and

even unpacking boxes didn't keep her that occupied. Within about 10 minutes she was running up and down the underground garage, which became the most fun activity. Needless to say, preparing and packing the freight took much longer than on previous expeditions.



Figure 4. Examples of some of the equipment used on the expedition. (A) Moseley packing the freight in the garage with her daughter. (B) Blakeley installs the homemade bear fence around the sleeping tents in Wulff Land. (C) Koltai prepares to use the 3D laser scanner. The Cardo Packtalk bluetooth communication device is seen attached to the helmet. (D) Moseley unpacks freight in the base camp tent at Wulff Land.

All photographs: Robbie Shone/Greenland Caves Project.

All rights reserved and not included in CC BY Licence.

Broadly, the freight included food (as lightweight as possible whilst still being nutritious, filling and interesting) in order to minimise ‘hangry’ (hungry plus angry) expedition participants whilst also accommodating vegan, vegetarian, omnivorous and nut-free diets; camp equipment (sleeping tents, one-person per tent to give each other space); a base-camp tipi-style tent (communal area, group shelter, cooking) (Figure 4) and kitchen supplies; caving and rigging equipment (helmets, SRT kits, drill and batteries, ropes, metalwork, protection); scientific equipment (core drill, various sampling equipment and bags, field notebooks, malaise trap, ethanol, temperature loggers, surveying equipment); electrical power (small generator and leads, solar panels); medical equipment (stretcher, medicines, first aid); and protection that included a home-made ‘bear fence’ constructed from wooden broom poles, lightweight dyneema, and loud pin-activated audio alarms (Figure 4). Freight was largely sent in aluminium transport boxes (Figure 4). Additionally, each participant then had their own personal gear typically weighing up to c.15 kg (mainly clothing and boots, sleeping equipment, hygiene products) that they travelled with on the expedition plus a few additional items such as the last medical items, a 3D handheld laser scanner (Figure 4) and the photography equipment.

Communication devices were the last main item on the agenda. Churcher tells a fantastic tale of how in 1978 his team went three months without any form of communication as their two high-frequency (HF) radios got damaged at the start of the expedition. By the end of the trip, they had lost a day somehow and were a day out for the pick up! Fortunately, it was a day early! In 2023, communication was very different to 1978 (and even different to the first expedition of 2015). With the advent of the internet and social media, there was a new pressure to constantly ‘stay connected’ and the team were even asked to make films about the preparations that were suitable for the social media platform known as ‘TikTok’. As required for the permit, the expedition took very-high-frequency (VHF) radios, personal locator beacons (PLBs) and satellite phones. In addition, the expedition had a Garmin In-Reach Explorer and an Iridium Go! with SOS function. Daily safety status messages were sent to Rasmussen. Additionally, since Robbie Shone was working as a photographer for National Geographic Magazine, a separate daily message had to be sent to the Disney Global Security Team. This caused some stress prior to the expedition since the Disney Team reported that if they didn’t receive the messages on-time each day then they would only leave a small buffer before initiating a rescue operation that would ultimately shut down the expedition. Somewhere the idea of the expedition being in the remote Arctic and reliant on sporadic satellite connection was not fully appreciated. It was found that the Garmin Inreach Explorer+ connected to the Garmin Earthmate ‘app’ on a smartphone was the most efficient way to send and receive such messages and worked much better than the satellite phones. In addition, the Garmin Inreach updated an online map that people at home could view to see the whereabouts and status of the expedition. Finally, for use between expedition participants on the ground, bluetooth-operated Cardo Packtalks were used (Figure 4). These worked incredibly well, allowed for smooth communication when out of voice range and also offered some comfort whilst prussiking alone at the top of a 900 m-high escarpment.

In May 2023, the pre-expedition meeting took place in Innsbruck, Austria, hosted by Moseley and Shone. Nathan Hudson-Peacock, the expedition medic, and Chris Blakeley, the expedition rope-access specialist were in attendance. Gabriella Koltai, a colleague of Moseley’s in the Institute of Geology, University of Innsbruck, and Hans Lange, an archaeologist from the Greenland National Museum in Nuuk, could not make it. At the meeting, logistics, budgets, evacuation plans, leads and targets were discussed as much as was possible at that stage.

