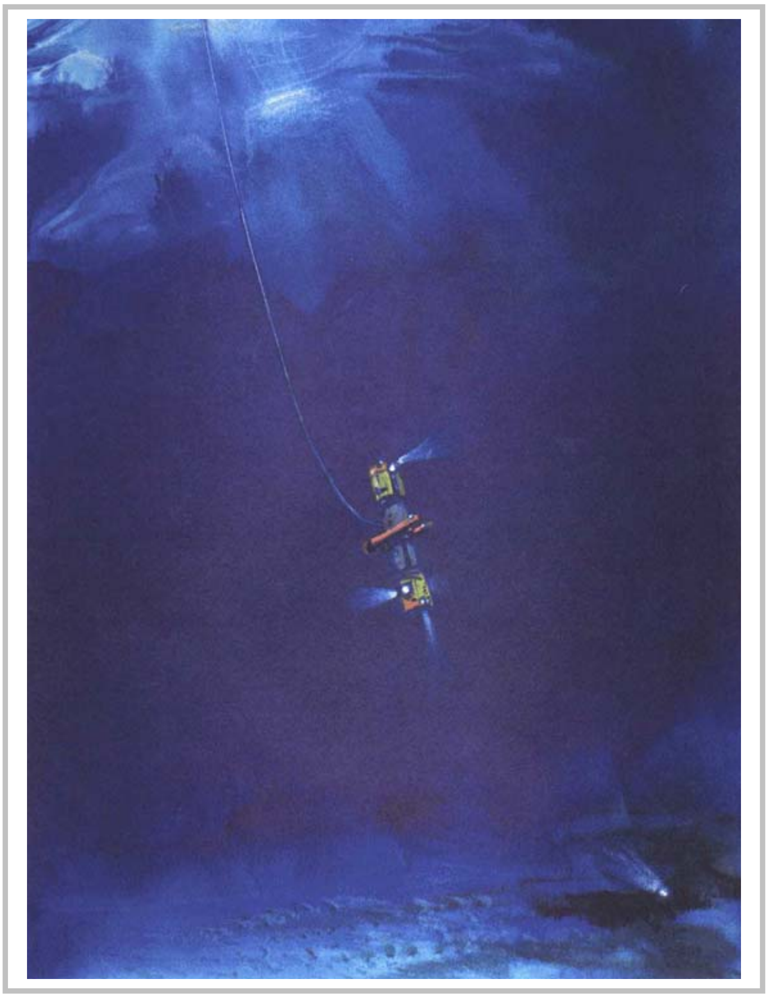
Exploration of Subglacial Lake Ellsworth



a concept document outlining the development, organisation and execution of an experiment to explore, measure and sample the environment of a West Antarctic subglacial lake

Draft 2, 9th February 2005.

EXPLORATION OF SUBGLACIAL LAKE ELLSWORTH

Executive summary

It is now an established hypothesis that Antarctic subglacial lakes house unique forms of life and hold detailed sedimentary records of past climate change. To test this hypothesis requires *in-situ* examination. The direct measurement of subglacial lakes has been debated ever since the largest and best-known lake, named Lake Vostok, was identified as having a deep water-column. However, the Subglacial Antarctic Lake Environments programme (SALE), set up by the Scientific Committee on Antarctic Research (SCAR) to oversee subglacial lakes research, state that prior exploration of smaller lakes would be a “prudent way forward”. Of the 145 subglacial lakes known in Antarctica, one lake in West Antarctica, named Subglacial Lake Ellsworth, stands out as a prime candidate for first exploration.

A UK-led consortium of over twenty scientists from ten universities and research institutions has been assembled to plan the exploration of Lake Ellsworth. A five-year programme is envisaged: two years for equipment development and testing; one year for field planning and operation; two years for sample analysis and data interpretation.

The science experiment is simple. Lake Ellsworth will be accessed using hot water drilling. Once lake access is achieved, a probe will be lowered down the borehole and into the lake. The probe will contain series of instruments to measure the lake water and sediments, and will be tethered to the ice surface through which power, communication and data will transmit. The probe will be dropped down the water column to the lake floor. The probe will then be pulled up and out of the lake, measuring its environment continually as this is done. Once at the ice surface, any samples collected will be taken from the probe for laboratory analysis (to take place over subsequent years). The duration of the science mission, from deployment of the probe to its retrieval, is likely to take between 24 and 36 hours. Measurements to be taken by the probe include: Depth, pressure, conductivity and temperature; pH levels; biomolecules (using life marker chips); anions (using a chemical analyzer); nitrogen isotopes (using a tuned laserdiode); visualization of the environment (using cameras and light sources); dissolved gases (using chromatography); and morphology of the lake floor and sediment structures (using sonar). After the probe has been retrieved, a sediment corer may be dropped into the lake to recover material from the lake floor. Finally, if time permits, a thermister string may be left in the lake water to take time-dependent measurements of the lake’s water column over subsequent years.

Given that the comprehensive geophysical survey of the lake is planned for 2006-7, a two-year development phase from 2005 makes it possible that the exploration of Lake Ellsworth could take place during the International Polar Year (2007-9). The project is ideally suited to the ambition of IPY theme #4 “To investigate the unknowns at the frontiers of science in the polar regions”. The exploration of Lake Ellsworth will be unique, interdisciplinary, and will result in major findings concerning subglacial lake environments and, consequently, will have a sizeable public interest. The programme is challenging yet feasible given the expertise within the consortium of scientists involved.

1. INTRODUCTION

Following the discovery that Subglacial Lake Vostok in East Antarctica has a water column over 500 m deep (Kapitsa et al., 1996), there has been widespread scientific and media interest in exploring Antarctic subglacial lake environments (Siegert et al., 2001). Such exploration is driven by the hypothesis that Antarctic subglacial lakes house unique forms of life and hold detailed sedimentary records of past climate change. Testing this hypothesis requires *in-situ* measurement and sampling. Lake Vostok is unlikely to be accessed in the foreseeable future due, predominantly, to its remote location at the centre of East Antarctica and its huge size, which affects detailed comprehension (Siegert, 2002). Of the 145 subglacial lakes known in Antarctica (Figure 1.1), one lake in West Antarctica, named Subglacial Lake Ellsworth (Siegert et al., 2004), stands out as a prime candidate for first exploration. This is because:

- Lake Ellsworth, being only ~10 km long, can be characterised meaningfully using seismic and radar surveying (see Figure 1.2).
- The lake is logistically accessible through both UK and US logistic operations.
- Lake Ellsworth is representative of other lakes, in terms of pressure and temperature conditions.
- The sediments across the floor of the lake may yield a record of West Antarctic ice sheet history.
- Lake Ellsworth is located ~20 km from an ice divide, which means that drilling from the ice surface into the lake would not be complicated by ice flow.
- The ice sheet surface over the lake is ~2000 m above sea level, which is more than a kilometre lower than the ice surface over East Antarctic lakes. Altitude related problems encountered by scientists at the centre of the East Antarctic Ice Sheet will not, therefore, be as much of an issue during the study of this lake.
- Subglacial access and sampling has precedent in West Antarctica, but not in East Antarctica.

