

## Geophysical exploration of a West Antarctic subglacial lake

### EXECUTIVE SUMMARY

One of the last places left on Earth where new and unique microbial lifeforms might be found is in subglacial lakes. The sediments that drape subglacial lake floors may also contain important records of past climate change and ice sheet evolution. *In-situ* sampling and analysis is the only way to measure subglacial life and sedimentary records. Before such work is possible, however, a detailed characterisation of a subglacial lake system must be made. We propose the geophysical exploration of a 10 km-long subglacial lake near the Ellsworth Mountains (Siegert et al., in press). Fieldwork will involve radio-echo sounding (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. We will also use numerical modelling to identify the 3-dimensional flow of ice over the lake, rates of subglacial melting and freezing, source areas of meltwater, and lake water circulation. The outcome of the project will be the first full characterisation of a subglacial lake and the establishment of an appropriate site for future exploratory research.

### Introduction and aims

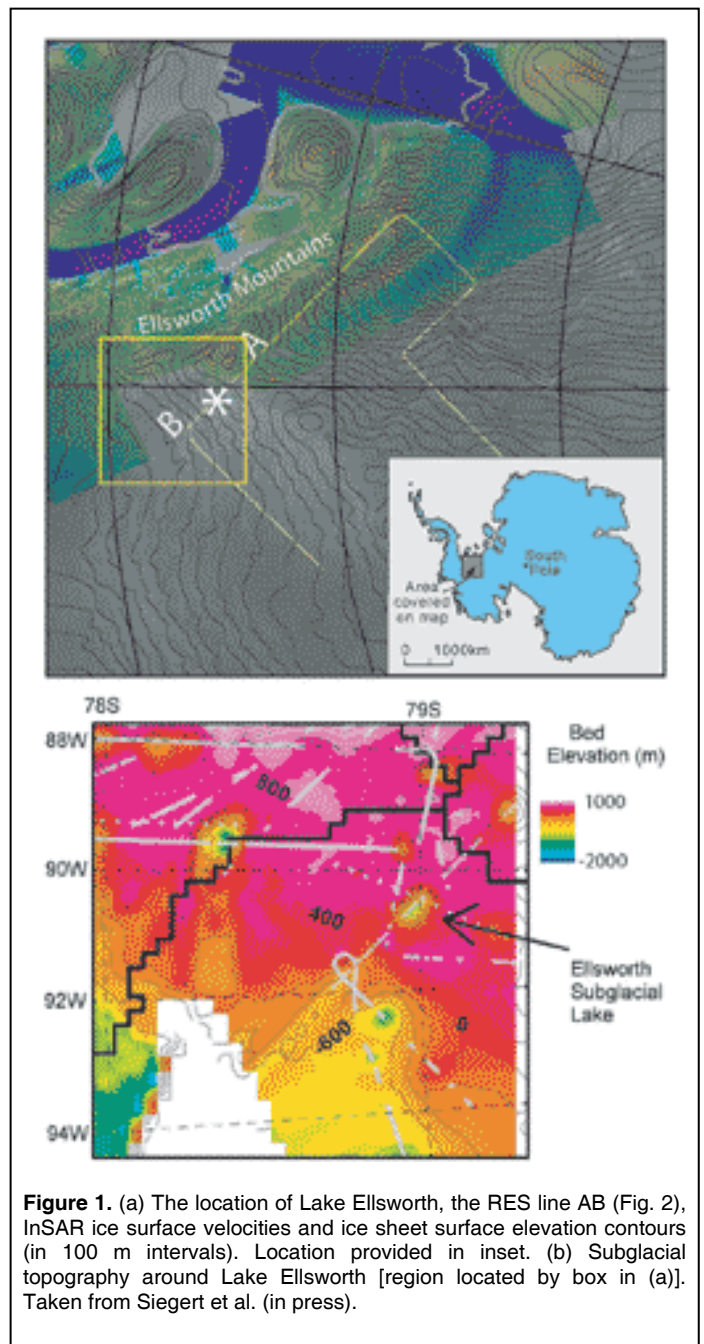
It is now an established hypothesis that Antarctic subglacial lakes house unique forms of life and hold detailed sedimentary records of past climate change (e.g. Siegert, 2000). A necessary prerequisite to *in-situ* measurement of these environments is a full comprehension of the glaciological and topographical setting from geophysical measurements.

