Proposed expedition: Volcanism and climate of southern Patagonia, January-March 2012

Expedition leader: <*Leader name*> (<*College name*>)

Abstract

This proposed expedition will entail a team of four geologists, three from the University of Oxford (two current postgraduate students) and a Chilean undergraduate, conducting approximately seven weeks of fieldwork in remote parts of southernmost Patagonia (Chile and Argentina), departing the UK on the 8th of January 2012, and returning in mid- to late March. The primary aim of this challenging fieldwork/expedition is to determine the history of volcanic eruptions in the region during the late Quaternary, and examine how this relates to climate variations (by interactions with ice cover). This will involve collecting peat cores (bearing layers of volcanic ash) from across the region, spending three weeks working on the remote volcano Monte Burney (first climbed only in 1973), and visiting the renowned granite towers Torres del Paine and Fitzroy.

Contents

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Cover image: Monte Burney (52.33°S, 73.40°W), the southernmost stratovolcano in the Andes, and the location/focus of study for the main phase of the proposed expedition.

1. Aims

1.1. Objectives

The primary objective of this proposed expedition will be to collect samples and other data in order to constrain in detail the history of eruptions of the volcanoes of the Austral-Andean Volcanic Zone (AVZ; 47–55°S), southernmost Patagonia, for the late Pleistocene and Holocene (i.e. the last ~20,000 years). A closely related supporting objective will be to conduct reconnaissance geological mapping of the most accessible (but completely unstudied) of these volcanoes, Monte Burney, with particular focus on identifying evidence for interactions between eruptions and ice. Subsidiary objectives include:

- Collecting additional data for hazard assessment of the AVZ volcanoes
- Making observations of and sampling granite outcrops from the region
- Assessing the potential for 'geotourism' at Monte Burney
- Reinforcing and developing collaborations with Chilean scientists
- Training volcanology students in field techniques and glaciovolcanism
- Personal development through planning and execution of an ambitious project in a challenging but stimulating environment

1.2. Justification

The volcanoes of the AVZ are poorly understood: major eruptions of Aguilera, Reclus, and Burney volcanoes have occurred in the last 20ka (thousand years) [Stern, 2008], but there has been no attempt to reconstruct a detailed regional eruption history, nor study any of the volcanoes in detail; this proposed expedition would collect data to do both. A high-resolution regional tephrochronology (i.e. history of ash-depositing eruptions) will improve dating and correlation of late Quaternary geographical/geological data collected from the region (and offshore). Furthermore, it will enable much better constraint of the magnitude of and dispersal of ash from past eruptions, invaluable data for assessing the hazard potential of the volcanoes, both for settlements and air traffic. It will also allow a regional test of the hypothesis that deglaciation initiated a global pulse of volcanic activity that contributed significantly to the late Pleistocene increase in global atmospheric CO_2 concentrations [Huybers & Langmuir, 2009]. Such regional tests are vital for evaluating the influence of deglaciation on volcanic activity, which has implications for our understanding of the effects of climate change and the controls on volcanism.

The fieldwork on Monte Burney will be integral to extending the eruption history of the volcano beyond the last 20ka, and to studying volcano-ice interactions, so revealing a long history of the links between changing climate and volcanism. This will provide insights into hazard evaluation for ice-capped volcanoes worldwide, as well as for Burney itself, which is alongside a major shipping route.

2. Background

2.1. Volcanism in southern Patagonia

As aforementioned, the eruption history of the volcanoes in the AVZ is very poorly constrained: Stern [2008] identifies the major events of the last 10ka that are exposed in road and river sections (sample numbers on Figure 2.1.1, showing the location of the volcanoes); these records are integrated with analysis of macroscopic tephra layers from terrestrial and marine cores taken by Kilian *et al.* [2003, 2007]. Many eruptions will have been undoubtedly missed by insufficient terrestrial sampling in northern Magellanes and by not identifying micro/crypto-tephra horizons in the stratigraphy; our sampling strategy will enable a more detailed tephrochronology to be extracted and analysed.