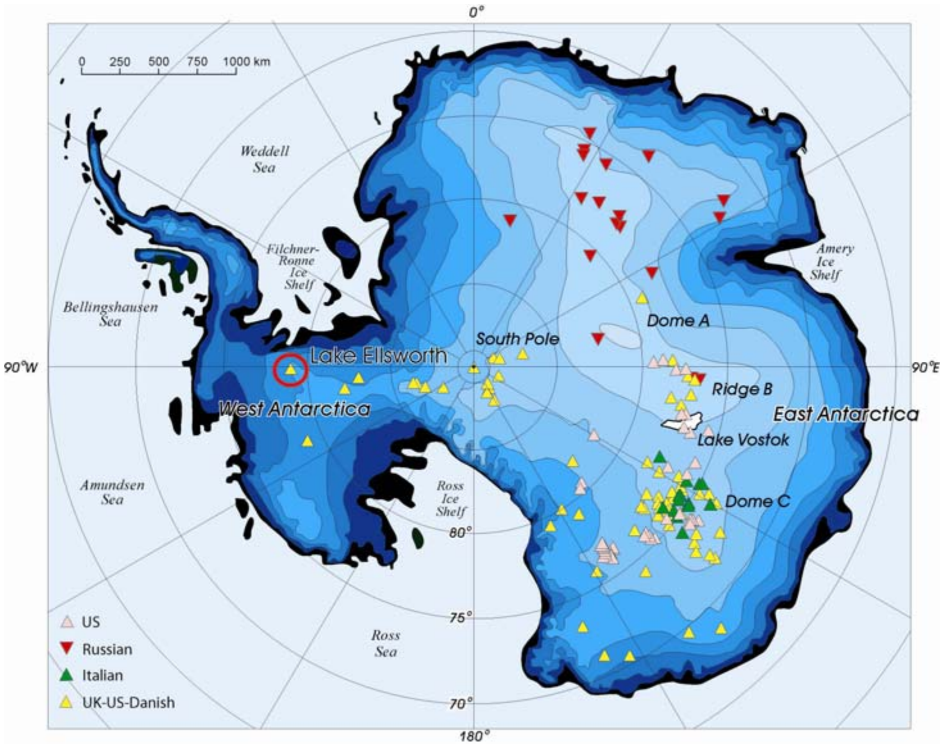


Figure 1.1. The location of 145 Antarctic subglacial lakes (Siegert et al., in press). Lake Ellsworth is circled.

This document describes the concept behind the exploration of Subglacial Lake Ellsworth. The two goals of the project (which are also the goals of subglacial lake exploration in general) are (1) to measure and comprehend life in this extreme environment and (2) to collect and assess climate records that will exist in the sediments on the lake's floor.

1.1. Background to Lake Ellsworth

Subglacial Lake Ellsworth is a 10 km long lake underneath ~3.4-3.2 km of ice near the Ellsworth Mountains in West Antarctica (Figure 1.2; Siegert et al., 2004). The ice sheet over the lake is ~20 km from the ice divide and its elevation is ~2 km above sea level, which makes the lake surface well over 1 km beneath sea level. Although, at the time of writing, only one radio-echo sounding (RES) transect has crossed the lake (Figure 1.2), several more are being collected by the British Antarctic Survey in 2004-5. Regional RES shows the lake to occupy a deep, distinct topographic hollow.

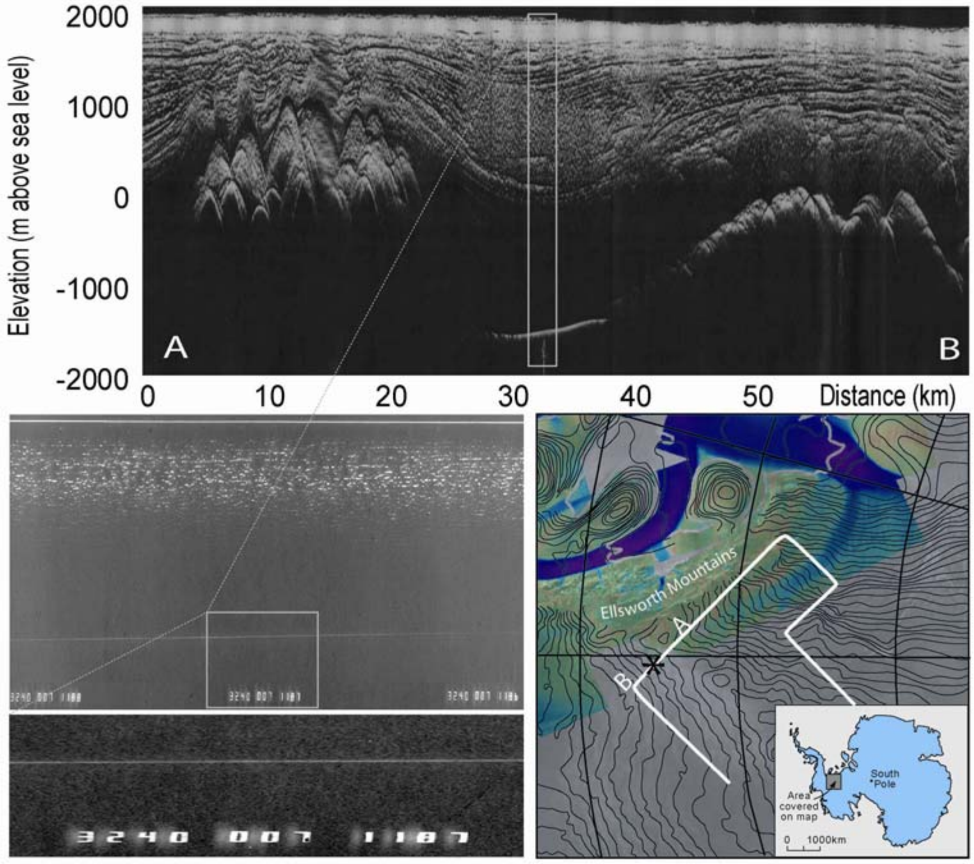


Figure 1.2. RES data from Lake Ellsworth. Transect AB. The lake is located by the bright flat reflector between 28 and 38 km. The insets show magnified sections of the RES data (demonstrating the mirror-like reflection indicative of a subglacial lake, and the location of Lake Ellsworth. Adapted from Siegert et al. (2004).

1.2. Meetings to date

A group of eight met at the British Antarctic Survey (26th April 2004) to assess the feasibility of a UK-led subglacial lake exploration programme. A larger group of sixteen subsequently met at the University of Bristol (1st September 2004) to develop the project further. Agenda and minutes of these meetings are available from the project's website (www.ggy.bris.ac.uk/ellsworth). These meetings followed several among those planning to survey Lake Ellsworth using geophysical methods (Section 5). As a consequence of the meetings held to date, a group of over 20 scientists from ten UK universities and research institutes (see Section 15) has been assembled to undertake the programme of activity proposed herein. A third meeting is planned for 8th March 2005.

1.3. Purpose of this document

This document provides brief details of the likely requirements of a subglacial lake exploration programme. It is important to note that the underlying theme of the proposed project is to undertake 'first access' of a subglacial lake environment and to explore this environment in a simple, efficient and cost-effective manner. More expensive and complex experiments may follow if this initial project is successful, but such experiments are not discussed in this document.

2. FUNDING ROUTES

2.1. Antarctic Funding Initiative (AFI)

A proposal to undertake a comprehensive geophysical survey of Lake Ellsworth (including RES, seismic surveying and a variety of surface measurements) has been submitted to NERC-AFI. The survey is planned for 2006-7, and data collected will supplement those acquired in 1978, and in 2004-5 (two RES transects are being flown over the lake by the British Antarctic Survey). The result of a successful project will be the first full characterisation of a subglacial lake and the determination of an appropriate location to undertake its physical exploration.

Given the current level of funding within the AFI (£1.5 million per year), is less than the exploration of Lake Ellsworth will require (Section 12), resources from outside of this programme will be required. Such resource may come from UK research councils and via international collaborators.

2.2. International Polar Year (IPY)

The exploration of Subglacial Lake Ellsworth will, as is evident in this document, be multidisciplinary, require international collaboration (see Section 14) and, if successful, will constitute a landmark achievement in the exploration of Antarctica and its subglacial environments. It is possible that the project could take place between 2007 and 2009. The project's scientific profile and its timing makes it ideally suited as a potential project of the International Polar Year (IPY, www.ipy.org). A letter of intent has been submitted to the IPY joint committee, and it is hoped that the project we secure IPY accreditation in due course. It should be noted that although the IPY will not provide explicit funds, its potential role within this project lies within the development and coordination of deep field logistics. Integration of various international research proposals is also possible via the IPY and SALE and within the project's own management.

2.3. UK research councils

Although the project outlined herein is as simple and cost-effective as is feasible (to accomplish the scientific goals), it will require a significant level of funding (of the order of several million pounds, Section 12). As the project is currently UK-led, NERC have been asked (through a letter to John Lawton, 14th September 2004) to consider how a cross-council project such as this may be established. Although the project is led by a UK team at present, international collaboration has been established within five countries (Sections 14 and 15). It is anticipated that funding can be provided by both UK research councils to a large degree and, to a lesser degree, the overseas project partners (who will have to apply for funding separately).