As the summer approached, the final transport logistics were constantly in flux. The plan had been to travel with the Twin Otter via Ellesmere Island (Figure 1) and on to west

Greenland, however, these Twin Otters never became available. The other Twin Otters servicing Greenland were based in Iceland, but two out of three were grounded and waiting for parts. The larger projects obviously had priority on the one operational Twin Otter whilst everyone else waited. COVID delays at the factory meant that no definite timeline could be given on when the two grounded planes would be fixed. Due to the constant logistical uncertainties, the project partners that Rasmussen had sourced in order to reduce costs decided about one month before the Northern Caves expedition was due to take place to postpone their field season until summer 2024. The expedition costs were once again out of reach and once again the chances of the Northern Caves 2023 expedition going ahead was hanging on a thin thread. Rasmussen performed another incredible save and managed overnight to rearrange everything, source new partners and plan a timetable such that everything was back on by the next day. With what seemed like a semi-final plan in place, it was now possible to finally send the freight, which was picked up one early afternoon at the end of June, 2023. The driver worked through the night and arrived in Kolding, Denmark, the next morning from where the freight was put on a ship a week earlier than planned. Having people on the team with substantial networks certainly paid off.

At the start of July, 2023, Moseley flew to the UK with her daughter. This was a mini pre-expedition of its own. Two-year-old Madeline would be living with her grandparents whilst the expedition took place but first of all she needed to integrate and settle into her new temporary life. Moseley spent two weeks in the UK prior to the expedition and in the end the separation seemed to be harder for mother than it was for daughter who had a fantastic time with her extended family. However, during these two weeks all was still not finalised for the expedition. The main invoice for the charter flights (Twin Otter and helicopter), which could only be sent at the beginning of July once the plans had been finalised, needed to be paid. However, despite Moseley having raised all the funding, the University of Innsbruck finance office had reservations about paying such a large sum and would not release the funds. With less than two weeks to go, the expedition once again looked as if it might be called off. In Innsbruck, many people applied pressure and after a few dreadfully stressful days, the University agreed to release the funds. Only one week before departing could schedule-flights be booked for the team to get to Iceland where they would meet the charter to Greenland. In the final few days, satellite phones were tested, the last security arrangements put in place, and a giant can-opener was sourced to breakdown jet fuel drums once empty as the expedition was responsible for removing them from the Northeast Greenland National Park.

NORTHERN CAVES 2023

The Northern Caves 2023 expedition departed for Iceland on 17th July, 2023. On 19th July, 2023, at c.10.00, Moseley, Blakeley, Hudson-Peacock, Koltai and Shone flew from Akureyri (Figure 1) in a King Air to Nerlerit Inaat Airport (Constable Point; Figure 1) where they picked up weapons (rifles and flares), ammunition, a spare generator, white gas and petrol. Here, they were challenged once again as the serial numbers on the rifles that were available did not match the serial numbers on the permit. They were advised to take what they needed and be prepared to deal with some additional administration with the military later on. This all took more time than planned and the pilots started to get a little impatient. They had a long day ahead and wanted to get going. Moseley and Koltai quickly collected a sample of topsoil that would later be analysed for pollen content. At c.16.00 the team touched down at Station Nord (Figure 1), the furthest point north that any of them had ever been. They were met by the station

