Supraglacial rock avalanches, Alaska

Aim: Sample supraglacially deposited rock avalanches to understand their influence on glacial biogeochemistry

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Expedition Foods

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1.0 MEET THE TEAM

EXPEDITION LEADER: WILL SMITH

Will is a PhD student at Newcastle University, investigating how supraglacially deposited rock avalanches can affect glacial biogeochemistry. This expedition was the first fieldwork of his current PhD research, which is focussing on Alaskan glaciers, due to the prevalence of rock avalanches in the region. During Will's time in academia (BSc Geography at Northumbria University and MSc Polar and Alpine Change at the University of Sheffield) he has undertaken glaciological fieldwork in the European Alps and Svalbard. In his spare time, he is also a keen rock climber and mountaineer, spending the majority of his time climbing / fell running / cycling in the Lake District and Northumberland.

STUART DUNNING

Stuart is a Senior Lecturer in Physical Geography at Newcastle University and Will's PhD supervisor. His main research focus centres on hillslope processes, often in cryospheric systems. He has undertaken fieldwork all over the world, including Greenland, Antarctica, Himalaya, New Zealand and the European Alps.

RICHARD SMITH

Richard is an aspiring mountain guide having recently completed a BA in Outdoor Leadership at the University of Cumbria. His aim, now he has finished university, is to undertake his walking, climbing and mountaineering awards to become a certified guide. He therefore spends the majority of his time in the Lake District, climbing and fell running, honing his skills in preparation. He has previous mountaineering and climbing experience in Scotland (winter) and the European Alps.

2.0 SCIENCE BACKGROUND / INTENTIONS

Slope processes are a critical control on sediment delivery onto ice masses, which is becoming increasingly important as glacial environments transition to deglacierized (e.g. Porter *et al*., 2010). During large rock slope failures (>10^6 m^3) rapid transport of this sediment promotes rock comminution, creating rare aggregates formed under intense pressure and heat (Weidinger *et al*., 2014). The delivery of this sediment onto ice masses causes large extensive deposits, covering larger areas than their non-glacial counterpart (Hewitt, 2009). This is due to the friction between the rock avalanche material and the ice, creating vast amounts of meltwater, lubricating the debris, promoting additional expansion. However, it is currently unknown how this meltwater interacting with fresh rock substrates affects meltwater geochemistry and subsequently the biogeochemistry of the glacier. For example, rock comminution is known to increase the bioavailability of certain compounds in glacial environments (Telling *et al*., 2015), but the impacts of these potentially nutrient-rich sediment inputs on fertilising supra-, sub-, and extra-glacial environments are unknown. Substantial nutrient delivery may stimulate autotrophic activity, creating a negative climate feedback loop. This project aims to quantify the biogeochemical effects of supraglacially deposited rock avalanches by sampling large fresh deposits in Glacier Bay National Park, Alaska, before laboratory analysis of these samples in the UK. Alaska is the ideal place to study these deposits because they are well documented, with known event dates and volumes. We hope to understand how initial rock avalanche deposition modifies glacial biogeochemistry through analogue experiments, but also understand how supraglacial deposits effect glacial biogeochemistry over time, through seasonal interaction with snowpacks and subsequently snowmelt.

This work will form part of the PhD thesis of William Smith titled "Effects of supraglacially deposited rock avalanches on glacial biogeochemistry", undertaken at Newcastle University.

3.0 EXPEDITION SUMMARY

The team set off to Glacier Bay National Park, Alaska to investigate two large rock avalanches (RA): the La Perouse RA deposit and the Lamplugh RA deposit, both of which were deposited on outlet glaciers of the Brady Icefield in 2014 and 2016, respectively. This huge icefield is one of the remotest parts of North America, and a region with some of the highest terrain, with peaks rising over 4000 m straight out of the Pacific Ocean. The areas proximity to the Pacific Ocean is also the reason for its reputation as having unforgiveable weather conditions.

We had a very short 10-day period in which to get in, get samples and get them back to the lab. This was always going to be a difficult task because a certain amount of snow was needed for ski plane landing, but we needed the rock avalanche debris to be relatively snow-free so we could extract samples. Our plan to land at one deposit, traverse the icefield to access the next deposit, before sampling and flying back to the main town, was ultimately unfeasible due to snowpack conditions. Instead, we were dropped on a higher tributary of the icefield, due to the better snow for ski-plane landing and from here, we traversed the width of the icefield each day to extract samples from the Lamplugh RA. Luckily, we had an excellent 5-day weather window and did not experience any of the rainfall described as 'too heavy for Gore-Tex'.