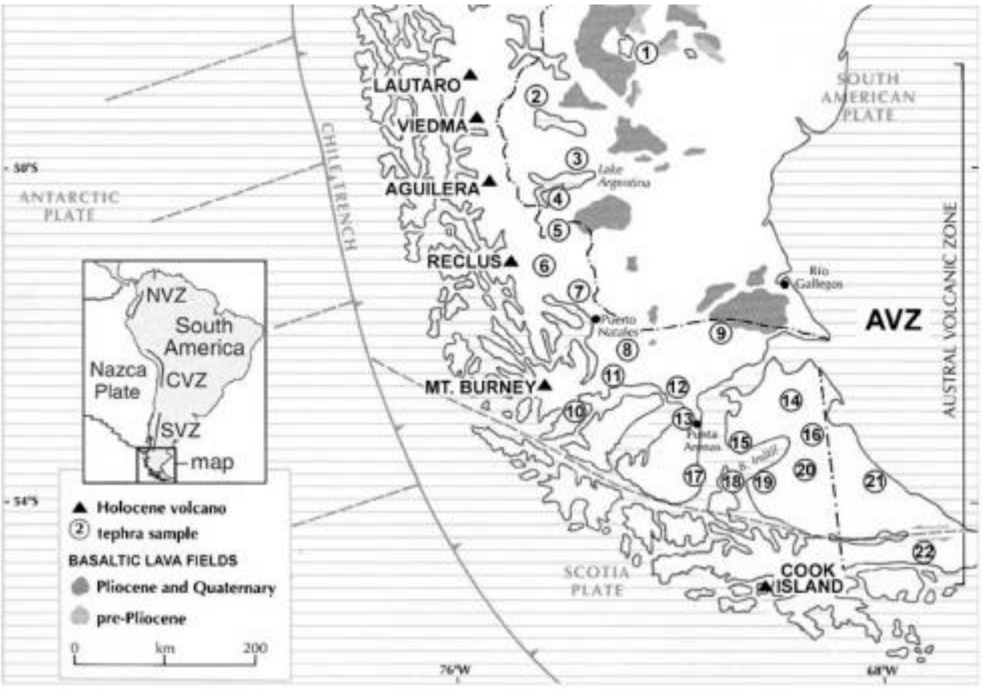


Figure 2.1.1: Map showing the six volcanoes of the Austral Volcanic Zone (black triangles), and locations where tephra have been previously sampled, albeit with little detail. Modified from Stern [2008].

2.2. Previous expeditions to Monte Burney

The Muñoz Gamero peninsula, on which Monte Burney sits, was first explored by Eric Shipton and others in 1961 and 1962, with bad weather prohibiting first ascent of the volcano. This was achieved in Shipton's third visit in March 1973. His Alpine Journal report (Shipton, 1974) describes persistently bad weather and difficult terrain of dense forest and swamps, but they still achieved a complete tour of the mountain in 16 days in 1962. The weather and terrain conditions were corroborated by John Shipton *et al.* [Shipton, 2008] in March-April 2007, who noted the persistent 800m cloud level. Study of the topographic map (Figure 2.2.1) suggests there are plenty of outcrops to investigate below this altitude. Although it is apparently not a technical climb to the summit, we do not intend to attempt it in the unlikely event of a spell of good weather.