personnel plus some pilots who started asking a lot of questions about weight. After some moments, it became clear that these pilots would be taking the team in the Twin Otter to Wulff Land the next day. They were stressed about the weight of the freight and wanted to know what else the team had with them. In total, the team plus equipment came to 1000 kg, which was the payload that Moseley had been working towards for the last few months. Only now in this moment was it communicated that the Twin Otter needed to take two drums of fuel with it to Wulff Land in order to be able to continue its journey. The drums weighed 400 kg. With 1400 kg the Twin Otter was too heavy to perform the operation to Wulff Land in one go. The pilots wanted to do two runs (at a substantial extra cost) unless an alternative could be found. Seeing a souvenir shop at the end of the runway and the chance to stamp one's passport with a Station Nord stamp offered a little distraction, but ultimately the evening was spent in another state of anxiety. The expedition had come so far, yet once again its future looked in doubt. In the beautiful surroundings of North Greenland, with the long polar days, looking out over the Arctic Ocean, discussions went round-and-round at the Villum Research Station as to what could be left behind (if anything) and should the expedition continue? Mathias Vogt, the helicopter pilot, was flying up the east coast of Greenland but would stay the night further to the south. The Station Nord military personnel tried to contact him to see if he could take any load, and others tried to establish if there was any spare fuel at Wulff Land. Everyone went to bed without any answers. In the morning, Moseley and Shone began separating out some kit to leave behind, but there really wasn't much that was indispensable (perhaps 20 kg). Within a few moments, everything was back on. The pilots turned up to say that the team should get ready to depart. Vogt had been in touch to say he could take 120 kg, and it turned out there was a spare full fuel drum at Wulff Land. The turn-around was extremely quick without much scope for really thinking about what should be left behind for the helicopter.

On 20th July, 2023, the Twin Otter took off at c.09.35 laden with five expedition members, a full fuel drum and the majority of equipment. Perhaps it was because the expedition seemed to finally be happening but to Moseley, this part of Greenland was the most dynamic and beautiful yet. As the Twin Otter approached the band of carbonates, everyone strained through the scratched windows looking for caves. 'NF1' in Nordenskiöld Fjord (Smith and Moseley, 2022) was potentially spotted but no others. Eventually Wulff Land came into view and the Twin Otter landed close to base camp (Figure 1) at c.11.30 on a wild and bumpy landing strip, in stunning surroundings with warm temperatures, beautiful blue skies and thousands of mosquitoes.

The Twin Otter was unloaded, refuelled by hand, and then set off for Qaanaaq on the west coast, where the expedition helicopter fuel was still in storage and Lange should be waiting for pick-up. The only task on this day was to set up base-camp. From the previous expeditions, the team now had some experience of the best approach, which included setting up the cook tent and toilet downwind as this is the direction that a polar bear is likely to approach from. On this particular day the wind was not blowing, and since winds change direction anyway, there was a lot of discussion. The team had also landed on a raised fluvial bench. It was clear that they did not want to camp at river level as they didn't know how it responded, plus the possibility of a glacial lake outburst flood should not be ignored. Depending on where camp was pitched resulted in a few blind spots that they tried to minimise. Besides the mosquitoes, it was a fairly pleasant experience setting up camp (Figure 4). At some point the team had to remind themselves to stop and take a break. They also discovered that in the rush to leave Station Nord they had left behind the drill that had been intended for the bear fence posts, and the shovel that was needed for digging the toilet. Never mind, the team had all day and



Figure 5. (A) Chris Blakeley prepares to descend down a gully from a plateau above WUL-8. (B) Gina Moseley prussiks up the rope next to the entrance of WUL-8. The extremely fossiliferous, thin bedding is clearly visible, as well as the greenish icy pool in the entrance and large car-sized boulders.

All photographs: Robbie Shone/Greenland Caves Project.
 All rights reserved and not included in CC BY Licence.

endless light, they pursued by hand. The ‘evening’ was spent doing some rifle practice. By the next day the weather had turned cool and overcast. The team installed a malaise trap to collect insects and other bugs as well as a temperature logger in a small Stephenson screen that was programmed to record at hourly-resolution for the next year. Beyond that, there was not much to do except discuss plans, drink tea, admire the surroundings and wait for the last transport logistics to be put in place. The Twin Otter arrived c.14.30 with five drums of fuel but no Lange. He had had trouble on the west coast due to bad weather and despite trying for a week, had not made it to Qaanaaq for the Twin Otter pick-up. He would not be joining the expedition after all. The plane was only on the ground for 10 minutes, then the pilots set off back to Cass Fjord (Figure 1). They had already carried out several shuttles in the morning to bring the fuel from Qaanaaq to Cass Fjord, and had now just achieved one dump of five drums on Wulff Land. At the request of Moseley, the second dump of five drums went to Warming Land (Figure 1) where it was expected the expedition would be operating in a few days’ time. The helicopter arrived around 17.00 and then the expedition was as complete as it was going to be.