The expedition gave us a chance to learn and experience proper self-sufficiency in the field and any limitations of our methodology, which will be invaluable for future work in other remote areas of Alaska. We were determined to get a large amount of samples for analysis, but also to enjoy the experience of being so isolated from civilisation – we succeeded in this and will hopefully be able to share some exciting new data from this expedition in the near future.

4.0 PLANNING

4.1 GLACIER BAY NATIONAL PARK

Glacier Bay National Park is a globally significant marine and terrestrial wilderness sanctuary. As the name suggests it is heavily glaciated, featuring large tidewater glaciers, valley glaciers and icefields. The area is particularly remote with only a few settlements within close proximity to the main glaciated peninsula. Access is only by boat or ski plane making it difficult to visit for tourists, who typically see the area on large cruise-ships. The area has some phenomenal peaks, the highest being Mount Fairweather at 4671 m, but numerous peaks remain unclimbed and numerous areas unexplored, due to harsh weather and accessibility issues.

4.2 OUR PLAN

The overarching aim of this project is to determine how rock avalanches deposited onto the surface of glaciers influence their biogeochemistry, and how this could modify extra-glacial ecosystems.

The main objective of this fieldwork was to visit two of the largest glacial rock avalanches (RA): Lamplugh and Le Perouse (Coe *et al.*, 2017) (Figure 1), which occurred in 2016 and 2014, respectively. To do this, we planned to be flown onto the Lamplugh glacier by Fly Drake, from their base in Haines. Once onto the glacier we planned to camp overnight at a suitable location, before walking up the Lamplugh RA deposit the following day, to extract multiple samples in the six different deposit zones, outlined in the MSc thesis of Bessette-Kirton (2017). Once sampling was complete, we would begin an 18-mile traverse of the Brady Icefield, to access the Le Perouse glacial RA (58°33'40.81"N, 137° 4'24.19"W). Due to this being planned as a late June traverse of the icefield, climatic conditions are typically at their most stable, theoretically giving us larger weather windows for our research. The main issue we envisioned to encounter was snowpack conditions. For a ski plane to land on the icefield, snow needed to be of a suitable depth and have undergone compaction to ensure a solid landing platform; however, for the team to sample RA debris, the deposit needed to be relatively snow-free. Late June is typically a time when this small window of opportunity is available.

Depending on climatic conditions, time constraints and current accessibility, three other RA deposits were to be investigated on the way between Lamplugh and Le Perouse RA deposits (58°38'35.38"N, 137°6'0.82"W; 58°37'52.53"N, 137°1'30.36"W; 58°38'51.10"N, 137°4'52.47"W). These occurred in 2016, 2010, and 1994, allowing collection of samples from deposits, which have existed on the surface for multiple years, potentially reducing their ability to affect glacial geochemistry. Once the Le Perouse RA deposit had been reached, we planned to sample the deposit in a similar way to that of the Lamplugh RA deposit. After completing all sampling, we would be extracted from the icefield by Fly Drake, back to their base in Haines.

All RA sampling would involve extracting at least four 500 g samples of RA material, at different locations within each RA deposit zone, to investigate spatial variation in deposit chemistry. Samples would consist of material from depths of 0-10 cm and sampling would be undertaken using sterile sampling apparatus i.e. hand trowel, and pre-sterilised bottles. All samples would be frozen in the field using a portable freezer connected to solar panels.