Only Lake Vostok, the mega subglacial lake in East Antarctica (Siegert et al., 2001), has been examined in detail by airborne geophysical techniques (Studinger et al., 2003). However, the Subglacial Antarctic Lake Exploration (SALE) group of specialists, set up by the Scientific Committee on Antarctic Research (SCAR) to consider and recommend mechanisms for the international coordination of a subglacial lake exploration programme, state that “*the size of Lake Vostok makes it very difficult to characterise in a meaningful way (e.g. seismic exploration of the lake will take many field seasons to complete)*” (SALE, 2003). Hence, it is now thought “*a more appropriate first study site would be one of the relatively small subglacial lakes*” (SALE, 2003).

This proposal aims to undertake the geophysical exploration of a small subglacial lake near the Ellsworth Mountains in West Antarctica (Fig. 1) [named hereafter as Lake Ellsworth]. Geophysical data will be used to model ice flow, heat transfer and water circulation within the lake. The outcome of the project will be the first full characterisation of a subglacial lake, and the establishment of an appropriate site for future exploratory research.

### Evidence for Lake Ellsworth

Eight lines of evidence collectively prove the existence of Lake Ellsworth (Siegert et al., in press). (1) RES reveals a strong, flat, specula return that could only come from an interface with a significant



**Figure 1.** (a) The location of Lake Ellsworth, the RES line AB (Fig. 2), InSAR ice surface velocities and ice sheet surface elevation contours (in 100 m intervals). Location provided in inset. (b) Subglacial topography around Lake Ellsworth [region located by box in (a)]. Taken from Siegert et al. (in press).