On 22nd July, 2023, Moseley, Blakeley and Shone went on the first helicopter flight to WUL-8, situated c.50 km south of base camp. Vogt circled around the west of the ‘mesa’ and flew up from the south with the ice-covered Apollo lake beneath. The face of the rocky brown escarpment loomed large out of the left window until the entrance of the cave came into view. Vogt hovered the helicopter in front of it, the first time anyone in this team had seen it in person. Everyone in the helicopter was quiet for some moments, all processing thoughts about what this incredible journey had led them to. To put it simply, it was an anti-climax. Blakeley voiced it first, Moseley muttered in agreement. It was not as big as was expected and the back wall could clearly be seen. Still, they were there and had a job to do. Vogt dropped them off on the plateau above the cave and set off to pick up Koltai and Hudson-Peacock. The rifles were loaded first and then Blakeley began preparing for his descent. It wasn’t long before he chose a gully to rig down and set off (Figure 5) down the shattered and loose rock. The remainder of the team arrived and the helicopter shut down. It was a long time until anything further was heard. In the eagerness to get going, the Cardo Packtalks hadn’t been set-up properly so there was no voice communication with Blakeley. Eventually, Shone set off down the ropes to find out what was going on and discovered that Blakeley had run out of rope. Shone returned to the plateau to collect more and then disappeared again. The others had a long wait on the surface. Eventually Moseley and Koltai set off in search of a ‘back-door’ entrance whilst Hudson-Peacock made an ascent to the highest point of the plateau. When Blakeley and Shone finally did return, they were full of excitement. Blakeley had thought he’d gone down far enough but when traversing over to the cave, found out that he was still far too high, which had meant reworking some of the rigging. In the end, 150m of rope was used and the entrance was huge (Figure 6)!

Moseley, Blakeley, Shone and Koltai headed back down the ropes. The bedding was extremely thin (centimetre to decimetre-thick) (Figure 5) and highly fossiliferous. Old, corroded, ex-situ flowstone was found in the gully. Once everyone was down, all four explored the cave together. A greenish pool with ice at the bottom that was present on Smith’s photograph from the 1990s still lay just inside the entrance (Figure 5). Huge boulders the size of cars scattered the floor. Birds nested on ledges high up above the ground. The team worked their way towards the back of the cave. The rear of the cave closed down in a hoar-frost covered boulder choke beneath the back wall. Everyone squeezed down into the darkness, trying to find a way on or a draught but none could be found. A number of small but human-sized passages were observed high up in the walls, but this wasn’t the time or place to mount a climbing expedition. Getting to this point had taken a substantial part of the day, and the team all still had

to get back up the wall and do two helicopter runs. With the pilot limited by his working hours, it was time to leave. The documentation could be carried out the following day. Back at base camp spirits were high. The team had successfully entered ‘WUL-8’, the infamous Wulff Land cave that had evaded so many people for 65 years. It was also Blakeley’s 50th birthday and another reason to celebrate! What a treat today had been.