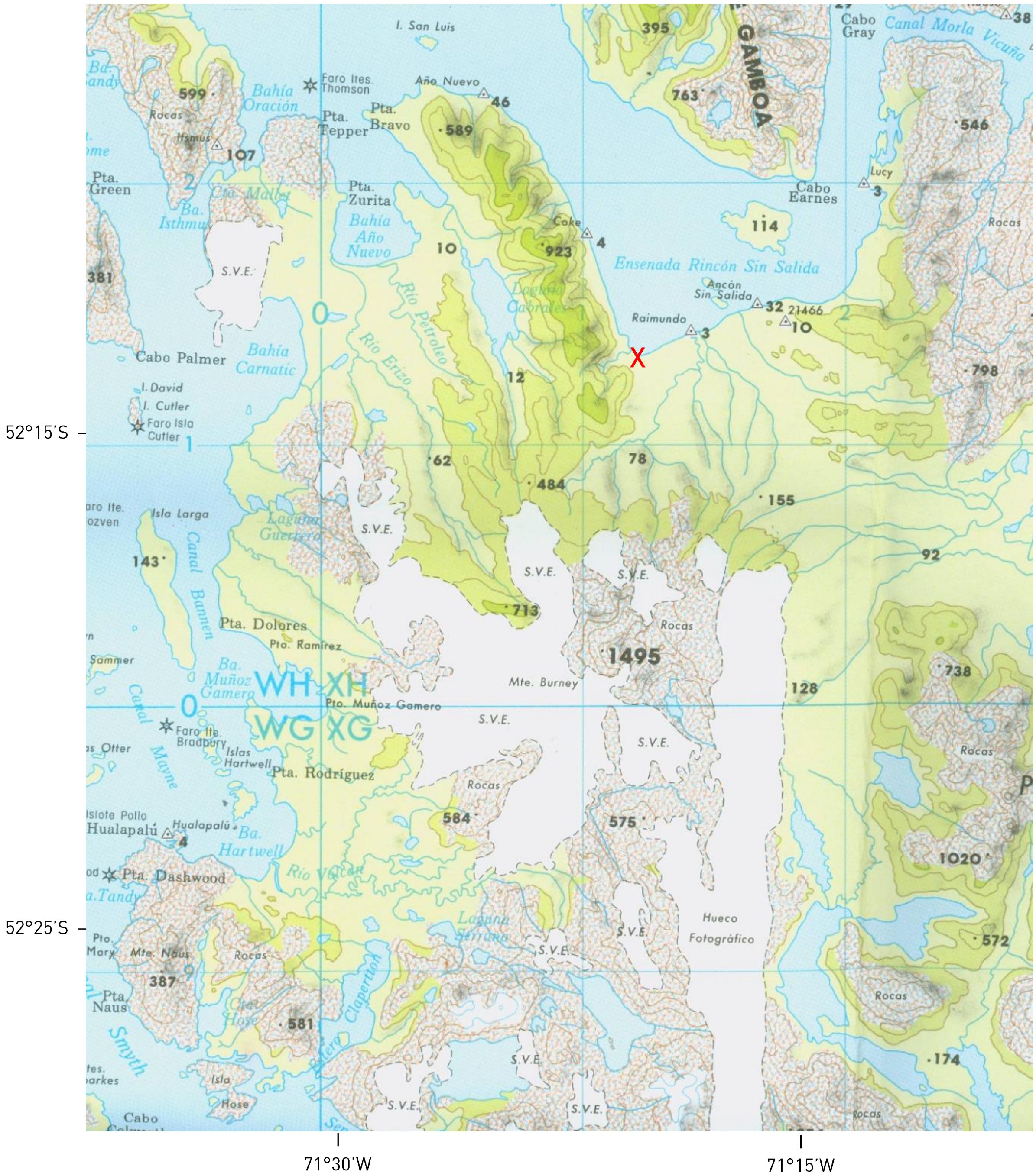


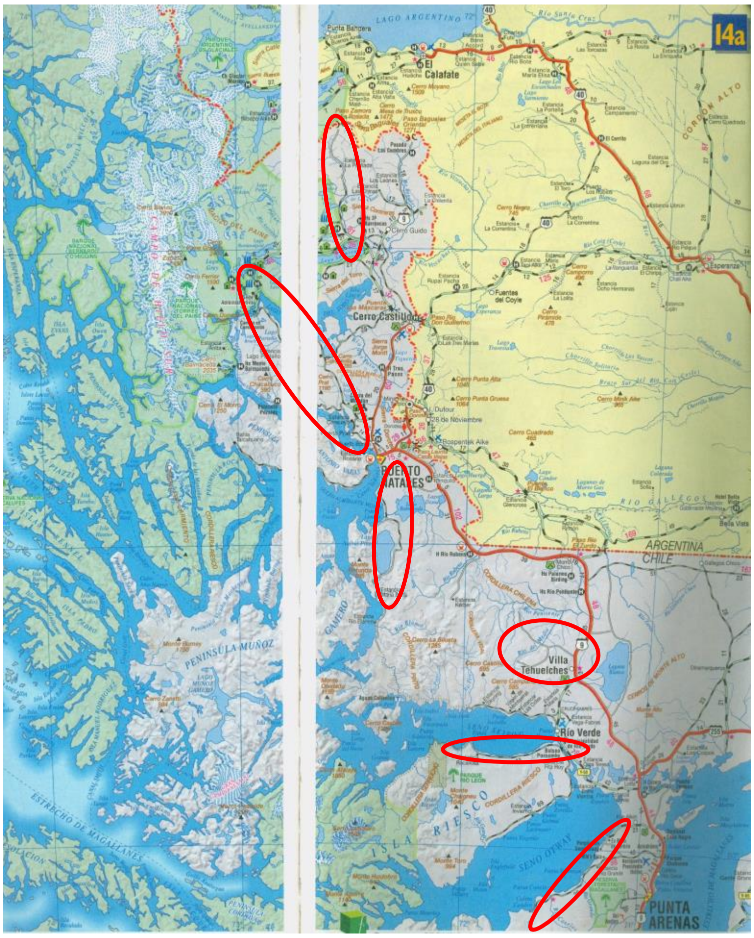
Figure 2.2.1: Map showing area around Monte Burney. Target areas for mapping, sampling, and analysis include the areas of exposed rock and river sections on the flanks of the volcano (centre of map). Red cross marks the planned drop-off/pick-up point (by boat) at the start and end of this phase of the expedition. Part of map of 'Seno Skyring' 1:250000 (SN-18-3) Insitituto Geografico Militar, Chile.

3. Proposed methodology

3.1. Phase 1: Peat/tephra sampling

The best-preserved record of explosive, tephra (ash)-dispersing eruptions over the past ~20ka is likely to be in the many peat bogs in the region. Typical peat thicknesses in the area are ~1–3 m, representing accumulation over the past 9–21ka [Yu et al., 2010]. We plan to collect ~20 cores in two weeks, from selected peat bogs south of 47°S (mapped in Yu et al. [2010]) that are accessible from the road network (Figure 3.1.1). Peat will be sampled with a one-metre Russian-type corer (Figure 3.1.2), extendable to up to five metres; the resulting cores will be logged and sub-sampled at 0.5cm (~50-year) resolution in the field. Visible tephra layers exposed in road/river sections will also be described, measured, and sampled, together with datable organic material. These field techniques are well-established, and have been previously used by Oxford volcanologists further north in Chile [Watt et al., 2011]. The effectiveness of this part of the fieldwork will be enhanced by the presence of <*Name of supervisor*>, head of the tephrochronology group in the Research Laboratory for Archaeology and the History of Art, University of Oxford. She is a practised tephrochronologist, with experience of driving the roads of the region, who has agreed to a supporting role for the first week or so of this work. On the advice of our local contacts, permission will be sought to sample and export from Dirección Nacional de Fronteras y Límites del Estado (DIFROL), and we have applied for a soil import licence (PHI 3A) from the Food and Environmental Research Agency (FERA).

Post-fieldwork laboratory analysis (as part of <*Leader name*>'s D.Phil. work) will involve separation, characterisation, and physical and chemical analysis of tephra using a variety of techniques (including electron microprobe analysis and inductively coupled plasma mass spectrometry; for a summary of tephrochronology methods, see Lowe [2011]). These data will be used to construct regional tephra correlations, and to trace the individual tephra horizons back to the source volcanoes [c.f. Watt et al., 2011]. Then, by high-precision radiocarbon dating of peat in key cores, careful age modelling, and the synthesis and re-analysis of published tephra and climate proxy records, a high-resolution regional chronostratigraphy of both volcanic events (including size, source location, and dispersal trajectory) and climatic change will be constructed. This regional picture will be directly comparable to the sparser tephrostratigaphy from northern Patagonia and the Chilean Lake District; it should also link (via key tephra units, or climate events) with the ocean-core records of the Southern Ocean and the Antarctic Peninsula.



LEFT: **Figure 3.1.1:** Map showing (in red ellipses) target areas for peat coring, to sample ash deposits from eruptions of volcanoes in the AVZ. Extract from Ediciones Guias y Rutas/ Telefonica de Chile Turis Tel Sur 2007.

BELOW: **Figure 3.1.2:** A peat core collected using a Russian corer, containing a prominent white layer of volcanic ash.