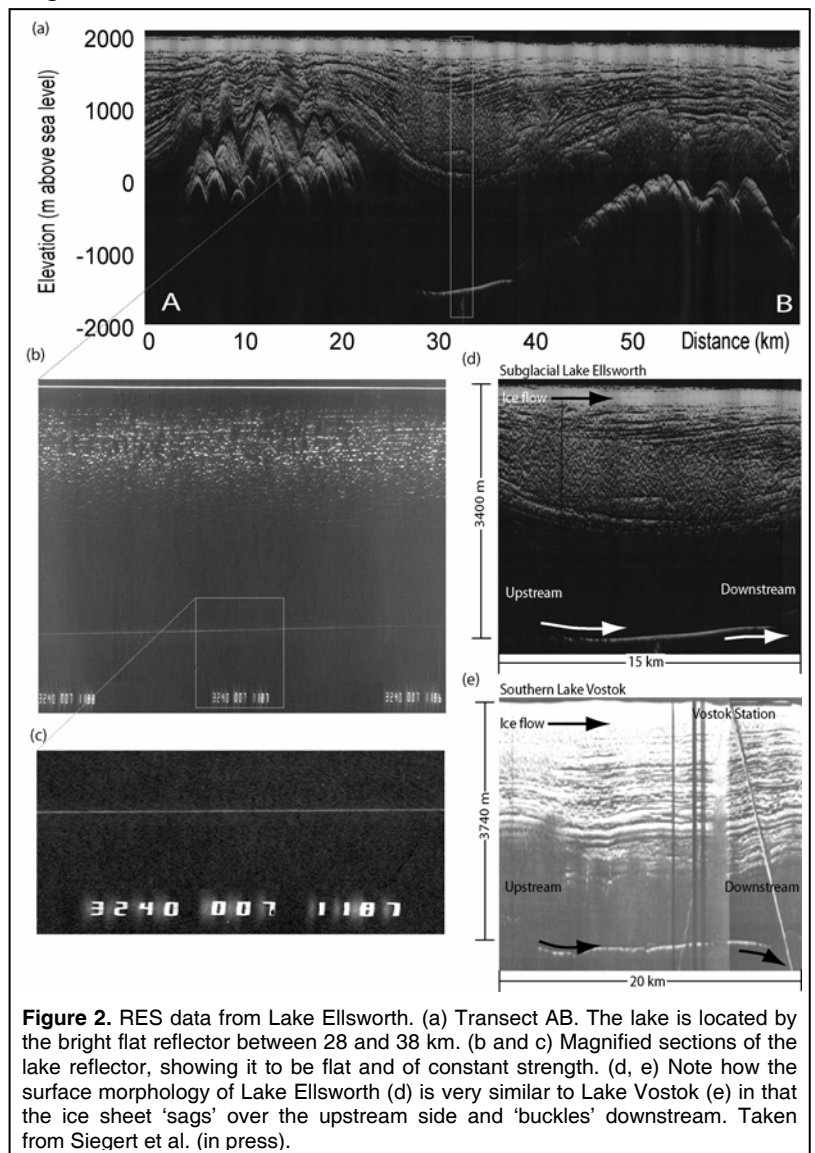
dielectric contrast, which has no roughness at the scale of the radio-wave (Fig. 2). Such an interface is best explained by the ice-water surface of a subglacial lake (Siegert et al., 1996). (2) Small scale changes in the slope of the reflector are apparent, which are very similar to those observed in Lake Vostok and are symptomatic of a lake beneath (Fig. 2d,e). (3) The ratio of the slopes of the ice-water and ice-surface interfaces, averaged over the lake, is at the amount required for the lake to be in hydrostatic equilibrium with the ice sheet. This, in combination with the points above, means that Lake Ellsworth passes every criterion used previously to identify subglacial lakes. (4) The slope of the ice-water interface is also noticeably less than the surrounding topography, inferring strongly that the water depth of the lake is several tens, possibly hundreds, of metres. (5) Internal ice sheet layers, observed above the lake (Figure 1), converge in vertical section with the lake surface (Fig 2c). Ice flow modelling that we have undertaken shows this is only possible if the ice base above the lake is melting at a rate of several cm per year. Hence, the internal layer pattern is consistent with the production of subglacial meltwater. (6) Thermo-mechanical ice-sheet models of West Antarctica predict that the bulk of the ice base is at the pressure melting point. Such models certainly expect melting beneath 3.4 km of ice, which is the ice thickness above Lake Ellsworth. (7) Thermodynamic calculations reveal the heat required for subglacial melting above Lake Ellsworth now and at the last glacial maximum (LGM) is 54 and 46  $\text{mW m}^{-2}$ , respectively. The basal heat flux calculated in West Antarctica from temperature gradients in boreholes is  $\sim 70 \text{ mW m}^{-2}$ . Hence, basal heating at the level expected is sufficient for Lake Ellsworth to exist both now and at the LGM. (8) Regional RES shows that our lake occupies a distinct subglacial bed depression; a topographic requirement for subglacial water to pond (Fig. 1b).

To summarise, these observations rule out the existence of a ‘frozen lake’ or a grounded ice base; they can only be explained by the presence of a subglacial lake.

### Why study Lake Ellsworth?

Lake Ellsworth has the following characteristics that make it highly appropriate for investigation.

- The lake is located  $\sim 20$  km from an ice divide, which means that drilling from the ice surface into the lake would not be complicated by ice flow. This characteristic is critical for future *in-situ* measurements.
- Lake Ellsworth is relatively small (defined by a 10 km long RES record, and the local sub-ice topography), and will therefore be easier to characterise than a large lake, such as Lake Vostok.
- Preliminary data show Lake Ellsworth to be enclosed topographically (Figure 1b), which suggests that it may have existed as long as thick ice covered the depression in which it resides, and may be stable to small changes in the overlying ice sheet.
- The ice-sheet surface over Lake Ellsworth is 2000 m above sea level, which is over a kilometre lower than the ice surface of central East Antarctica. Altitude related problems (both personal and logistical) encountered at Vostok Station, for example, may not be such an issue during the study of this lake.



- The base of the East Antarctic Ice Sheet has yet to be reached by drilling, which makes the planning of East Antarctic lake exploration particularly difficult in terms of environmental conservation. However, there have been numerous occasions when the base of WAIS has been reached, sampled and measured. In particular, ice-wet bed contacts have been observed several times on the Siple Coast (e.g., Gow et al., 1968; Kamb, 2001). Hence, although the environmental issues relating to West Antarctic subglacial lake exploration are important, they may not be as prohibitive as those in East Antarctica.
- If sediments occur across the floor of Lake Ellsworth, they may contain a unique record of ice sheet stability and glacial history in the Quaternary. Such a record would be fundamental to understanding how WAIS responds to future environmental change.