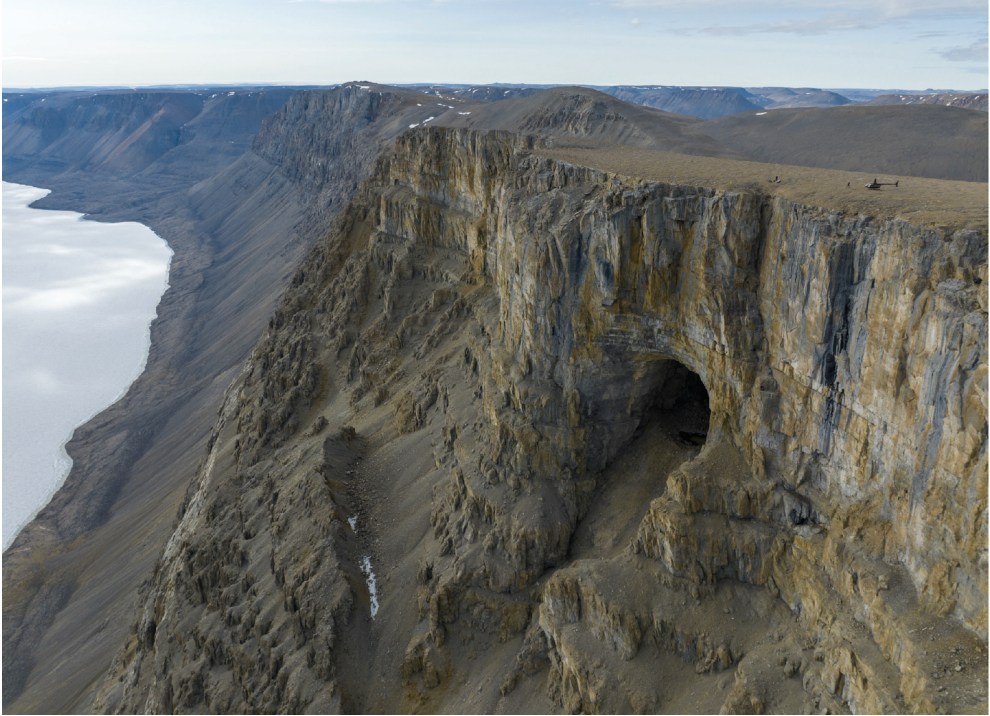


Figure 6. *The entrance of WUL-8 overlooking Apollo Lake with a helicopter and person for scale on the plateau above the cave. The gully down which Blakeley undertook the rigging is shown to the right of the entrance.*

Photograph: Robbie Shone/Greenland Caves Project.
All rights reserved and not included in CC BY Licence.

The team returned to the cave on 23rd July, 2023, and started with aerial photographs (Figure 2). Much to Shone’s dissatisfaction the weather was more overcast than it had been the previous day and the photographs didn’t turn out as planned. Time was once again limited by the pilot’s working time so with only a few hours available everyone worked as fast as possible. Samples were collected for different microbiology analysis from the pool, ice, sediments and bird faeces. Koltai and Blakeley undertook a traditional survey with DistoX and an android phone, which showed the entrance to be over 35 m high and over 40 m wide. At its tallest point the cave was over 39 m high and was approximately 100 m in length, which by Greenland standards is quite long (Moseley *et al.*, 2020). Moseley took approximately 1000 photographs for photogrammetry, Shone took documentary photographs (Figure 7), and Koltai undertook a 3D laser scan. No speleothems were observed within WUL-8 for palaeoclimate research, and if they had even been present, they were likely underneath the boulders. With time ticking on,



Figure 7. *Looking east out of the entrance of WUL-8 across the icy pool.*
Photograph: Robbie Shone/Greenland Caves Project.
All rights reserved and not included in CC BY Licence.

Moseley returned to the surface so that the first helicopter run to base camp could take place whilst the other three undertook the de-rig. Despite the huge entrance, it was still a surprise to see how bad the weather had become. It was very windy and when Moseley and Hudson-Peacock arrived at base camp they met a state of chaos. The tarpaulin over the generator was flapping around on one anchor point, all pins on the bear fence were out and the alarms going off, and the pilot's tent had been pierced by a snapped pole. Moseley and Hudson-Peacock made eye contact with Vogt, expecting him to fly off at any moment to fetch the others. He didn't and instead signalled with a cutting motion across his throat. What was happening? Were they in danger? The engines turned off. Were the other three going to be trapped out in the storm? It turned out he had to refuel, which added a delay whilst the weather continued to get worse. He did manage to collect the others who had also started to discuss their options for being stranded from base camp. That evening, Vogt was particularly worried about how bad the weather would get and the stress it could put on the helicopter if not protected. The next day (24th July, 2023), the wind had died down but the visibility was poor hence the team stayed around base camp. For the rest of the expedition, the weather remained fairly challenging. One team managed to go out for half a day on 25th July, 2023, everyone was grounded on 26th July, 2023, and both teams got out on 27th July, 2023. Several substantial caves were explored (though not as big as WUL-8) and speleothems were finally found during the last possible exploration hour of the expedition. The speleothems were flowstones, similar to those present in Northeast Greenland (Moseley *et al.*, 2020) and they were found in a cave with a stunning keyhole-shaped passage for an entrance. This cave clearly maintained its original morphology, meaning that the speleothems were not beneath boulders. In hindsight, several 'small' phreatic tubes and some with notches at the base, were observed in the wall near WUL-8, however, from the helicopter they appeared too small to enter. Later investigations showed that these passages are in fact human-sized and could prove useful places for searching for speleothems in the future.