3.2. Phase 2: Reconnaissance mapping & sampling at Monte Burney

We plan to visit rock outcrops on/around Burney over a three-week period camping on the volcano, with the aim of collecting a suite of representative samples (of lavas, pyroclastic deposits, glaciovolcanic deposits, intrusions, and any dateable carbon) from throughout the eruption history. This sampling will be targeted with the assistance of satellite imagery [Figure 3.2.1]. We will also make observations/interpretations of the eruption sequence, and evaluate the extent of the influence of snow/ice on eruption style, and how this varies through time [c.f. Mee et al. [2009]). Spatial information will be noted to enable a geological map to be drawn; the level of detail achieved will be dependent upon how restrictive the weather and terrain are. This work requires only basic equipment (rock hammer, GPS, camera), but will be facilitated by provision of digital mapping equipment from the British Geological Survey, which will allow integration of ground observations with satellite imagery and digital elevation models in the field. The Oxford personnel are all trained in geological mapping and sampling techniques, and <*Leader name*> has received additional field training in mapping/sampling of volcanoes and interpretation of evidence of glaciovolcanism, most notably from being a member of a five-week expedition to Volcán Sollipulli (Araucania Region, Chile), a similar volcanic system to Burney. The Chilean member of our team will assess the potential for geotourism at Monte Burney. He has had a key fieldwork role in the establishment of Chile's first geopark, encompassing a number of volcanoes in the Araucania region. On the advice of our local contacts, permission will be sought for the fieldwork and for export of samples from Dirección Nacional de Fronteras y Límites del Estado (DIFROL).

Post-fieldwork laboratory analysis (as part of <*Leader name*>'s D.Phil. work) will involve petrographical, physical, and chemical analysis of the lavas and glaciovolcanic and explosive eruption deposits sampled, using a variety of techniques (including x-ray fluorescence and electron microprobe analysis). Eruptive events will be dated using radiocarbon and Ar-Ar techniques, and integrated with field observations and satellite and geochemical data to produce geological and hazard maps as well as a long eruption chronology, with emphasis on the links between changing climate and volcanic activity.

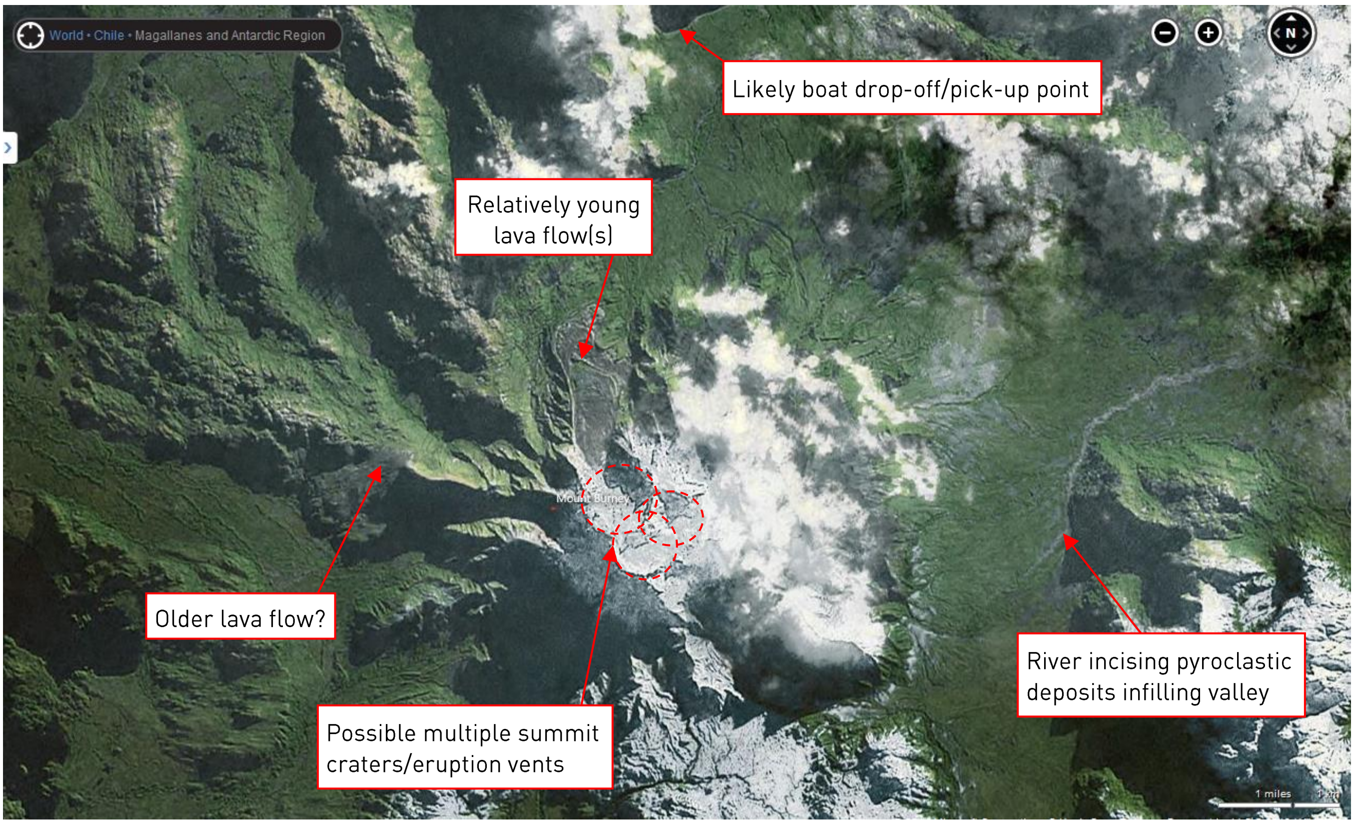


Figure 3.2.1: Satellite image (courtesy of Bing Maps) of Monte Burney; smaller white bar in right-hand corner of image is 1km in length. A variety of geological features are recognisable; such analysis (using better imagery) will be carried out in order to constrain priority target localities for sampling to fulfil the expedition's objectives.