There is significant support within the Antarctic microbiological community for exploratory research to be undertaken in Lake Ellsworth (see Letter of Support 1). The environment of Lake Ellsworth is essentially the same as in any subglacial lake (i.e., it is under the same boundary conditions). Biological selection and function processes are as likely to occur here, therefore, as they are in any subglacial lake environment. The gradient of Lake Ellsworth's ice-water interface (200 m over 10 km) is greater than many subglacial lakes (e.g. Lake Vostok's interface changes by 400 m over 250 km). Consequently, as this gradient drives water circulation, Lake Ellsworth is likely to be more dynamic than other subglacial lakes, which may be advantageous for life in the lake.

### **Hypothesis and science questions**

We hypothesise that: '*Lake Ellsworth is a deep enclosed body of water, which is a suitable candidate for in-situ investigations*'. In order to test the hypothesis, the following eleven scientific questions need to 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?

### **Objectives and Methodology**

To answer the Science Questions we propose ten objectives. They are split into two groups. The first four relate to data acquisition, the rest concern data processing, visualisation and numerical modelling.

*Objective 1: Undertake a RES survey of Lake Ellsworth and its locale.* As the lake is only ~10 km long, we anticipate that a closely-spaced network of RES transects can be established over the study region. Ground-based RES can acquire data at a rate of ~50 km per day and we will spend the first four days undertaking a coarse survey of the subglacial lake and its local area (i.e. mapping a 40×40 km region). Preliminary processing of these data in the field will establish the outline of the lake. The detailed survey of the lake and subglacial surrounding (right up to the ice divide, 20 km away) will then take place in the remainder of the field season. A dense network of RES transects will be acquired over the lake itself, with a line spacing of approximately 300 m. In addition, a coarser survey of the subglacial drainage basin, with a line spacing of 1 km, will be undertaken. Two skidoo-pulled radar systems will be used. First, a low-frequency RES system will be used to sound the base of the ice sheet, and internal layering below about 200 m from the ice surface. Second, a ground-penetrating radar (GPR) system will be used to measure layering in the upper 200 m of the ice sheet along selected RES transects from the ice divide to the far side of the lake. We will apply to the NERC Geophysical Equipment Facility for the GPR equipment. The deep penetrating RES equipment will be built at BAS. RES data will be linked to GPS navigation and surface elevation measurements. It should be noted that the research team has considerable experience in undertaking RES surveys and analysing RES data (e.g. Siegert et al. 2004a).

*Objective 2: Undertake a seismic survey of Lake Ellsworth.* The seismic work will comprise two experiments. The first will involve a grid of spot-depth measurements (~2 km spacing) over the lake to build a picture of its bathymetry. Around 40 stations will be established, for which approximately two weeks will be required. The remaining field time will be devoted to the second experiment, which involves seismic reflection transects across the lake. One ~10 km seismic line will be taken along an ice flow line across the approximate centre of the lake. We will also acquire a series of shorter (~5 km) lines orthogonal to this main line. JW, AS and EK have considerable experience in the appropriate seismic surveys (King et al., 2004). We will use small explosive charges (300-450 g) at ~20 m depth and require

a 24-channel acquisition system. To avoid spatial aliasing and maintain high resolution, geophone spacing will be 10 m. Profiles will be single fold, for which the appropriate shot interval is 120 m. Shot holes will be drilled with a small hot-water drill. Two people will be able to acquire the seismic reflection profiles at a rate of 5 km per week. Data from thick floating ice are often dominated by water-layer multiple reflections and BAS are experienced in processing data from this unique situation.