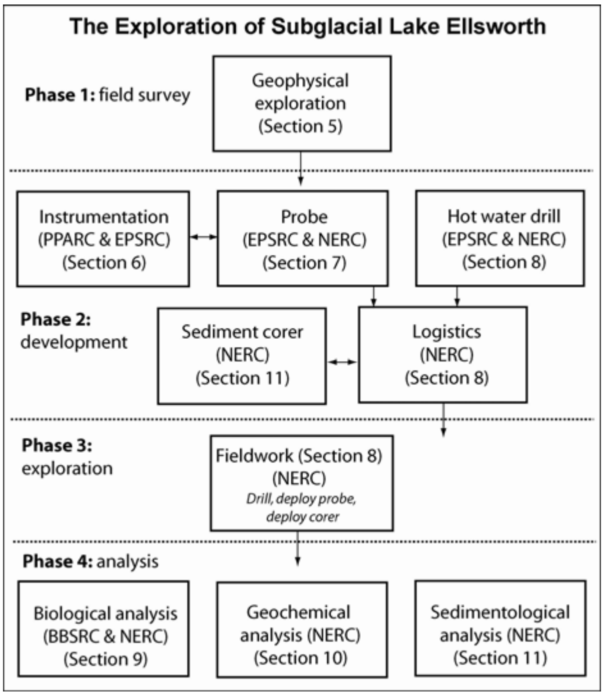


Figure 4.1. Structure of the project. Indications of research council suitability to each phase of development is provided.

3. WEBSITE AND MEDIA INTEREST

There has been considerable public and media interest in plans to explore Lake Ellsworth. Details of this interest, and the project in general, can be found from the project website (www.ggy.bris.ac.uk/ellsworth), constructed to help schools and colleges follow the progress of work, and to assist the media in understanding the proposed research. A television production company (Endemol UK) is proposing to make a documentary about the project, involving live broadcasting from the field when lake access is achieved.

4. STRUCTURE OF THE PROJECT AND OBJECTIVES

The exploration of Lake Ellsworth requires a multidisciplinary approach. A considerable level of management is required to integrate the various project elements. Currently the project is being managed by a steering committee (the authors of the various project elements detailed below), and through a series of project meetings (two having been held in 2004, the next to be held in March 2005). The project is arranged in four phases, outlined below, each with distinct objectives, which are also outlined (Figure 4.1).

It should be noted that a considerable group (in terms of size and breadth of expertise) has been put together to undertake the exploration of Lake Ellsworth. We collectively are known as the 'Lake Ellsworth Consortium'. Given the long-term nature of the project, requiring instrument development, fieldwork and laboratory analysis, future publications arising form this project will be authored by the group name, rather than by individuals.

4.1. Phase 1: geophysical exploration

The first phase of the project is to measure the size and shape of Lake Ellsworth, the flow of the ice sheet over the lake, and the subglacial topography surrounding the lake. This part of the project must take place before the physical exploration (as it will be essential for fieldwork planning), but will probably take place independently (an AFI application has already been made for this phase). The objective of this first phase of the project is as follows (Section 5):

- To undertake a comprehensive geophysical survey of Lake Ellsworth and its locale.

4.2. Phase 2: Instrument and logistic development

The second phase of the project involves assembling equipment and logistics necessary to undertake the physical exploration of Lake Ellsworth. In this phase the following objectives are required:

- To build, assemble and test instruments to detect life in the lake, to measure the physical and chemical properties of the lake's water and to sample the lake water and sediment (Section 6);
- To construct and test a probe to house the instruments and to allow communication between the probe and the ice surface by which data may be sent back to the ice surface (Section 7);
- To build and test a hot-water drill and organise field logistics (Section 8).

Phase 2 of the project will also require the following objective, if climate records are to be recovered:

- To acquire and test a sediment corer, capable of extracting a 2-3 m core from the floor of Lake Ellsworth (Section 11).

Contamination of subglacial lake environments as a consequence of the lake access experiment must not occur. Hot water drilling, using bio-filters, has been used on numerous occasions to reach the base of the West Antarctic ice sheet. The use of hot-water drilling in this project means that all the contamination controls used previously to study the ice sheet base, and surface lakes in Antarctica, will be employed for experiments in Lake Ellsworth. We will seek further assistance on this issue from the SCAR-SALE scientific research project prior to fieldwork.

4.3. Phase 3: Fieldwork

Once the necessary equipment has been built and tested, we will be in a position to undertake fieldwork. To meet the goals of the project the following objectives are required:

- To use a hot water drill to gain access to the lake from the ice-sheet surface.

We anticipate a 30 cm wide core, held open for 24-36 hours. Prior to lake entry, 400 m of water within the core will be taken out to ensure core water does not enter the lake (as the base of the core will be at greater pressure than the water within the lake).

Once lake access is achieved, the following objective is required:

- To deploy a probe into the lake capable of measuring the lake's biology, chemistry and physical environment.

The probe will be dropped down the water column to the lake floor. Recordings taken on this journey could be used to plan sampling on its return up the water column (recordings also being taken on its return journey). The probe will then be retrieved.

Subsequent to the deployment and retrieval of the lake-water probe and if lake access is ensured for an appropriate length of time, the following objective is required:

- To deploy a sediment corer into the lake to retrieve a 2-3 m sediment core.

In addition, a possible third experiment involves the installation of a permanent station into the lake. No details of such an experiment are provided in this document, but his element of the project may be discussed further in later meetings.

4.4. Phase 4: Data analysis and interpretation

To accomplish the project's goals the following objectives regarding data analysis and interpretation are required:

- To assess data sent by the probe in real-time to the ice surface, to comprehend the physical and chemical structure of the lake, and to ascertain the form, level and distribution of microbial life in the water column and water-sediment interface.

If samples of water and sediment are recovered, the following objectives will be needed:

- To conduct microbiological examination of lake water and sediment in a laboratory (Section 9);
- To undertake geochemical analysis of water and sediment (Section 10).

The results from these objectives will supplement the real-time measurements made by the probe.

If a sediment core is acquired, then the following objective is necessary:

- To conduct sedimentological laboratory analysis of the lake floor sediment core (Section 11).

If a permanent station is deployed, a means by which data retrieval and dissemination will be needed.

4.5. Project components

The following seven sections provide a 'concept' of the requirements of each phase of the project. The first is the geophysical survey (Section 5). Second is the instrument development for the probe (Section 6). Third is the probe development (Section 7). Fourth is the hot-water drilling and fieldwork (Section 8). Fifth is the biological analysis of water samples (Section 9). Sixth is the geochemical analysis of water samples (Section 10). Seventh is the sedimentological analysis of lake-floor deposits (Section 11).

5. GEOPHYSICAL SURVEY
(MARTIN SIEGERT, ANDY SMITH, JOHN WOODWARD, HUGH CORR)

Objective:

- To undertake a comprehensive geophysical survey of Lake Ellsworth and its locale.

This component of the project involves the geophysical exploration of Lake Ellsworth. A NERC-AFI proposal has been submitted (to AFI round 7, result expect in May 2005). Fieldwork will involve RES of the ice base, seismic surveying of the lake floor, GPS monitoring of ice flow and a series of other ice surface glaciological measurements. Following the fieldwork, numerical modelling will be used to quantify water flow within the lake, ice flow over the lake, and the distribution and rates of melting and freezing and the lake-ice interface.

In completing the fieldwork, the following eleven questions will be answered:
(i). What is the water depth of the lake? (ii). What is the topographic setting of the lake? (iii). What is the sediment thickness across the lake floor? (iv). How old is the lake and what is its history? (v). How does the ice sheet flow over the lake? (vi). What is the roughness of the bed around the lake? (vii). What are the rates of subglacial melting and freezing over the lake? (viii). Does the lake have detectable tides? (ix). How is the lake water circulation configured? (x). Where does the melt-water originate? (xi). What is the geothermal setting of the lake?