3.3. Phase 3 (provisional): Granite sampling

Granite samples will be collected from Burney, Torres del Paine, and Mt Fitzroy, as three accessible locations spanning 49–52°S. A representative suite of samples will be collected from each site, reflecting textural and chemical variations inferred from visual assessment of outcrops. This will be achievable with basic equipment, from footpaths around Torres del Paine and Mt Fitzroy, in accordance with national park regulations (after confirming permission to do so from the appropriate park authorities). All members of the expedition team are well trained to do such work. This work partly supports the primary objective of the expedition by allowing geochemical comparison of Cenozoic and more recent magmatic activity in the region, but primarily serves as preliminary data collection to assess the value of a full research project and expedition focussing on these granites. This will require some post-fieldwork petrographical and chemical analysis (using a variety of techniques, such as scanning electron microscopy) of the samples, to be interpreted in the context of the field observations. This analysis will be led by colleagues in the Department of Earth Sciences, University of Oxford.

4. Provisional schedule

(Personnel codes given in Section 5)

8th-9th January: Fly from the UK to Santiago.
10th-11th January: Meetings with collaborators at Servicio Nacional de Geología y Minería (SERNAGEOMIN) in Santiago, and El Centro de Estudios Científicos (CECs) in Valdivia (overnight bus between the two cities).
12th-17th January: Assist with collaborator's fieldwork (not considered as part of this expedition; expedition funds will not be used to cover expenses in this period).
18th January: Fly to Punta Arenas.
19th January: Meet with local contact/collaborator at Dirección de Programas Antárticos, Universidad de Magellanes; collect 4WD rental vehicle.
20th January-1st February: Expedition Phase 1 – SL, RN, VS (until January 28th), OB (provisionally from January 28th).
2nd-3rd February: Ship peat samples back to UK; travel to Puerto Natales by coach, and meet boat owner.
4th-25th February: Expedition Phase 2 – SL, RN, HR, OB. Travel between P. Natales and Burney by boat.
26th-28th February: Rest day in P. Natales; ship samples from P. Arenas.
29th February-11th March: Expedition Phase 3 (provisional) – SL, HR, OB. Dates include 2 days of coach travel to/from the national parks.
12th-13th March: Overnight coach to Santiago.
15th-16th March: Fly from Santiago to UK.

Phase 3 is provisional, as it may yet be replaced by <*Team member names*> conducting a joint expedition with a few SERNAGEOMIN volcanologists to do tephrostratigraphic studies of remote volcanoes in the Southern Andean Volcanic Zone (Corcovado (43.18°S, 72.80°W), Yanteles (43.50°S, 72.80°W), Melimoyu (44.08°S, 72.88°W), and/or Hudson (45.90°S, 72.97°S)) for up to three weeks (returning to UK on ~23rd of March). SERNEAGEOMIN will cover some, but not all, of the expenses associated with such an expedition, but the cost would be justified considering the value of the scientific, educational, and collaboration benefits to such joint fieldwork.

The expedition is timed for the late Austral summer as a compromise between minimal snow cover on Monte Burney and minimising the risk of experiencing autumnal storms.

5. Personnel

5.1. Expedition team members

<*Leader name*> (SL) – Expedition leader, lead scientific officer, medical officer

2nd year postgraduate student at <*college name*> and in the Department of Earth Sciences. He has had extensive training in volcanology and geological mapping, sampling, and analysis methods from his undergraduate degree at Oxford, as well as the first year of his D.Phil.. He has previously carried out extended fieldwork on volcanoes in Mexico, the Caribbean, and Chile. The Chile fieldwork involved a five-week expedition to Volcán Sollipulli in February-March 2011, which had similar aims to Phase 2 of the planned expedition, and involved working in a similar environment, albeit less remote. Took the Wilderness Medical Training 'Far From Help' 2-day course in September 2011; lower intermediate level Spanish speaker.

<*Team member name*> (RN; Phases 1 & 2) – Treasurer, field assistant

Graduated with a Masters in Earth Sciences from <College name>, Oxford, in 2011. Has worked as a field assistant on two research fieldtrips, in Iceland and on Santorini (Greece), where her rock-carrying abilities and indefatigable enthusiasm earned her glowing references, and make her an ideal field assistant for this expedition. Took a fieldwork first aid course run by FieldSkills (valid until 04/2012), and has a GCSE in Spanish.

<*Team member name*> (HR; Phases 2 & 3) – Vice-treasurer, field assistant, 'student'

1st year postgraduate student at <College name> and in the Department of Earth Sciences. Previously an undergraduate at the University of Cambridge, she started a D.Phil. in October focusing on Mocho-Choshuenco volcano in northern Patagonia. She will therefore benefit greatly from informal training in sampling methods and analysis of the features of volcano-ice interactions from being a field assistant for this expedition. She has experience of geological fieldwork in northern Chile, where she did her undergraduate mapping project, and developed intermediate competence in spoken Spanish.

<*Team member name*> (OB; Phases 2 & 3, and end of Phase 1) – Field assistant, scientific officer, translator, driver

Final-year undergraduate student in Geology at the Universidad de Chile, Santiago. Has carried out fieldwork on a number of Chilean volcanoes, and was a part of the 2011 Sollipulli expedition with <*Leader name*>. During this expedition, he assessed the potential for establishing a 'Geopark' by identifying key geological features of wider interest or worthy of preservation. Fluent in Spanish and English, and holds a Chilean driving licence.