Objective 3: Deploy and survey GPS stake network. Two weeks of the field season will be devoted to Objectives 3 and 4, to obtain ancillary data. Objective 3 comprises a GPS survey of the ice surface over the lake. Forty aluminium poles (each 4 m long) will be secured at 2.5 km intervals into the ice sheet (arranged in a triangulation system), and GPS readings made at each site. The poles will be left in the ice, and resurveyed in the next season. Three GPS recorders will run continuously throughout the field season. One will be located on the nearest rock outcrop for geodetic control (probably on the flank of the Ellsworth Mountains), a second will be at the field camp, and a third will be towards the upstream edge of the lake. The stake network and the RES and seismic lines, will be surveyed using two additional GPS receivers. We will apply to the NERC Geophysical Equipment Facility for the GPS equipment.

Objective 4: Dig snow pits, collect shallow ice cores for accumulation measurements, and deploy “coffee-can” vertical strain sensors. When combined with GPS measurements, these will help to establish whether the net outflow of ice and water from the lake is in steady state with the local snow accumulation (as in Hamilton and Whillans, 2000). Each task will take approximately one day.

Objective 5: Use RES data to define the outline of Lake Ellsworth and its glaciological and topographic setting. RES data acquired in (1) will be processed to reveal the lake outline and topographic setting. This exercise follows from previous investigation of RES data across Lake Vostok, which has led to the establishment of a good understanding of the lake surface and its surroundings (Studinger et al., 2003). Such information is relatively easy to extract from the RES data given our considerable experience.

Objective 6: Extract internal layer surfaces from RES data. RES and GPR data acquired in (1) will be processed to extract englacial layering. The internal reflecting horizons are believed to be isochrons, and their englacial position is a function of accumulation rate and ice flow. Studies of internal layers allow former flow patterns to be identified and rates of subglacial melting and freezing to be calculated. MJS and HC have considerable experience in such work.

Objective 7: Use seismic data to define the lake’s bathymetry and the sediments across the lake floor. The spot-depth seismic data will map the lake bathymetry. The seismic reflection profiles will be interpreted to reveal any sedimentary structure and may also determine the sediment thickness.

Objective 8: Use GPS readings to determine the ice flow field across the lake. The GPS surveys (from the main field season and the resurvey) will determine the surface velocity and strain fields across the lake and to the ice divide. The processing is relatively simple, and will take no more than two weeks.

Objective 9: Use new data visualisation techniques to view RES and seismic data. Data from (5) (6) (7) and (8) will be interpreted and imaged using new 3-D dynamic data visualisation techniques. Jakobsson (project collaborator, see Letter of Support 2) has extensive experience of such techniques. This work will come at little cost to the proposal, and is a major ‘value added’ aspect.

Objective 10: Numerical modelling to quantify ice flow across the lake, heat transfer within the lake (including melt/freeze rates) and lake water circulation. Results from the other objectives will be used as inputs to three numerical models that will quantify the lake system. First, we will model ice flow over the lake using a model that utilises internal ice sheet layers to constrain the flow, to accurately determine ice flow processes and rates of surface ice accumulation and basal melting/freezing (e.g. Siegert et al. 2003). This modelling will help us to understand (a) source regions of the ice which melts into the lake; (b) rates of subglacial melting and freezing over the lake; and (c) the lake response to changes in ice sheet conditions. Second, we will undertake thermo-mechanical heat balance modelling of the lake, in order to investigate its geothermal setting (Siegert and Dowdeswell, 1996). We will also investigate how former ice configurations may have affected the lake’s size and extent. Third, we will model water circulation with code developed within an existing NERC project (NER/A/S/2000/01144).

### **Addressing the research questions**

The objectives detailed above will address the project’s science questions in the following ways:

i. What is the water depth of the lake? *The spot-depth seismic shots (Obj. 2), with limits defined by the first, coarse RES survey (Obj. 1), will reveal the water depths at each location. We will import the data to a GIS (Objs. 7 and 9) and, using interpolation procedures, define the lake’s bathymetry.*