The outcome of the project will be the first full characterisation of a subglacial lake and the establishment of an appropriate field site for exploratory research. It is hoped that fieldwork can take place in 2006-7, making it possible to undertake the physical exploration of the lake afterwards during the IPY (2007-9). Full details of the plans for geophysical exploration are available on the project website and are not expanded on here.

Research Council relevance:	NERC (proposal submitted)

6. INSTRUMENT DEVELOPMENT
(JOHN PARNELL, MARK SIMS, MATT MOWLEM, DAVE CULLEN)

Objective:
- To build, assemble and test instruments to detect life in the lake, to measure the physical and chemical properties of the lake's water and to sample the lake water and sediment.

6.1. Background

Developing the instrumentation for the probe (Section 7) is focused on measuring the physical and chemical properties of the lake water and identifying life within the lake. Consequently, a number of key considerations guide the choice of instrumentation:

- The experiment should be thought of as a 'demonstration project', and should not expect to do everything that we might wish in the lake waters. Some selectivity will be required from our original list. Once first access is achieved and this experiment completed, it may well be appropriate to develop more sophisticated experiments afterwards.
- All items need to be depth (pressure)-rated to 4-5 km (the likely pressure of Lake Ellsworth).
- The number of items requiring significant development needs to be kept to a minimum, to avoid the project becoming unreasonably expensive, overly ambitious, and difficult to accomplish within the timeframe of the IPY.
- Where possible, UK manufacturers will be used, for ease of collaboration and regular iteration, as this project (at the moment) is UK-led.
- Instruments need to be miniaturised to fit a casing of ~20cm diameter (the drill hole will be ~30cm wide). Pressure-protected instruments may need confining in 15 cm diameter.
- The first measure of success will be to demonstrate measurements in water. Sample return is attractive, but will be a bonus, and so has lower priority.

6.2. Basic instrumentation

The following comprise essential characteristics of the probe's array of instruments:

- A basic OTS camera/light system, and a custom-built CCD (charge-coupled device) system with photon-level resolution, and UV light source, to detect fluorescence/bioluminescence etc.
- Life detection will be more efficient if the water is filtered to concentrate organics. Multiple devices are required to deploy at different water depths (possibly 3 depths, but this number will need discussion).
- Measurement of ions within the lake water will be made but only using equipment that is OTS.
- Two sonar devices (top and bottom of probe) are needed to allow depth-to-probe and water-depth measurements.
- If a sampling capability is adopted, there are a number of options. The simplest sampling option is a series of sampling chambers/cavities which may be switched to recover water from the target environment. If more specific directed sampling is required (unlikely in the first instance – this may be useful for recovering samples from the lakebed), a simple rotary drill may be used (eg. as in DS2), but a micro-actuator based on the use of parallel sets of shape memory alloy wires may provide actuation by the application of electrical power to initiate temperature changes without the use of reciprocating parts.

6.3. Detection of life

Defining the equipment needed to detect life within the lake water is critical to the success of the experiment. The following make up the possibilities defined at present:

- A clear generic marker of active terrestrial life is ATP. Technology to identify it is already available. The reaction vessel would be imaged by the photon-counting camera. At present 4 measurements (3 at various water depths and one in sediment) are envisaged. If water cannot be filtered, however, there will be no point to deploy such equipment other than in the lake-floor sediment.

- Fluorescence will be measured using a UV light source and detector.
- Raman spectroscopy could be deployed on (i) filtered particulate organic material, and (ii) a SERRS (surface-enhanced resonance Raman spectroscopy) surface, exposed to extract organics from solution. Deployment into sediment may also be possible using a fibre optic probe.
- A Life Marker Chip, using readily available antibodies, is high risk (in terms of the timescale for development) and expensive. If it can be developed, such equipment would be central to the project's life-detection goal.

The first three life-detection devices, if used in tandem, would result in a multi-pronged approach to the problem. The fourth would be a bonus if it can be developed in time.

6.4. Alternative equipment

In addition to the probe's basic apparatus and its life detection equipment, the following items may also be available for use in the lake:

- Ion-selective electrodes could be used, but they are bulky individually. A JPL group is developing an integrated system (DC investigating).
- A parallel track application could be made for development of an integrated, optically-based measurement suite to include imaging, chemical sensing (ions, isotopes), oxygen, other gases, pH/Eh, Raman, opacity, ATP, other biomolecules. Funding a feasibility study then construction and testing is probably outside the timeframe available, but ultimately desirable.
- The Beagle 2 corer-grinder is a possible alternative for sediment sampling, but requires waterproofing.

The project needs to decide if the probe will be left in the lake with most of the instrumentation, and just sampling chambers retrieved. Retrieving the whole avoids another manoeuvre, but means the hole has to be able to accommodate the whole probe width on withdrawal.

(For Discussion): We need to identify ~8-10 measurements to be made, of which no more than four are not OTS.

Items for development, in order of priority are:

1. Photon-counting camera for measuring fluorescence, bioluminescence, ATP etc.
2. Water filtering system
3. Raman spectrometer
4. Life marker chip
5. Water and sediment sampling
6. Integrated, optically-based instrument suite

6.5. Costs

Basic development	£200,000
Pressure adaptation	£100,000
Life marker chip	£150,000
Staff	£200,000
Total	**£650,000**

Research Council relevance:	PPARC, EPSRC

7. PROBE DEVELOPMENT
(MATT MOWLEM, ALEX ELLERY)

Objective:

- To construct and test a probe to house the instruments and to allow communication between the probe and the ice surface by which data may be sent back to the ice surface

The probe development will require two elements: (a) The construction of electronics to ensure data from the probe's instruments are transferred to the ice surface, and (b) the building of the probe case and tether (capable of withstanding appropriate pressure of the borehole and Lake Ellsworth).

7.1. Probe electronics

The Surrey Space Centre (SSC) with Surrey Satellite Technology Ltd (SSTL) are world leaders in micro- and nano-satellite development with a history of successful micro- and nano-satellite launches for over two decades. They have extensive experience in the design and manufacture of small-volume, low-mass and low-cost spacecraft with payload capabilities rivalling that of larger platforms. Their expertise lies in the packaging of instruments and electronics into small volumes. SSC are currently developing a 2-3 kg micro-penetrator probe platform for orbital deployment on Mars, Europa and Near-Earth Asteroids (with MSSL).

The following are characteristics of the probe's electronics and communications system:

- It is anticipated that the probe will draw power and data through its tether which will be required to be highly robust. This will be a potential single point failure mode as the Dante II robot (designed to explore active volcano craters) failed when its winch-deployed rapelling tether snagged and fractured on its maiden descent in 1994. The power distribution bus should be isolated from the data distribution bus in separate wiring harnesses. The DS2 microprobes used Kapton-based multilayer circuit carrier of 30 nanowires of plastic coated thin metal film (which offered greater tensile strength than copper wires).
- The probe will have a thin geometry due to the narrowness of the borehole of <20cm diameter – similar to sondes used in petroleum wireline logging. The penetrometer shell should be of semi-monocoque construction with thermally isolated internal equipment spaces. Although aluminium alloy may be suitable for the probe structure, wireline logging sondes are generally constructed from titanium alloy. Indeed, the probe may potentially be constructed from compartmentalised segments connected together through standard interfaces at the deployment site as in wireline logging making transport and packaging of the probe easier.
- The probe is essentially a hollow cavity which allows the accommodation of scientific instruments and supporting subsystems with minimal mass overhead. The centre of mass of the probe should be close to the nose forward of the centre of pressure to ensure stability during the descent.
- Thermal control may be achieved through an inside layer of carbon foam or silicon aerogel with a thermal capacity of 300 W/cm^2 (multi-layer insulation is likely to be too thick within the limited diameter). Thermal isolation straps may be constructed from low thermally conductive glass fibre reinforced epoxy.
- The probe must house the service support subsystems and the relevant scientific instruments.
- The probe electronics should be housed within the probe connected through each segment by electrical interfaces and a bus architecture (eg. CANbus). The internal circuitry may be optimised to minimise the length of the wiring harness. Circuit paths should be short with electronics packaged into circuit board stacks linked through an integrating backplane. The electronics comprises:
  1. Power microelectronics based on CMOS ASICs (application-specific integrated circuits) for switching voltage regulation and overcurrent protection of onboard devices.
  2. Control and data handling microelectronics (a microcontroller including internal multiple ADC channels) for the storage of telemetry and scientific data and mission sequencing.