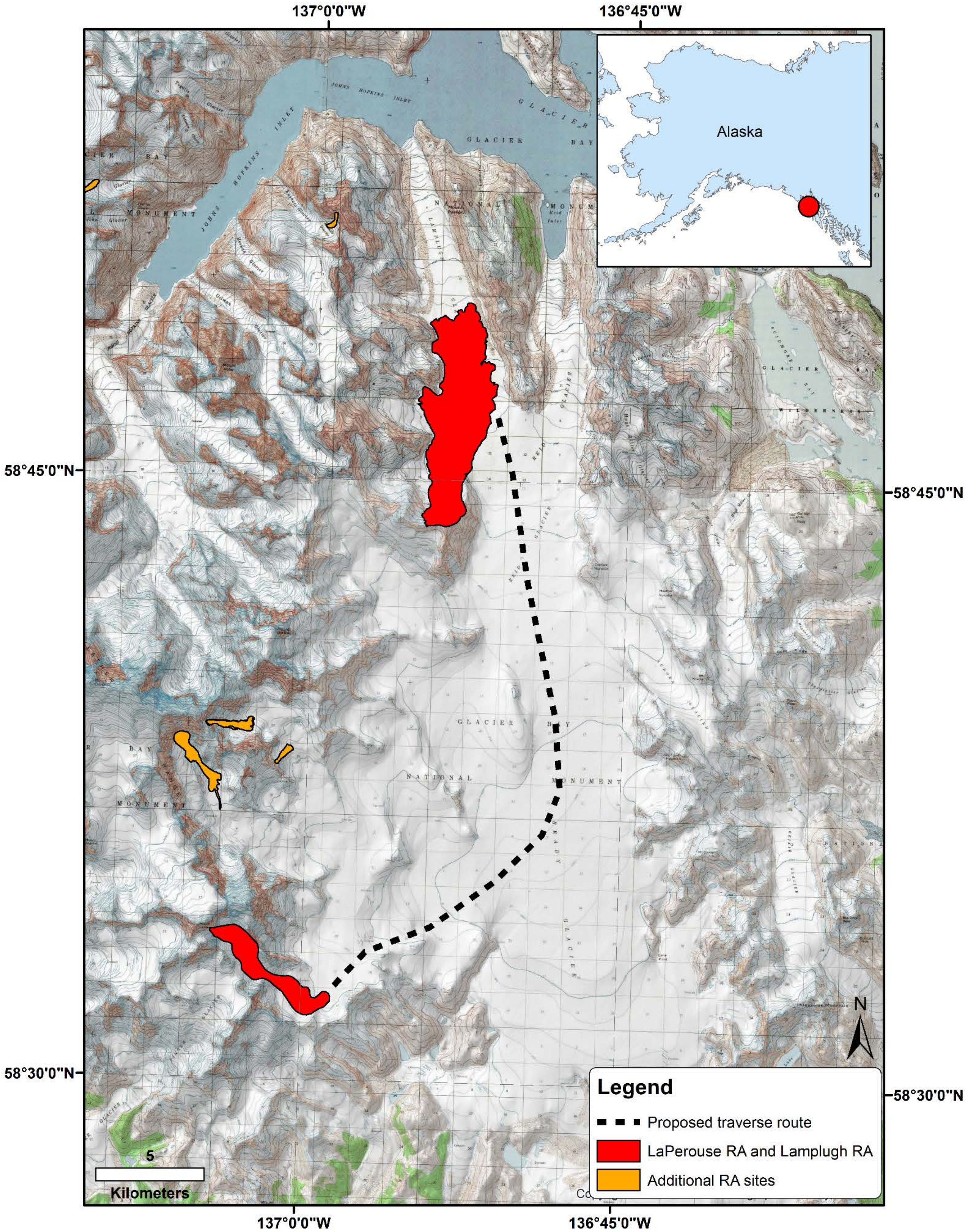

Figure 1: The planned traverse of the Brady Icefield to attain samples of the two largest glacial rock avalanches (RA). Red RA deposits depict primary objectives (Lamplugh the larger deposit towards the north of the figure, and La Perouse the smaller deposit in the south); orange RA deposits depict secondary objectives.

5.0 DIARY

PART 1 – GETTING TO HAINES

We set off from Newcastle University at 5 am on the 21st June to drive to Manchester airport, where we would get the first flight of our journey at 12:55 pm to Seattle Tacoma. This gave us plenty of time to sort out our 130 kg of baggage… or so we thought. We had booked enough excess baggage for all of our gear but because a portable freezer is apparently not something people usually carry in hold luggage, we had a couple of issues. This freezer was integral to our project, because samples would be useless if they were not frozen immediately after their extraction (it would prevent any chemical/biological changes to the debris before laboratory analysis), and therefore we needed it to come to Alaska with us. After a lot of persuasion, the freezer finally went off on its long journey down the baggage conveyor belt – we all let out a sigh of relief. Once arriving in Seattle we caught our next flight to Juneau, where we stayed the night in the airport. Check out our luxurious sleeping quarters below:

Awaking the next morning we caught the 4.5-hour ferry from Juneau to Haines, on board the Le Conte ship, where we got some stunning views of the Lynn Canal and its surroundings.