- ii. What is the topographic setting of the lake? Using the RES (Obj. 1) and seismic data (Obj. 2) we will build a DEM of the lake surface (Obj. 5), its bed (Obj. 7) and the subglacial topography (Obj. 5) surrounding the lake, across the whole of the subglacial drainage basin (using the existing bed DEM as an initial guide to field planning). This will allow the topographic setting of the lake to be assessed at an unprecedented level. The whole lake system will be viewed in 3 dimensions (Obj. 9).
- iii. What is the sediment thickness across the lake floor? The seismic profile along the length of the lake (Obj. 2) will allow a detailed assessment of the subglacial lake floor morphology and any relatively shallow seismic structure (e.g. bedding) within the sediment. The rocks of the nearby parts of the Ellsworth Mountains are dominantly well-cemented quartzite. It is therefore possible that local erosion and deposition rates will be low and the lake sediment may be of limited thickness. Previous seismic work (undertaken by AS, JW and EK) has imaged unconsolidated sediments up to 200 m thick beneath 3000 m thick ice. Hence we do expect to be able to detect a reflection from the lake sediment-basement interface, which will allow an estimate of sediment thickness.
- iv. How old is the lake and what is the lake's history? The age of the lake cannot be determined explicitly by our project. However, we can provide an indication of the age of the ice directly above the lake, through a simple depth-age model, which will constrain the age of the lake water. Numerical modelling will assess the sensitivity of the lake in response to WAIS change. Numerical ice sheet modelling of WAIS is currently underway (as part of AJP's NERC CPOM project) and we will use the results to provide an assessment of the history of the lake (Obj. 10).
- v. How does the ice sheet flow over the lake? GPS measurements will determine the flow vectors and strain rates of the surface ice (Obj. 3). These data, plus internal layers detected by RES (Obj. 1) will be mapped (Obj. 6) and used as input to a numerical ice flow model (Obj. 10) to determine the 3-D flow of ice across the lake (using models developed in MJS and RH's NERC project NER/A/S/2001/01011).
- vi. What is the roughness of the bed around the lake? The roughness of the grounded ice sheet base is important to the ice flow. Moreover, the characteristics of the ice-water interface could give information about the rates of melting and freezing as it changes from a rough interface at the margin to a smooth one over the lake itself. Spatial spectral analysis of the RES data (Obj. 1) will be undertaken to quantify the bed roughness across the whole study region, as has been done in similar investigations in East Antarctica (Siegert et al., 2004b).
- vii. What are the rates of subglacial melting and freezing over the lake? When used as input to an ice flow model, the geometry of isochronous layers, obtained by RES, will indicate the spatial variation of surface accumulation and basal accretion and melting (as in Siegert et al., in press). When using the accumulation, velocity and strain data (Objs. 4 and 8) as input, the model will test whether the lake is in steady state.
- viii. Does the subglacial lake have detectable tides? Lake Vostok's tides are small (Dietrich et al., 2001) and since the lake near the Ellsworth Mountains is far smaller, we are not expecting a significant tidal signal from the lake. However, if present, tides would have a significant influence on water circulation processes. Data from GPS stations on the lake (Obj. 3) will be analysed to determine if tidal processes (or any periodic changes) affect the subglacial lake.
- ix. How is the lake water circulation configured? The subglacial lake bathymetry (Obj. 7), lake ceiling (Obj. 5), and calculations of melt/freeze rates (Obj. 10), will be used as boundary conditions to a computational fluid dynamics model (Obj. 10) in order to understand the water circulation within the lake (as has been done for Lake Vostok; Williams, 2001; Mayer et al., 2003).
- x. Where does the melt-water originate? Glacial ice that melts into the lake, originates from snow deposited upstream. To understand the geochemistry of the melt water, samples of snow and firn from the source region need to be collected and analysed. We will use the ice flow model (Obj. 10), which will match results to 3-D isochrons (Obj. 6) to determine the flow paths of ice and, thus, identify the source area of the meltwater. Such work will be critical to future geochemical investigation.
- xi. What is the geothermal setting of the lake? Using measurements of ice thickness (Objs. 1 and 5), surface accumulation rates (Obj. 4), and an ice flow model (Obj. 10) we will determine the likely geothermal flux that permits subglacial melting to take place across the site of the subglacial lake. As the lake is located close (~20 km) to an ice divide, a simple 1-D thermal model (Siegert and Dowdeswell, 1996) can be used. However, as we will be determining the 3-D flow of ice across the lake using a thermomechanical model (Obj. 10), we will also determine the geothermal flux from this more

sophisticated model. Comparison of results from the two models will bound the geothermal flux, and allow us to assess the influence of heat from ice flow processes on the melting rates.