Transputer (or other co-processors) may be employed to perform image processing (which have been deployed on SSTL micro-sats). Lossless data compression methods may be employed to reduce data rates.

- Onboard microprocessors will enable limited data manipulation on the vehicle; will manage data storage and transmission to the surface command station; will control onboard systems; and will calculate attitude from inertial and magnetometer sensors. Attitude data can be combined topside with the sonar images to provide accurate positioning information vital in the measurement of the small currents expected in the subglacial lake.
- Although it is anticipated that onboard power will be supplied through a tether, backup primary Li-thionyl batteries designed for a significant period of operation at low temperatures should be included for redundancy. This depends on the duration within the target waters (unknown) and the time for descent and ascent (~20 hours).
- Conductive fins will be required to radiate battery power dissipation.
- The tether link should provide sufficient capacity to support the telemetred data rate, eg. 500 kbps depending on the scientific instrument polling rate and data density (eg. imaging).

Onboard instrumentation should employ dedicated on-chip signal conditioning electronics to allow efficient interfacing to the databus. However, the requirement for minimal volume overhead suggests that tight scientific payload integration into a single system is required to eliminate modular boxes with electrical connectors. This architectural trade-off will require critical examination.

7.2. Probe casing

- The probe concept consists of a negatively buoyant cylindrical vehicle with no propulsive capability. It will be lowered under its own weight into the borehole and subsequently to the subglacial lake. The predicted borehole diameter at retrieval limits the vehicle width to less than 200 mm. Length is relatively unconstrained and will be varied to accommodate the required instrumentation and systems. The diameter limit has the most profound effect on the area available for tip mounted instruments (shown in fig1, imaging sonar, CTD, water sampler tube, sediment corer / sampler, video camera and light). Water sampling and pumping for analysis elsewhere on the vehicle eases this pressure somewhat.
- Movable surfaces / covers could be considered but are currently avoided by the use of a fixed cage at the rear of the vehicle which guides the cable away from the sonar and encourages the vehicle to centre itself into the borehole for retrieval. A fixed cowl (not shown) protects the tip mounted instrumentation. The generation and use of hot water for both lake entrance and exit is possible but requires further investigation.
- At a maximum depth of 4 km below an estimated 3.4 km thick ice sheet, the probe will experience an ambient pressure of ~370 bar. Systems that are not resistant to this loading will be placed in a pressure resistant cylinder (Figure 7.1. green tube). Pressure tolerant devices that need to be isolated from water will be

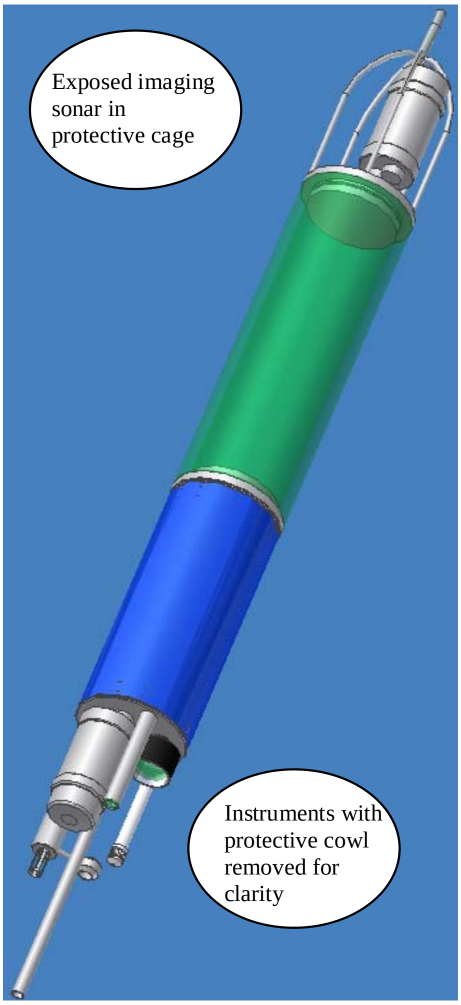


Figure 7.1. Example of probe casing.

housed in an oil filled pressure balanced cylinder with diaphragms to enable differential expansion. This cylinder will have a greater useable diameter due to its thinner sidewalls. All other devices can be exposed to the environment directly or in free flooded areas of the vehicle.

- Standard oceanographic CTD cable with optical fibre and dual conductor link (e.g. A303950, Rochester Cables) can be used. 4 km of 11 mm diameter cable weighs ~2900 kg (~1300 kg in water). Using this cable the maximum probe weight is ~4500kg. This cable can be used to transmit ~100W (@300v) to the probe; a similar power is dissipated in transit.
- Trade studies are required to compare power strategies (including raising the voltage, using different conductors or supplying onboard batteries). Primary communication will be via optical fibre, with a modem backup using the cable conductors. The backup system will not be able to transmit high rate video.
- Sonar images of both the ice roof and lake floor will use features such as the borehole for position determination. This feature will require development.

Significant equipment will be required at the surface including a suitable winch (~3t), power generator, optical and conductor communications link processing, data storage and visualisation with integrated command and control. Testing and verification of components, systems and the integrated vehicle can be undertaken both in the pressure test facility at SOC, and on sea trials.

7.3. Costs

Electronics		
Staff (PI, PDRA PhD, SSTL)	£95,000/y	£285,000
Equipment (software, hardware)		£3,000 (hardware)
£3,000 (licences)		
Electronics and integration		£12,000
Management (travel, accommodation, etc)	£4,000/y	£12,000
Total		£315,000
Probe		
Probe casings hotel and basic communications systems		£32,000
The winch and wire		£200,000
Total topside equip budget approx		£25,000
Staff	£45,000/y	£135,000
Total		£392,000
Total		**£707,000**

Research Council relevance:	EPSRC, NERC

8. DRILLING, LOGISTICS AND FIELDWORK (DAVID BLAKE, KEITH MAKINSON)

Objectives:

- To build and test a hot-water drill and organise field logistics;
- To use a hot water drill to gain access to the lake from the ice-sheet surface;
- To deploy a probe into the lake capable of measuring and sampling the lake's biology, chemistry and physical environment;
- To deploy a sediment corer into the lake to retrieve a 2-3 m sediment core.

8.1. Background

- Exploration of Lake Ellsworth at 90.5 W, 79 S will be undertaken during the 2007/08 or 2008/09 season.
- Hot water drilling equipment will weigh a total of 30 tonnes. Each separate item will be 1 tonne or less and be capable of being carried in a Twin Otter.
- A total of 200 drums of fuel will be needed to make 2 entries into the sub-glacial lake. The lake is at a depth of 3400 metres.
- A total of 10 personnel will be needed on site (3 engineers, 5 scientists and 2 GAs).
- Staff will need to be on site for a period of 7 weeks; 5 weeks to set-up the equipment and 2 weeks to drill and decommission.

8.2. Hot water drilling equipment

- **Drilling system**: 1.7 MW, 4.5 litres per second, 90°C, reducing to 55°C at 3400 m.
- **Lake access hole**: Initial hole diameter of 36 cm, reducing to 20 cm after 36 hours. Drilling time approximately 50 hours, using 12000 litres (60 drums), assuming no problems. Further reaming of the hole consumes approximately 6000 litres per day.
- **Drilling hose**: 1.5" bore should be acceptable with 4.5 litres per second at up to 90°C, with an estimated pressure loss of less than 2000 psi with 3400 m of hose. The hose will have to be supported using additional strength members, or integral strength member bonded to the hose (expensive), if the top 300-400 m of the core is air filled. A new drilling winch will be required to handle the new hose and additional load.
- **Biological filtering** using a modular cartridge filter system to remove all bacteria and many viruses (down to 0.045 micron) from the water used during drilling.
- **Borehole pumps**: To minimise lake contamination, the drilling water can be filtered and the water level maintained at 300-400 m below surface, thus allowing further reaming of the hole while fuel is available. 5 x 7.5 kW pumps or 3 x 11 kW pumps each with associated hose, power cable, rope and 3-phase generator. Estimated suspended weight of 1100-1500 kg per unit when in use, 800-1000 kg during recovery. A suitable winch will be required to assist in the pump recovery.
- **Heating units**: need 30 of the existing 60 kW units, could use larger units to reduce unit numbers.
- **High pressure pumps**: need 8 of the existing design diesel powered units (38 l/min, 2200 psi)
- **Miscellaneous:** Surface hoses, fittings, valves and monitoring instrumentation will need upgrading from the existing design and additional units/spares will be required, e.g. pumps, heaters, generators, general spares as failures can and will occur.