Due to warnings from the Greenland Met Office about an approaching storm 'like had never been seen at this time of year in North Greenland', the helicopter departed late on 27th July. The rest of the team then had four days at base camp waiting for the impending storm and Twin Otter pick-up. Naturally they sorted through gear, started packing and considered resources in case the pick-up was delayed. Apparently, the storm raged all around them but base camp remained fairly secluded and unaffected. It was cold with freezing rain and a bit of snow, but not as bad as expected. In total, three and a half days out of a planned nine were utilised for cave exploration. The team ticked off all the main objectives including accessing, exploring surveying, photographing and sampling for microbiology in WUL-8. They completed a slimmed-down version of these tasks in three other caves and also collected speleothems. At base camp they collected a jar full of Diptera with two dominant groups being *Culicidae* (mosquitoes) and *Chironomidae* (non-biting midges), which is being analysed at the University of Oxford Museum of Natural History. They also undertook some basic meteorological studies and collected precipitation samples for stable isotope analysis. At base camp they saw Arctic hares, herds of musk ox and two wolves. Despite the challenges, the expedition was a success. At today's exchange rate, it cost £310,522.

ACKNOWLEDGEMENTS

The author thanks the Greenland government for permission to undertake this field-work (KNNO Expedition Permit C-23-11; Genetic Resources G23-030 and G23-087; General

Scientific Research Permit GSR-1-2023-03; Rifle Permit C-23-11; Radio Permit 2023-6569; Export Permit 2023-97). Further, the Mineral Licence and Safety Authority (MLSA) assessed the activities of the project and concluded that the activities fell beyond the scope of the Mineral Resources Act. The expedition therefore did not require a Scientific Permit from the MLSA. She additionally thanks Sebastian Rasmussen at Polog, Norlandair and Mathias Vogt at Volcanoheli for planning, logistics and transport support as well as the team at Villum Research Station and Station Nord for welcoming and hosting the expedition members prior to and after the expedition. Finally, Moseley would like to thank the incredible expedition team, Chris Blakeley, Nathan Hudson-Peacock, Gabriella Koltai and Robbie Shone, as well as Hans Lange who unfortunately did not get to participate in the expedition. Thanks are extended to Bob Churcher for providing historical accounts, M. Paul Smith for his support throughout the entire project, Ian Cowie for permission to publish his father's letter, and Lena Friedrich for production of Figure 1.

FUNDING

We would like to thank the following organisations and individuals for supporting and funding this project: Rolex Awards for Enterprise, National Geographic Magazine, Global Climate Change Foundation, Austrian Science Foundation, Petzl Foundation, Mount Everest Foundation, Transglobe Expedition Trust, Austrian Academy of Sciences, British Cave Research Association, Wings Worldquest. Additionally, we would like to thank Petzl, Cardo Outdoor, Grayl and Stella Prolights for equipment sponsorship. Expedition participants Gina Moseley, Robbie Shone, Chris Blakeley, Gabriella Koltai, Nathan Hudson-Peacock also invested in personal equipment. This research was funded in whole or in part by the Austrian Science Fund (FWF) grant DOI 10.55776/Y1162. For open access purposes, the author has applied a CC BY public copyright licence to any author accepted manuscript version arising from this submission. The CC-BY licence excludes all work of Robbie Shone for which all rights are reserved.