<*Supervisor name*> (VS; start of Phase 1 only) – Supporting specialist, driver

Head of the tephrochronology group of the Research Laboratory of Archaeology and the History of Art, University of Oxford; subsidiary supervisor of <*Leader name*>. Has done extensive work on establishing tephrochronologies from peat/lake sediment cores, so will be able to advise on the best sampling practices in the field to optimise sampling efficiency and effectiveness. Furthermore, she has experience of driving in the region using a 4WD vehicle.

5.2. Advisors

The following scientists have assisted with the planning of the expedition/research programme:

- Prof. <*Supervisor name*> (Dept. of Earth Sciences, University of Oxford): Volcanologist with 20 years experience working on young tephra deposits in Chile and elsewhere. As lead supervisor of <*Leader name*>, proposed the PhD project (with only a rough outline of the objectives) and has subsequently provided guidance/advice on the scientific objectives of the fieldwork and analysis techniques.

- Dr <*Supervisor name*> (Dept. of Earth Sciences, University of Oxford): Volcanologist; **Home contact/agent** for the expedition. As second supervisor to <*Leader name*>, has also provided guidance/advice on the scientific objectives of the fieldwork and analysis techniques.
- Dr <*Supervisor name*> (British Geological Survey): Volcanologist/GIS specialist; has worked on volcano-ice interactions and volcano mapping in Chile (Nevados de Chillan); subsidiary supervisor of <*Leader name*>. Advising on interpretation of glaciovolcanic deposits and methods for integrating field data with satellite/aerial imagery and visualisation techniques.
- Dr <*Local contact name*> (SERNAGEOMIN, Santiago): Volcanologist/regional geologist, with 35 years experience working on (and mapping) Chilean volcanoes and their recent activity and hazards; unparalleled expertise in the Holocene tephra stratigraphy of southern Chile. Providing guidance reflecting his position as our main collaborator at SERNAGEOMIN, as well as access to maps, aerial photography and other imagery. **Local contact/field agent** for the expedition.
- Ms <*Advisor name*> (University of Cambridge and Universidad de Magellanes): Geologist/Quaternary scientist, who is just finishing a PhD on the post-glacial climate history of the region, involving analysis of sediment cores from near Monte Burney. Her local knowledge is of great value for planning the detailed logistics of the expedition.
- Dr <*Local contact name*> (Universidad de Magellanes): Chemist with interest in tephra chemistry and the environmental effects of eruptions on the region. Providing local logistical assistance, and potential research collaborator. **Local contact/field agent** for the expedition.

Our collaborations with SERNAGEOMIN and U. Magellanes are of great value, as they guarantee that our results will feed directly to the agencies with a 'need to know', and so have an impact.

6. Budget

6.1. Projected expenses

Pre- and post-expedition administration:	£0 [1]
Field equipment:	£0 [2]
Flights (LHR-MAD-SCL-MAD-LHR x4, PMC-PUQ x4, PUQ-SCL x2, ZCO-PUQ-ZCO):	£4600 [3]
Two weeks 4WD hire in Punta Arenas, plus fuel:	£1350 [4]
Coach travel (various between P. Arenas and P. Natales and national parks):	£150 [5]
'Far from help' course for medical officer:	£260
Travel insurance (1x 1month, 2x 2months, 2x 3months, plus equipment cover):	£250
Accommodation (3px13n, 4px6n @ £14/n for 2p):	£400
Food (£7/person/day):	£1100
Shipping equipment between UK and P. Arenas:	£600 [6]
Shipping samples from P. Arenas to Oxford:	£1500 [7]
Soil import licence:	£220
Post-fieldwork analysis and dissemination of results:	£0 [8]
OUEC bulletin:	£200
Contingency funding (10%):	£1070
TOTAL:	**£11,700**

[1] Will use department resources
[2] Will use personal, borrowed, and department equipment (includes expedition medical kit)
[3] Based on quotes from 'The Flight Centre'
[4] Europcar quote for planned dates: £1053.45
[5] Based on estimates in 'Lonely Planet' guide
[6] Based on quote from 'Excess Baggage'
[7] Based on (painful) previous experience
[8] Should be covered by the PhD funding to <*Leader name*> (from the UK Natural Environment Research Council and British Geological Survey), hence the limited contribution from this source towards the cost of the expedition.

6.2. Sources of income

Fieldwork allocation in doctoral training grant to <*Leader name*>:	£3000
Allocation from Chile fieldwork grant held by Prof. <*Supervisor name*>:	£1000
University College Oxford Senior Scholarship held by <*Leader name*>:	£400
Academic Travel Award, Santander (through the University of Oxford):	£1000
Geographical Fieldwork Grant, Royal Geographical Society/Rio Tinto:	£1000
Graduate Travel Award, <*College name*> Oxford Old Member's Trust:	£350
TOTAL:	**£6,750**

Pending applications to the Jeremy Willson Charitable Trust and the Explorer's Club; will shortly be submitting applications to the Transglobe Expedition Trust and Gilchrist Educational Trust.