8.3. Constraints

The constraints on what can be taken into the field depend on the carrier available. For Twin Otter, the two constraints are: (1) door, 1.4 m wide by 1.25 m high; (2) payload, 850-1000 kg.

The drill will weigh approximate 30 tonnes and will require 20 tonnes of fuel (for reference, the RABID drill included 19,000 kg of kit and 36,000 kg of fuel). The Lake Ellsworth drill will require

2x the thermal capacity of the RABID drill. It may be possible for some of the equipment from the RABID drill to be reused.

8.4. Access and fieldwork

- The delivery of equipment, materials and personnel to the drill site, will use chartered aircraft. There will be a heavy lift from South America to Patriot Hills with onward carriage by Twin Otter and Basler aircraft.
- All field activities and arrangements will be organised and provided by BAS including transportation, tents, clothing, field equipment, communication systems and food. BAS will also support the field party.

8.5. Fieldwork analysis

The probe will deliver information concerning physical, chemical and biological properties of the lake's water column. Appropriate scientific expertise will be present in the field to:

- Manage the probe's sampling strategy;
- Interpret the probe's results to comprehend the environment of Lake Ellsworth.

Data collected by the probe will be recorded on site and made available to project members in the first instance, and the international scientific community via SALE and the IPY.

If samples are recovered, it may be possible to undertake first analysis on site. The bulk of material recovered will be packaged and transferred to laboratories where detailed analysis can take place.

Objectives related to interpretation of data and samples are discussed in Sections 9, 10 and 11.

8.6. Costs

All budgetary costs are at 2004/05 rates, indexed at 3% per year for 2008/09. BAS labour rates 04/05 are £243/day for band 5, £207/day for band 6, £158/day for band 7.

Drill rig including consumables	£703,000
Transportation of equipment and materials from South America to Patriot Hills	£900,000
Transportation of equipment and materials from Patriot Hills to Lake Ellsworth (charter Twin Otter for 2 seasons)	£675,000
Fuel (768 drums)	£173,000
Tents, field equipment, clothing and food, communications	£116,000
Conference/training for fieldwork	£11,000
Direct labour- development of drill rig (2 engineers for 84 weeks)	£106,000
Direct labour – fieldwork (3 engineers and 2 GAs for 10 weeks)	£73,000
Management overhead	£22,000
Total	**£2,779,000**

Research Council relevance:	NERC, (EPSRC for drill development)

9. BIOLOGICAL ANALYSIS
(DAVID PEARCE, CHARLES COCKELL)

Objectives:

- To assess data sent by the probe in real-time to the ice surface, to comprehend the physical and chemical structure of the lake, and to ascertain the form, level and distribution of microbial life in the water column and water-sediment interface;
- To deploy a probe into the lake capable of measuring and sampling the lakes biology, chemistry and physical environment;
- To conduct microbiological examination of lake water and sediment in a laboratory.

9.1. Background

Microorganisms have been found in some of the most extreme environments on Earth; organisms thrive in ice, boiling water, acids, water-cores of nuclear reactors, salt crystals and toxic waste. Lake Ellsworth has the potential to be one of the most extreme environments on earth with combined stresses of high pressure, low temperature, permanent darkness and probably low nutrient availability. The identification of significant subglacial bacterial activity, as well as the work on permafrost communities, suggests that life can survive and potentially thrive at low temperatures, and it has been shown at Lake Vostok that all of the accreted ice samples between 3541 and 3611 m contained both prokaryotic and eukaryotic microorganisms. In addition, viable microorganisms have been recovered from one million year old Antarctic permafrost, which makes it likely that prolonged preservation of viable microorganisms may be prevalent in Antarctic ice-bound habitats. Thus, existing data suggests that the Antarctic ice sheet may at least provide a source of microorganisms to inoculate the lake.

9.2. Does Lake Ellsworth contain life?

Members of the microbial world encompass the three domains of life, the Bacteria, the Archaea and the lower Eukarya. About 4,200 prokaryotic species have been described out of an estimated 10^5 to 10^6 prokaryotic species on Earth. The overlying ice core at Lake Vostok is known to contain the full diversity of microbial life: the algae, diatoms, bacteria, fungi, yeasts and actinomycetes (Ellis-Evans and Wynn-Williams, 1996). A combination of microscopy, biochemical and molecular biological techniques will be used to determine the characteristics of microorganisms present in the Lake.

9.3. Where is life located within the subglacial Lake?

Such a unique environment is expected to harbour significant chemical gradients, including even oxygen (from gas hydrates released from ice). Microbial life in Lake Ellsworth may, therefore, be pelagic, associated with sediment particles, distributed along gradients, in accretion ice or in overlying meteoric ice. The localisation of any living system along with the determination of the elemental composition of the surrounding media will provide clues to potential biogeochemical activity and the sources of energy and carbon that would be necessary to sustain metabolically active populations.

9.4. What are the characteristics of Lake Ellsworth communities?

The mere presence of life in itself would be a major scientific discovery, however, we might expect such organisms to possess special or unique adaptations to this hostile environment. Analysis of the metabolic activity and capability or novel physiologies (using a metagenomic approach) and energetics through biochemical pathways of returned samples, will help to gain a fuller understanding of the role of Lake Ellsworth microbes in biogeochemical cycling and the functioning and control of the ecosystem.

9.5 Techniques

- Microscopy; fluorescent and electron microscopy (linked to specific gene probes).

- Biochemistry (biogeochemical cycling); In the absence of light, the microorganisms within Ellsworth must be using either organics or inorganic redox couples to gather energy. We will use gene probes available for different biogeochemical activities to assay the water/samples for the presence of biogeochemical activity. This will include probes for iron cycling (reduction and oxidation), nitrate cycling, manganese reduction and other pathways of dissimilatory metal reduction and oxidation.
- Molecular biology; Genomic DNA will be extracted from material obtained and used to construct a metagenomic library to screen for novel physiologies.

9.5 Costs

Microscopy	£25,000
Biochemistry	£160,000
Molecular biology	£195,000
PDRA for fieldwork and lab work, 3 years, plus lab support	£200,000
Total	**£580,000**

Research Council relevance:	BBSRC, NERC

10. GEOCHEMICAL EXPERIMENTS
(MARTYN TRANTER, MARTIN SIEGERT)

Objectives:

- To assess data sent by the probe in real-time to the ice surface, to comprehend the physical and chemical structure of the lake, and to ascertain the form, level and distribution of microbial life in the water column and water-sediment interface;
- To deploy a probe into the lake capable of measuring and sampling the lakes biology, chemistry and physical environment;
- To undertake geochemical analysis of water and sediment.

The aims of this Section are to first detail the expected geochemistry of the lake water, and then assess the various measurements and analyses required to quantify the lake's physical and chemical environments (including measurement/sampling strategies and prioritisation of laboratory experiments).

10.1. Background: Expected bulk geochemistry of Lake Ellsworth

Let us assume that the dimensions of Lake Ellsworth are 10 km x 10 km x 250 m; then the **volume of water is 25 km^3**. Let us then assume that the melting into the lake equals freezing out of the lake, so that the lake volume is in steady state, and that melting occurs over 50% of the lake at a rate of 10 cm/yr. The **annual input of melt** to the lake is therefore 10 km x 10 km x 0.5 x 10 cm/yr or **5 x 10^{-3} km^3/yr**.

The **residence time of water** is 25/5 × 10^{-3} yrs or **5 kyr.** Assuming the **age of Lake Ellsworth** to be **400 kyr**, there have been 400/5 or **80 renewals of water over this period**.