PART 2 - PREPARATION

After arriving in Haines we were taxied into town by John of Haines Shuttle (the only taxi service in Haines), stopping off at a hardware store to collect some science essentials e.g. gaffer tape and zip ties. Looking at the weather forecast for the next few days, it looked as if we would have a 5-day weather window, so had to ensure we were fully prepared for departing the next day. This involved some unconventional crevasse rescue practice using a hotel balcony, and a trip to buy a battery to power the freezer while in the field. The next day we got the call from Drake to say he could get us out there, after he had picked up another expedition who were attempting to summit Mt Bertha.

PART 3 – THE GRAND DEPARTURE

We arrived at the airstrip, cooked some lunch on the runway – an interesting place to eat, and Drake arrived. Due to the plane size, it was decided that two trips would be necessary: firstly one person with all the kit, and then the other two people with the remaining kit. Stuart volunteered and before we knew it, he was in the air and on his way. One hour later and we were loading up the plane ready for departure. Drake had scouted around multiple landing sites on the icefield during the first flight, deciding that our optimum-landing site next to the Lamplugh deposit was too dangerous. This was due to the hummocky snow surface, caused by differential ablation of the snowpack. The snowpack was also very wet at this altitude, potentially causing the skis to dig in and flip the plane on landing. Drake settled for a landing spot on a tributary of the Reid glacier, about five miles from the Lamplugh deposit (58.73, -136.776). After all team members and kit were on the glacier, we were left alone in the National Park for the next 4 days.

PART 4 – THE SCIENCE

During our first night on the ice, there was heavy rain, but we awoke to much calmer weather conditions. We kitted up and headed on over to the descent off the Reid tributary glacier, which was a 200 m snow and gravel slope with a gradient of ~50 %. For the first day, we decided to go light and take only one pulk and all sampling apparatus, to assess the conditions. Once down the descent, we negotiated a large amount of crevasses, which generally turned out to be a maximum of 20 cm wide, before traversing the icefield over a very wet snowpack. Even with a light pulk and snowshoes, there was considerable resistance from the snowpack, something that could have potentially been eradicated with the use of skis.

Sampling commenced once we arrived at the Lamplugh deposit, and after we had filled up on some excellent vegetable tikkas provided by Expedition Foods. Luckily, the majority of the deposit was snow free and therefore easy to sample, and in areas of snow cover, there were visible debris patches that were accessible. On the first day, we collected half of the samples needed. Once back at base camp we discussed the logistics of getting to the La Perouse deposit and concluded that if was unfeasible to sample. The two main reasons for this included: it was unknown if Drake would be able to collect us from the La Perouse deposit because snow conditions were unknown in that area, and the weather window was now only 3 days long. In addition, the steep descent would have been dangerous with 80 kg + of freezer, battery and solar panels and the snow conditions would have made dragging all equipment difficult and unfeasible in such a short amount of time. It was decided that Lamplugh would become the main objective, with more samples taken of the Lamplugh deposit than originally intended to counteract the lack of La Perouse samples. The second day was much like the first day, collecting the remaining samples and getting back to camp. In total, 20 sediment samples, 2 water samples, 12 snow samples and 10 clasts were collected for laboratory analysis.

PART 5 – THE 'DAY OFF'

After sampling was complete, we were contacted by Drake to inform us of weather conditions. The weather window allowed one more day on the ice, we therefore used this day to explore the area and attempt an ascent of Contact Nunatak. Cloud rolled in and out of camp frequently throughout the day, with visibility varying between 2 m and 20 km. We approached the base of Contact Nunatak and assessed the snow: it was similarly wet and unstable and the ascent required continuing up a corniced snow ridge, which looked inherently unstable. It was at this point that we decided the risk was too great, and although it would have been an excellent way to finish the trip, we had already been successful in sampling. We walked back to camp and relaxed for the rest of the evening.