7. Logistics

- Visas: tourist visa obtained on arrival (valid for 90 days) is sufficient; none required in transit.
- Passports: validity OK.
- Language barrier: local contacts all speak good English; Chilean member of team is fluent, so able to translate for likely problematic conversations (e.g. shipping).
- Public transport: previous experiences of coaches in Chile have been very positive; regular services on all planned routes.
- Phase 1: roads are sealed or well-maintained gravel, with very light traffic, so are low risk for an experienced driver. Hired vehicles are generally reliable, but will take appropriate precautions in case of breakdown anyway. Do not intend to go off-road.
- Phase 2: currently awaiting a reply from a local contact about being transported by boat between Puerto Natales and Monte Burney; if this line of enquiry fails, we have identified a few outdoor adventure companies based in the town that run boat excursions, who we will contact. Working conditions will be tough; care will be taken to ensure the team is appropriately equipped.
- Phase 3: the national parks are extremely popular with tourists, so the infrastructure is good and information is readily available.
- Shipping between Chile and UK: currently making many enquiries to try to find cheapest method, but contacts with experience in such shipping suggest that it's probably futile.

8. Health and safety

8.1. Risk assessment

Hazard		Associated risk	Precautions/control measures	Further action
1. Team	a) Health/fitness problems	Injury/illness resulting from pre-existing medical conditions or inability to cope with physical demands of fieldwork	Seek professional advice on physical capability before expedition; expedition leader/medical officer to be made aware of any health/fitness problems as they arise, and monitor them during the expedition	Pre-existing medical conditions/relevant medical history to be noted before expedition, in case of emergency; leader to reduce workload on affected team member(s) if required to reduce risk
	b) Poor attitude/behaviour	Risk of ignoring control measures, resulting in injury/illness	Select team to minimise hazard; training and discussion of hazards/risks (involve team in risk assessment drafting); clear leadership from expedition leader	Hold team meeting/review at end of each day of expedition, to allow grievances/problems to be raised and discussed; ask problematic member to leave team if risk deemed high
	c) Inadequate experience/training	Increases risk associated with most other hazards	Select team to minimise hazard; provide training (e.g. first aid, language) before expedition if possible and appropriate	Expedition leader to check that whole team are comfortable with their training/experience level before attempting any activity
	d) Personal equipment	Injury/illness resulting from absence, inadequacy, or failure of equipment	Expedition leader to check that all team members have proper equipment for expected environmental conditions and fieldwork activities, and means to repair it	Team members to regularly ensure that equipment is well-maintained
2. Environ-ment	a) Remote location	Increases risk of more serious injury/illness or death as a result of most other hazards	Crisis management plan; two team members to be trained in first-aid, with one having 'far from help' medical training; team to have two satellite 'phones	Expedition leader to discuss acceptable level of risk with team in the context of the remote location before any possibly hazardous activity
	b) Poor route selection	Increases risk associated with other environmental hazards	Stay on marked trails where possible; study maps, satellite imagery, and digital elevation models to select most appropriate off-trail routes	Regular review of changing risk level along trekking routes by all team members; all team members to have navigation equipment
	c) Terrain	High (but sub-2000m) ground, steep slopes, cliffs, rocky areas, and peat bogs could result in elevated risk of injury	No trekking/fieldwork after dark or in dangerous weather conditions; plan routes to minimise exposure to hazardous terrain; wear helmets and/or use ropes where deemed appropriate	Regular review of changing risk level by all team members
	d) Climate/weather:	Damage to protective	Take risk of extreme weather conditions	

	strong winds, heavy rain, low cloud, strong sunshine	equipment; increased risk from environmental/team hazards; injury/illness due to exposure	into consideration when deciding camp locations, route selections, and travel and fieldwork plans; discuss impact upon team/enviro. hazards; team to have clothing for extreme-case weather	
	e) Ice/snow: crevasses, snow blindness, avalanches, meltwater	Injury due to exposure to hazards without appropriate protective equipment	Avoid hazards where possible; use protective equipment where risk deemed low enough to proceed through hazard area	Careful route and contingency planning in case of exposure to hazardous weather conditions
	f) Volcanic: effusive or explosive activity, lahars, ashfall	Injury/illness due to exposure to hazards; disruption to travel and/or food/water supplies	Clear evacuation plans and flexibility to fieldwork plans; team to carry protective equipment (dust masks, helmets)	Expedition leader (most experienced volcanologist in the team) to regularly assess hazards/risks, with advice from contacts
	g) Wildlife: pumas, guanacos, black widow spiders (no real insect hazards due to climate)	Injury/illness resulting from attack	Avoid all potentially hazardous wildlife: all are considered to pose a low threat, so specific protection is not necessary, but team members should be aware of risks (from prior training)	Take steps to discourage animals from approaching campsite (e.g. appropriate storage of food, prominent camp location)
3. Health	a) Endemic diseases (e.g. Hepatitis A, Tetanus, Measles, Typhoid)	Illness from contraction of a disease; increased risk if inadequately vaccinated	All team members to have standard UK vaccinations, plus Typhoid, Hepatitis A, and a recent Tetanus booster.	Medical officer/expedition leader to ensure that team members are fully trained, and, with the environmental manager, will monitor camp health/hygiene
	b) Polluted water (chemical or biological contamination, e.g. giardiasis)	Illness resulting from consumption	Purify all drinking water by boiling, filtration, and/or purification tablets if there is any doubt over biological purity of the water supply; avoid any potentially chemically contaminated sources	
	c) Contaminated food		Ensure whole team properly stores, prepares, and cooks food; consume only non-perishable items whilst working in remote areas	
4. Local population	a) Political climate: fuel protests and roadblocks (c.f. January 2011)	Injury and/or damage to equipment	Check FCO website and local media for updates on any unrest, and adjust travel and fieldwork plans accordingly	Seek advice from local contacts on particularly hazardous locations, best accommodation, etc.; travel with team members who are fluent in Spanish when possible
	b) Risk of attack and theft		Take standard precautions, e.g. keep valuables out of sight, don't travel alone/late at night	