Let us assume that all the solute from the melting ice stays in the lake, since ~0.1% is incorporated into accretion ice. The **chemical composition of the lake is therefore 80 times that of the average incoming ice melt chemistry**, if no other sources or sinks of ions occurs.

Let us finally assume finally that the chemistry of ice melt is equivalent to the average chemistry recorded in the Byrd Ice Core.

Units: µeq/l	**H^+**	**pH**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**	**K^+**	**NH_4^+**	**Cl^-**	**SO_4^{2-}**	**NO_3^-**	**HCO_3^-**
Average Byrd Ice Core	1.8	5.7	~1.0	0.4	1.5	0.05	0.13	2.0	1.0	0.7	~1.2
Inferred Lake Ellsworth	<140	>3.9	>80	30	120	1	<10	160	80	<50	>100
Lake Ellsworth (including contribution from glacial flour)	~10	~6	~420	~90	120	3	1	160	240	1	240

Table 10.1. Expected bulk chemical composition of water in Lake Ellsworth

The inferred concentrations of **Ca^{2+}, Mg^{2+}, Na^+, K^+ SO_4^{2-} and HCO_3^- are probably on the low side**, since these ions are generated from interactions between glacial flour and ice melt. We guess that concentrations may be up to a factor of 3-5 higher, putting these concentrations similar to those estimated for Lake Vostok.

The inferred concentrations of **H^+, NH_4^+ and NO_3^- are probably too high**, since glacial flour uses up H^+ in chemical weathering actions, and microbial activity will remove NH_4^+ and NO_3^-. We guess that the pH of the water will be about 6 and that NO_3^- and NH_4^+ concentrations will be around 1 µeq/l, similar to those in Lake Vostok.

10.2. Experiment sampling strategy

Given the short but intensive duration of the field experiment (24-36 hours), it is essential to formulate a measurement and sampling strategy to acquire appropriate real-time data and quantities of the lake water to ensure its geochemistry can be characterised appropriately. Our three-stage plan for exploration is as follows:

1. Once in the lake, lower the probe continuously to the lake floor taking measurements of lake's physical environment.
2. At the lake floor, collect sediments, deploy life marker device into sediment, scrutinise physical-lake data.
3. On the basis of an analysis of data to this point, a sampling strategy should be developed the return journey up the water column. In this way we can be confident of acquiring the most interesting material.

10.3. Physical environment

Physical environment (flow, temperature, conductivity, density, pH etc) is likely to be one of the first results of the programme. The analysis involves data emplacement within a 3-D context (the broad 3-D physiography having been established from earlier geophysics from an AFI project in 2006-7).

Questions that can be answered include: Is the lake thermally and/or chemically stratified? What is the rate of water flow? Is the water saline? Does water flow through hydrothermal action? A short period of post-fieldwork processing will be required, in conjunction with 3D visualisation of the lake system.

Sonar (possibly side-scan) may provide fascinating imagery of the lake floor (if side-scan is used), and would compliment seismic results of water depths acquired in 2006-7.

10.4. Geochemical environment from laboratory analyses

Given that sufficient water is sampled, a strategy to utilise the samples most effectively is required. In the following tables, measurements of various components are prioritised and the minimum amount needed for the measurement is indicated.

The first procedure for all samples is to separate water from particulates. Analysis of filtered particulates will reveal the following results:

- Particulate concentration
- Particulate size frequency
- Particular lithology and mineralogy
- Contribution to solute

Having established the particulate content of lake water, experiments of the water itself can be conducted, with a priority as follows:

Species	**Min volume for analysis (ml)**	**Cumulative min volume (ml)**
Major cations and anions Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-} and Cl^{-}	2	2
DIC/DOC	5	7
Nutrients (NO_3^{-}, NH_4^{+} and PO_4^{3-}, DON and DOP)	10	17
$\delta^{13}C$ – DIC, $\delta^{18}O$ – H_2O,	8	25
If anoxic, Fe, Mn, HS^{-}	5	30
Assume that there is too little sample to do $\delta^{34}S$ and $\delta^{18}O$-SO_4^{2-}		
Should attempt to measure O_2, CO_2 , CH_4 and N_2 in the gases in the head space above the water samples		

Table 10.2. Prioritisation of geochemical analysis

10.6. Lake-floor sediments

A strategy for analysis of lake-floor sediments is requires in a similar way to the lake water. A prioritisation of experiments, with amount of material required for each, is as follows:

Species	**Min weight of sediment (g)**	**Cumulative min weight (g)**
Grain size distribution	0.1	0.1
CHNOS	0.1	0.2
SEM/EDAX	0.1	0.3
Mineralogy	1	1.3
Sequential extraction for nutrients and Fe	10	11.3
Sulphides	5	16.3
X-ray lamination*		
Magneto-stratigraphy**		

*X-ray analysis required use of all material in the sediment core, but will destroy none.

** Magneto-stratigraphy, see Section 11.4

Table 10.3. Prioritisation of sedimentological analysis.

10.7. Costs

PDRA for fieldwork and lab work, 3 years, plus lab support	£200,000
Laboratory consumables	£25,000
Isotope costs	£20,000
Fieldwork costs, PDRA + 2 others	£10,000
Total	**£255,000**

Research Council relevance:	NERC

11. GEOLOGICAL EXPERIMENTS
(MIKE BENTLEY, DOMINIC HODGSON, GARY WILSON, MARTIN SIEGERT)

Objectives:

- To acquire and test a sediment corer, capable of extracting a 2-3 m core from the floor of Lake Ellsworth;
- To deploy a sediment corer into the lake to retrieve a 2-3 m sediment core;
- To conduct sedimentological laboratory analysis of the lake floor sediment core.

11.1. Background

Sediment in Lake Ellsworth will come from two primary sources, namely mineral dust (plus other particulate matter such as propogules, micro-meteorites) from the overlying ice, and sub-glacially-eroded sediment. The dust component is likely to be volumetrically very small, whilst the sub-glacially eroded component is likely to be substantially greater but more spatially restricted to the edges of the lake.

These sediments are likely to be easily sampled using a standard gravity corer. Providing a physical link can be made between the surface and the lake (i.e. a hot water hole) it is feasible that a sediment corer could be dropped to the lake floor to sample and retrieve the sediments.

Retrieval of a shallow sediment core has several potential benefits to understanding the lake’s environment, its biota and its long-term history.

- In ultra-oligotrophic (extreme nutrient-poor) lakes the sediment-water interface is one of the most likely niches for life to exist and so a sample of this environment is necessary to fully test hypotheses of life in the lake. For example in most Antarctic lakes the vast majority of biodiversity resides in the sediment.
- A sediment core adds the time dimension: the sediments will record a history of environmental conditions within the lake, including any records of life such as preserved organic remains (biomolecules etc). If no life is found in the water column then the sediments may show if life *ever* existed in the lake.
- The sediments provide the potential for answering the question of how life got to, and evolved within, the lake. In particular if a sediment core can sample the transition between pre-glacial sediments and those deposited in the lake then the development of the lake and its life may be tracked through time.

Those listed in (1)-(3) may even be a *necessary* addition to entering the lake if we are to fully answer the question of whether life exists/existed in Lake Ellsworth.

Furthermore, a sediment core from Lake Ellsworth could address three issues concerning the glacial history of West Antarctica:

- The record West Antarctic Ice Sheet (WAIS) evolution, particularly the transition to full ice sheet conditions and
- The timing and duration of periods of WAIS collapse, and
- The variations in lake ‘climate’ introduced by glacial-interglacial variations in the ice sheet above.

11.2. Corer

A cable-operated gravity corer suitable for deployment through a hot water drilled hole has already been developed by UWITEC. This exists and indeed, is being used this season to retrieve sub-glacial sediment from below the Rutford Ice Stream. A version of this could be built for retrieving sediment from Lake Ellsworth. Of particular importance to the construction of the corer will be knowledge of the sediment thickness and water depth: both of which are scientific objectives of the proposed Geophysical Exploration of the lake (Section 5).

11.3. Analyses

Table 11.1 lists the various sedimentological measurements that could be made on a sediment core from the floor of Lake Ellsworth, and the scientific results that may follow. One of the measurements listed, the magneto-stratigraphy method, is expanded in Section 11.4.