PART 6 – DEPARTURE DAY

Awaking early, we got the call from Drake that he would pick us up around 11 am, so camp was packed up and we awaited his arrival. The weather looked unnerving with low cloud frequently reducing visibility to only a few metres. Luckily, Drake managed to land, so Will and Stuart went first with the intention to collect Richard, and all the gear, after he had dropped those two back at base. On the first flight, the weather looked very unfavourable for another pick up, and everyone was unsure as to whether Richard would have to spend another day or two on the icefield alone. Drake was quick to drop kit and refuel before flying back out almost immediately, to try collecting Richard and the remaining gear. When he landed,

the conditions were perfect and while we were waiting back at the airstrip, wondering what was happening, Drake and Richard were walking around on the icefield, taking in the stunning views once more. While waiting we managed to persuade one of the local airlines to let us use some electricity to power the freezer and keep samples frozen. Richard and Drake finally arrived back and we headed into Haines, for the remaining two days of the trip. We were lucky to have excellent weather and a successful sampling campaign. It was unfortunate we could not sample all objectives, but we successfully negated this by taking more samples of the Lamplugh RA deposit.

6.0 THE FINAL ROUTE

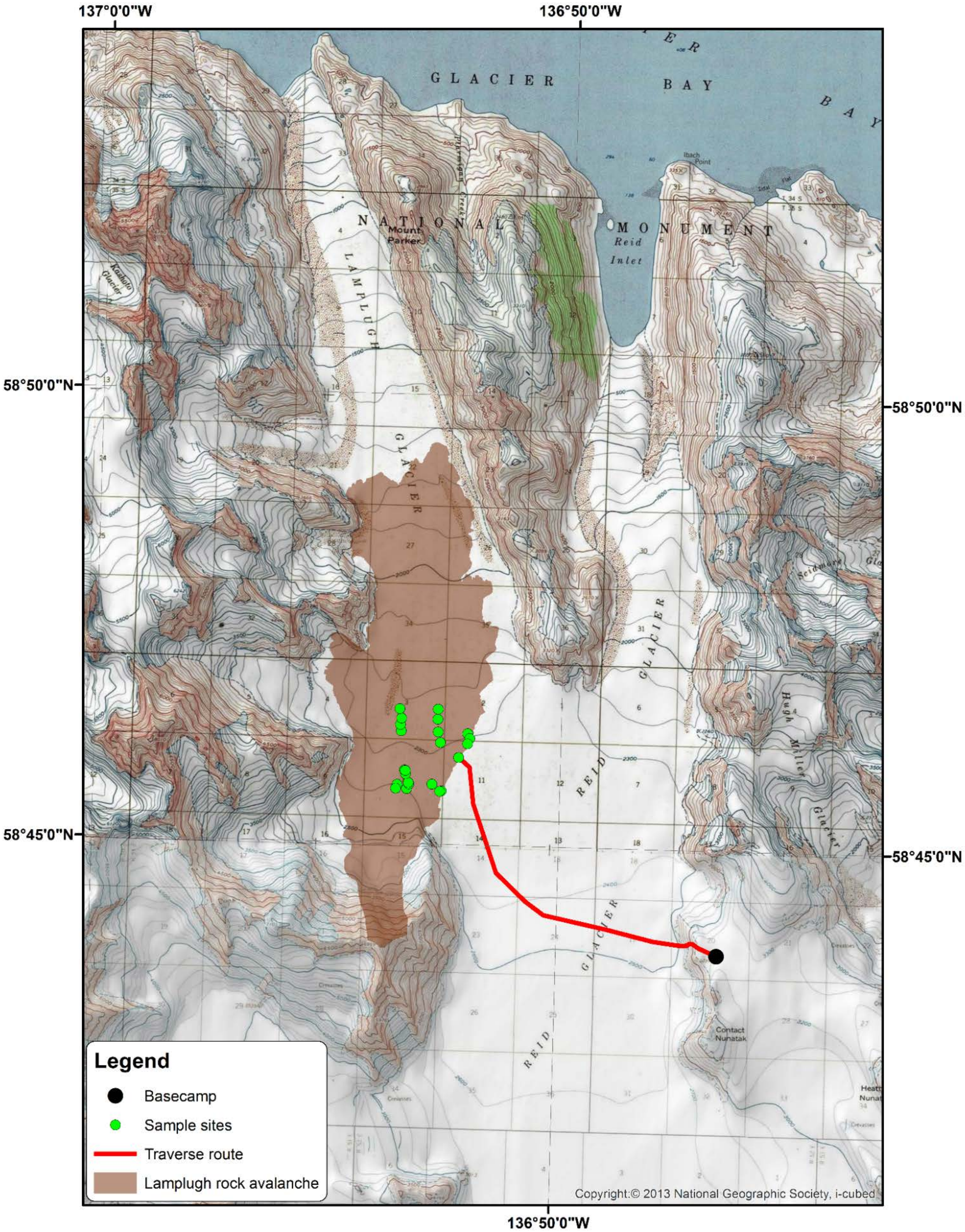

Figure 2: Map displaying basecamp, sample sites and the traverse route undertook on both days. Contact Nunatak is 1 km south of basecamp.

7.0 FUTURE WORK

Samples were successfully transported frozen back to the UK. Laboratory analysis has not yet been undertaken but is due to commence in the first quarter of 2019.

8.0 GLACIER BAY NATIONAL PARK SPECIFICS

PERMITS

A permit was obtained from the US National Park Service, with liaison primarily through Lewis Sharman. A permit should be applied for at least 3 months prior to fieldwork commencement.

MAPS

Google Earth and topo maps accessible through the USGS, were used for expedition planning.

EQUIPMENT TRANSPORTATION

All expedition equipment was taken as excess baggage on Thomas Cook Airlines and Alaska Airlines. A duplicate list was used to export and re-import equipment from the UK. If equipment were more valuable, a carnet would have been obtained.

FOOD AND ADDITIONAL EQUIPMENT