	c) Living conditions	Injury/illness due to exposure to disease or other hazards	Purchase food from reputable sources (major supermarkets) and use decent accommodation	
5. Fieldwork activities	a) Trekking	Increases exposure to environmental and team hazards; exacerbated by carrying samples/equipment	Limit daily sample collection to that which can be comfortably carried by the team when burdened with equipment; trekking routes to be agreed in advance each day, and subject to weather	See assessments of environmental and team hazards
	b) Rock hammering	Injury by flying rock fragments	Wear safety goggles and thick clothing	(Team is already fully trained in hammering)
	c) River crossings	Injury/drowning	Plan routes to minimise crossings; cross only where water is no more than ankle-deep (if strong current) or knee-deep (if no current); rope up if a strong current; carry minimal equipment	Plan crossings considering risk of change in water level due to weather changes
	d) Equipment	See 1.d)		
6. Travel	a) Remote location	See 2.a)		
	b) 4x4 driving on poorly-maintained roads/tracks	Injury and/or damage to equipment due to an accident	Use better-maintained roads where possible; use speed appropriate for road conditions; carry spare tyres, repair kit, and a satellite 'phone	Notify UK/local contacts of daily driving plans, and 'check in' every evening; team members to gain experience of driving large vehicles/ 4x4s prior to fieldwork if possible
	c) Other road users		Take extra care when encountering other traffic	
	d) Public transport		Travel with reputable companies; avoid routes with particularly bad road conditions	Research prior to fieldwork, and seek advice from local contacts
7. Accom-modation	a) Camping: stoves/fires; exposure	Injury, illness and/or damage to equipment; increased risk from environmental hazards	Team to regularly check equipment; fire hazard to be minimised by careful campfire construction, with extinguishing media on hand	Medical officer and environmental manager to monitor camp health/hygiene
	b) Hostel accommodation	Injury/illness due to exposure to hazards such as electrical equipment, stairs, contaminated food, etc.	Take advice from local contacts on most reputable accommodation; team to collectively assess risks on arrival at selected hostels	Move to alternative accommodation if risk deemed high

The risk assessment will be reviewed regularly during the expedition by team discussions; the post-expedition report will outline any incidents and changes made to the risk assessment. A provisional version of this assessment has been approved by the Department of Earth Sciences, University of Oxford, who have legal and financial ownership of the project.

8.2. Crisis management plan

A) Roles and responsibilities in an emergency situation

- Expedition leader/medical officer will be responsible for overall incident co-ordination and leading provision of temporary immediate care (ideally these would be designated to separate people, but team size is too small); in the event of the expedition leader being injured/absent, this role will be taken by the most experienced first-aider.
- Expedition leader will nominate another team member to monitor scene safety, and co-ordinate communication, under the direction of the leader. If two uninjured team members are present, the most experienced first-aider will be asked to assist in providing medical care.

B) Initial response steps

Summary of procedure following a serious incident: (team will be trained in procedure beforehand)

i. Assess likelihood of further danger to group: unless low, consider moving group and casualty to safe location
ii. Locate casualty; medical officer to assist and treat
iii. If no further medical treatment is required, assess causes of incident and make changes to safety plans accordingly
iv. If further medical attention is judged to be necessary by medical officer/expedition leader, prepare for evacuation
v. If medical assistance can be reasonably reached on foot (less than an one hour walk with reasonable terrain and weather conditions, with the casualty being in a suitable condition for such travel), do so
vi. In all other cases, explore emergency evacuation options, contacting insurance/local/UK contacts and emergency services as appropriate; considerations will include the condition of the injured (time-criticality, medical requirements) and the availability of different transport methods from the incident site
vii. In the event of serious injury or death, the expedition leader/medical officer will co-ordinate assistance from the appropriate embassy, UK/local contacts, and the insurance company, with regards to contacting next of kin, repatriation, activating media plan, etc.

C) Emergency services: contact numbers

Police: +56 133
SAMU (Ambulance service): +56 61-205246 or +56 131
Medical helicopter (DAP, Punta Arenas): O'Higgins 891; +56 61-616100

Contact details for park ranger offices for Torres del Paine and Los Glaciares (Fitzroy) national parks will be obtained upon entry to the parks; will have contact details for in-country/UK contacts, British embassy, and insurance company.

D) Medical facility information

El Calafate: Hospital Municipal: Juio. A. Roca 1487; +54 02902-491173
Puerto Natales: Hospital P. Natales: Ignacio Carrera Pinto 537; +56 61-411582
Punta Arenas: Hospital Regional: Calle Angamos 180; +56 61-205123

E) Trip itinerary and evacuation options

Exact itinerary and contact details of accommodation for each night (when applicable) to be confirmed and provided to on-call contacts prior to expedition, in addition to mobile and satellite 'phone numbers.

Phase 1: Will be on/close to road network, and so accessible to standard emergency services if more appropriate than evacuation using our own transport (probably quicker if in a relatively remote location).

Phase 2: Helicopter evacuation is unlikely, given the prevailing weather conditions, so casualties will probably have to be carried to the nearest accessible coastal location, for pick-up by boat (requested from P. Natales) to transport to P. Natales, or nearest location where faster transport to professional medical care can be provided.

Phase 3: As with Phase 2, helicopter evacuation is unlikely to be possible, but limited assistance with evacuation logistics and providing first aid should be obtainable from park rangers in both national parks. In the event of helicopter and park ranger assistance being unavailable, casualties will have to be transported to the nearest road (less than 10km away).

9. References

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