Measurement technique	Result	Comments
Nd-Sr	Provenance of sediment	
Grain size	Sediment flux/source origin Possibly info on age if grain size follows glacial cycles	
XRD, XRF	Mineralogy of sediment	
SEM	Source of sediment	Distinguish aeolian (dust) *vs* sub-glacial
Extraterrestrial material (imaging?)	Long-term averages of meteorites etc, testing of hypotheses of links between extraterrestrial flux and climate change	
Magneto-stratigraphy (see section 11.4)	Age of sediment, e.g. by using magnetic polarity timescale	May be crucial as the most likely way to date the sediment.
^{10}Be, ^{3}He etc	Could measure timing of isolation of lake by ice using cosmogenic isotopes	Dependent on sample size available
Other radioactive isotopes	Presence of isotopes with variety of half-lives helps constrain flux of ice/sediment from surface and/or timing of isolation of site (e.g. presence of ^{14}C ($t_{1/2}$=5600 yrs) would be v. difficult to explain without fairly recent exposure or contamination.	Could test ice flow models.
Carbonate isotopes	Environmental conditions in lake	Requires presence of carbonate precipitate in closed system (difficult), but might find ikaite (cf calcite or aragonite)
Oxygen isotope analysis of penecontemporaneous minerals	Comparison to marine oxygen isotope stratigraphy – ice flow model could give the age offset	
U-Th dating	Age of sediment	Requires presence of carbonate precipitate in closed system (may not be present because of high pressure and low T (high $p\mathrm{CO}_2$ therefore high acidity). Upper age limit of *c.* 0.5 Ma.
Bedrock sample	Local geology	Highly dependent on sediment thickness [possible, but unlikely that a bedrock sample could be retrieved with a gravity corer]
Sedimentology (pre-glacial marine sediment *vs* sub-glacial lake sediment)	Has WAIS ever collapsed ?	If multiple WAIS collapses are found in sediments then this raises interesting question of how life in basin adjusts from marine environment to re-glaciation on each occasion Question of sediment scouring becomes important if Lake Ellsworth is shallow.
	How (and when) did WAIS develop ?	

Table 11.1. Analysis of a sediment core from Lake Ellsworth

11.4. Magneto-stratigraphy

Magneto-stratigraphy may be essential to understanding the age of sedimentary material recovered from the floor of Lake Ellsworth.

11.4.1. Chronology:

If the core is quite condensed, the first experiment will be to test whether the Brunhes/Matuyama Boundary (780,000 years ago) can be detected. Assuming the record is complete, it may also be possible to pick up younger field excursions but it would be difficult to work with these unless there is some independent chronology to integrate with. However, the bonus of being proximal to the South Pole is that we can easily detect polarity from inclination records alone (it is doubtful that core material will have azimuthal orientation to it).

It should also be possible to recover a secular variation and field intensity record. It is not known whether the secular variation will help with dating as the location is so close to the pole and azimuthal orientation will be absent. However, such a record has never been taken so close to the South Pole, which makes its acquisition important scientifically. Similar issues relate to field intensity measurements.

11.4.2. Provenance:

Environmental magnetic parameters may well indicate provenance and transport pathways for sediment.

11.4.3. Benefits of palaeo-magnetic and environmental magnetic studies:

A ‘U-channel’ cut from the split core half (2.5 × 2.5 cm × length of core), and all analysis, will be non-destructive and will not modify the sample so all material can be available for further study post magnetic measurements.

11.4.4. Requirements:

Apart from being able to U-channel the core, it is probably best if this is done before the core has the chance to come into any unknown magnetic fields. The coring barrel will be magnetic but this can be compensated for. Exposure to stray magnetic fields from engines, ships, steel objects, etc can modify or overprint the magnetic signal and this can prevent the success of magnetic studies. Shields for U-channels are available to prevent this during transport.

11.5. Costs

The technology for retrieving a core exists and would only need to be modified according to what we learn about water and sediment depth. Therefore there are unlikely to be significant development costs. The equipment could be deployed down the existing hole (from water-borne experiments) within a matter of a few hours. The sediment analyses would be time consuming and would require a PDRA. It is assumed here that existing biological laboratory facilities (used by biologists analysing water column of lake) could be used for those sediment analyses where contamination is an issue, and so there are no laboratory development costs. The coring kit (incl. tripod and winches, c. 0.75 tonnes) would add to logistics burden. A preliminary estimate of costs would be:

Coring equipment (OTS)	£75,000
PDRA	£150,000
Laboratory costs	£50,000
Logistics	£50,000
Total	**£325,000**

Research Council relevance:	NERC

12. PROJECT COSTING

Estimates for the cost of the exploration of Lake Ellsworth are as follows:

Geophysics costs. £400,000 (applied for, BAS to cover logistics)	
Instrument costs.	£650,000
Probe costs 1. electronics	£315,000
Probe costs 2. casing and tether	£392,000
Sediment Corer	£75,000
Drilling and Fieldwork	£2,780,000
Biological analysis	£580,000
Geochemical analysis	£255,000
Sedimentological analysis	£250,000
Managerial and secretarial	£100,000
Total	**£5,397,000**

The potential breakdown of research council contributions is as follows:

Research Council	**Costs**
NERC	Main contributor: Logistics and fieldwork (£2,779k); Geochemistry (£255k); and Sedimentology (£325k). Part contributor: Probe development (£707k); Microbiology (£580k).
EPSRC	Main contributor: Probe development (£707k). Part contributor: Instrument development (£606k); Drill development (£703k)
PPARC	Main contributor: Instrument development (£606k)
BBSRC	Main contributor: Microbiology (£580k)

13. TIMETABLE OF ACTIVITIES

It is possible to plan the physical exploration of Lake Ellsworth to take place during the Austral summer of 2008/9, providing:

(1) The proposal to undertake the geophysical exploration of Lake Ellsworth is funded and fieldwork takes place in 2006/7 (RES and seismics) and 2007/8 (resurveying GPS positions);
(2) Funds to develop the instruments, probe and drill are made available by the start of 2006; and
(3) Logistic support for deep hot water drilling at Lake Ellsworth is in place for the IPY period.

In this case, the 5-year timetable of activity for exploration is outlined in Table 1.

Project	**2005/6**	**2006/7**	**2007/8**	**2008/9**	**2009/10**
Phase 1: Geophysical survey	▨	AFI Fieldwork I	AFI Fieldwork II	▨	
Phase 2: Instrument development		▨	▨	▨	
Phase 2: Probe development		▨	▨	▨	
Phase 2 and 3: Hot-water drill and fieldwork		▨	▨	IPY Fieldwork	▨
Phase 4: Biological analysis				IPY Fieldwork	▨
Phase 4: Geochemical analysis				IPY Fieldwork	▨
Phase 4: Sediment analysis				IPY Fieldwork	▨

Table 13.1. Timetable for the exploration of Subglacial Lake Ellsworth

14. INTERNATIONAL COLLABORATION

The Scientific Committee on Antarctic Research (SCAR) commissioned a group of specialists (now a Scientific Research Programme) named SALE (Subglacial Antarctic Lake Environments) to "consider and recommend mechanisms for the international coordination of a subglacial lake exploration program" (Priscu et al. 2003).

It should be noted that SCAR has no money to fund research. Consequently, its scientific research programmes will not undertake research themselves. Instead, these programmes have been configured to facilitate research and encourage international cooperation through workshops and symposia. Funding for projects within a SCAR SRP must be sought by national funding agencies.

SALE has submitted a broad 'umbrella' proposal to the IPY, involving numerous projects concerning subglacial lakes from a variety of nations, which includes the exploration of Lake Ellsworth. SALE will assist the Lake Ellsworth project in terms of environmental planning, data management and dissemination of results.

Details of the SALE project can be found on its website: http://salegos-scar.montana.edu/

While the project is UK-led, it involves scientists from Belgium, Germany, New Zealand, Sweden and the USA.

Hence, through its links with SALE and international project partners, this project will have a significant international profile.

15. PROJECT MEMBERS

List of project members, their expertise, affiliations and email addresses:

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