All food for the trip was bought from Expedition Foods and transported to the US as excess baggage. Freeze-dried food was available to buy in Alaska Sport Shop. Any outdoor equipment required (i.e. fuel, clothing etc.) was also available to buy at Alaska Sport Shop or Alaska Backcountry Outfitter.

COMMUNICATION

An Iridium satellite phone was used for all communication while in the field. Haines is not a big town but they had numerous cafes and a public library with free WiFi.

RISKS

The main risks were glacier travel i.e. crevasses, but weather was also known to be highly changeable in the area. Bears were also a risk, so we were advised to take an air horn for additional safety. A full risk assessment was undertaken and approved by Newcastle University.

MEDICAL ARRANGEMENTS

In case of small emergencies, we would contact Drake of Fly Drake. For any severe emergencies, our satellite phone had an SOS button, which would immediately put us in contact with local emergency services, which in our case would be the US Coast Guard.

9.0 MEF SPECIFIC QUESTIONS

OBSERVATIONS ON THE ACCURACY, OR OTHERWISE, OF GOOGLE EARTH IMAGES.

Google Earth images generally represented the area well and were sufficient for initial investigation of the study area and planning.

SUGGESTIONS FOR NEW ROUTES OR NEW SUBJECTS FOR STUDY IN THE AREA.

The icefield is generally poorly understood because of harsh conditions and accessibility issues. Snowpack evolution research would be particularly useful in this area due to the amount of snow deposited over the year and the hummocky topography it is characterised by, due to differential ablation. Simple melt rate research would also be valuable, providing mass balance estimates and estimates of discharge.

NOTES ON ACCESS, PORTERS, OR OTHER ISSUES OF INTEREST TO FUTURE VISITORS.

Fly Drake was an excellent pilot with exceptional knowledge of the area; this was invaluable for us during our time there.

DETAILS OF ANY INJURY OR ILLNESS TO EXPEDITION MEMBERS AND/OR PORTERS.

No injuries or illnesses during the expedition.

DETAILS OF WASTE DISPOSAL.

All human waste was buried in deep trenches, with all non-human waste brought back to be disposed of properly in Haines.

A SUMMARY OF EXPEDITION ACCOUNTS, INCLUDING INCOME AND EXPENDITURE.

Income

Source	**Amount**
Mount Everest Foundation (18-22)	£2,000
Gino Watkins Memorial Fund	£1,500
Newcastle University Research Training Support Grant	£6,300
Total	£9,800

Outgoings

Expenditure	**Amount**
Flights, Charter flight and in country travel	£5,593
Science and safety equipment	£3,454
Food	£458
Accomodation	£295
Total	£9,800

10.0 REFERENCES

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