REFERENCES

- Adams, P.J. and Cowie, J.W. 1953. A Geological Reconnaissance of the Region Around the Innerpart of Danmarks Fjord, Northeast Greenland: *De Danske Ekspeditioner Til Østgrønland 1947-52 Under Ledelse Af Lauge Koch*. Reitzel.
- Commission for Environmental Cooperation (CEC). 2010. *North American Glaciers and Sea Ice, 2004*. Natural Resources Canada (NRCan), Instituto Nacional de Estadística y Geografía (INEGI), U.S. Geological Survey (USGS). Ed. 2.0, Vector digital data [1:10,000,000]. Updated 2023 [Dataset].
- Cowie, I. 2012. *Dr. John Watson Cowie, Ph.D. F.G.S., 17th September 1919 — 25th January 2012*. Available at: <https://afinitas.org/Cowie/Bios/JWC1919B.html> [Accessed 24.7.2024].
- Davies, W.E. 1956. President's Column. *NSS News*. **14**. 10. 95.
- Davies, W.E. 1957. Rillenstein in Northwest Greenland. *Bulletin of the National Speleological Society*. **19**. 40-46.

- Davies, W.E. and Krinsley, D.B. 1960. Caves in Northern Greenland. *Bulletin of the National Speleological Society*. **22**. 114-116.
- Donovan-Beerman, T. and Mullan, G.J. 2020. Obituary: Desmond Thomas Donovan 21 June 1921 - 23 December 2019. *Proceedings of the University of Bristol Speleological Society*. **28**. 2. 181-182.
- Higgins, A.K. 2010. Exploration history and place names of northern East Greenland. *Geological Survey of Denmark and Greenland Bulletin*. **21**. 1-368.
- Moseley, G.E. 2016. *Report on the findings of the Northeast Greenland Caves Project 2015 expedition to Kronprins Christian Land, Northeast Greenland*. Innsbruck, Austria: Northeast Greenland Caves Project. 91pp.
- Moseley Y, G.E. 2018. *Chasing Shadows, Preliminary Report of the EAGRE18 Expedition*. 12pp.
- Moseley, G.E. 2020a. Guest Editorial. *Cave and Karst Science*. **47**. 2. 54.
- Moseley, G.E. 2020b. Greenland Caves Project 2019 Expedition Report. Appendix 10. Expedition Budget and Sponsors. *Cave and Karst Science*. **47**. 2. 116.
- Moseley Y, G.E., Barton, H.A., Spötl, C., Töchterle, P., Smith, M.P., Bjerkenås, S. E., Blakeley, C., Hodkinson, P.D., Shone, R.C., Sivertsen, H.C. and Wright, M. 2020. Cave discoveries and speleogenetic features in northeast Greenland. *Cave and Karst Science*. **47**. 2. 74-87.
- Obu, J., Westermann, S., Bartsch, A., Berdnikov, N., Christiansen, H.H., Dashtseren, A., Delaloye, R., Elberling, B., Etzelmüller, B., Kholodov, A., Khomutov, A., Kääb, A., Leibman, M.O., Lewkowicz, A.G., Panda, S.K., Romanovsky, V., Way, R.G., Westergaard-Nielsen, A., Wu, T., Yamkhin, J. and Zou, D. 2019. Northern Hemisphere permafrost map based on TTOP modelling for 2000–2016 at 1 km² scale. *Earth-Science Reviews*. **193**. 299-316.
- Rolex. 2021. *Gina Moseley 2021 Rolex Awards Laureate*. Rolex.org. Available at: <https://www.rolex.org/rolex-awards/exploration/gina-moseley> [Accessed 29th July 2024].
- Schuster, L., Maussion, F., Langhamer, L. and Moseley, G.E. 2021. Lagrangian detection of precipitation moisture sources for an arid region in northeast Greenland: relations to the North Atlantic Oscillation, sea ice cover, and temporal trends from 1979 to 2017. *Weather Climate Dynamics*. **2**. 1. 1-17.
- Smith, P. and Moseley, G.E. 2022. The karst and palaeokarst of North and North-East Greenland – physical records of cryptic geological intervals. *GEUS Bulletin*. **49**. 8298.
- Zollinger, M. 2015. *TOP to TOP, The Schwoerer Family — When the Earth Turned into a Nursery* (English Translation). 180pp.

Gina E. Moseley
Institute of Geology, University of Innsbruck,
Innrain 52, 6020 Innsbruck, Austria.
gina.moseley@uibk.ac.at