**Timetable and assignment of responsibilities**

Table 1 shows the project’s timetable. We propose that this three-year project begins on 1 April 2006, allowing several months for field preparation and planning at BAS, and for Objectives 1 and 2 to take place within Year 1. Objectives 3 and 4 will be complete after a short ‘resurveying’ season in Year 2. This will leave most of Year 2 and all of Year 3 to undertake objectives 5-10.

We will require 2 field seasons. The first is a major field season, involving 4 members to work in the deep field for 2.5-3 months. The second field season is short (3 weeks), and is required to resurvey the GPS stations in order to measure ice-sheet strain rate and surface velocity. Such measurements cannot be completed in a single season due to the slow flow of ice. They are, however, critical to the determination of subglacial melting and freezing above Lake Ellsworth and the establishment of an appropriate site for future lake access. Once field data have been obtained and processed (end of Year 2), we will undertake a full programme of numerical modelling experiments similar to those made for Lake Vostok. We have all the necessary modelling tools and experience for such numerical investigation.

Objective	Year 1 (2006-7)												Year 2 (2007-8)												Year 3 (2008-9)											
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
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Table 1. Timetable for the completion of the project objectives.

**Year 1.** Objectives (1-4): Plan for fieldwork (AS, JW, EK, HC, MJS, PDRA), build RES equipment and develop RES software (BAS engineer), undertake analysis of preliminary data (PDRA, MJS, HC), and undertake fieldwork (JW, PDRA). Objectives (5) and (7): Begin data processing (JW, PDRA, MJS).

**Year 2.** Objectives (5) and (7): Continue data processing (JW, PDRA, MJS). Objectives (3) and (4): Plan and undertake resurvey (PDRA, MJS). Write up results of Objectives (5) and (7) (bathymetry, JW; lake surface and topographic setting, PDRA; lake floor sediments, JW, AS, EK; internal layers, PDRA, HC, MJS; snowpits etc., PDRA). Objective (8): Process results from Objectives (3, by PDRA) and (4, by BAS chemists) and supply all data to Martin Jakobsson (collaborator). Objectives (9) and (10): Begin 3-D visualisation of the lake system (Jakobsson), and initiate numerical modelling experiments (ice flow, RH; thermal modelling, TP; water circulation, MJS).

**Year 3.** Objectives (6) and (7): Complete analysis of RES and seismic data (JW, AS, EK, HC, MJS, PDRA). Objective (9). Complete 3-D visualisation of the lake system (MJ), write up survey results and complete analysis of subglacial lake (All). Objective 10: Continue, complete (RH, AJP, MJS) and write up (All co-Is and RRs) numerical modelling experiments.

**Request for resources**

*Personnel.* A 3-year PDRA is requested. Dr David Rippin has agreed to be named as our preferred candidate for the PDRA. Dr Rippin has experience of deep fieldwork in Antarctica (GR3/AFI2/65), and has several years experience in processing RES data. The PDRA will help plan the RES survey through examination of existing satellite and geophysical data and, after the fieldwork, will process the RES data. The PDRA will be based in Cambridge for the first 18 months of the project (overheads transfer will be made from Bristol to BAS through arrangement between the two institutions), and at Bristol for the second 18 months. A RES system capable of sounding through more than 3 km of ice is essential for

this project but no suitable equipment exists in the UK, or even for purchase internationally. Hence we request 12 months technical staff time at BAS to develop and build a RES system based on a proven University of Washington design (as successfully used by the US-ITASE expedition; Welch and Jacobel, 2003), and write software for post-fieldwork data processing. We have identified N. Frearson, who has considerable recent experience developing comparable airborne radars, as suitable for this post. Staff time of ½ month is requested for BAS chemists to process the shallow ice core, and 1 month of technical support is sought for Northumbria University to maintain the seismic processing facility.

*Computing.* Funds are sought for computer hardware. Desktop PCs are required for the PDRA and for the seismic processing system at Northumbria. Field laptops are required to run the seismic, RES and GPS acquisition systems and for basic on site data quality control. Funds for software to process RES and seismic data, and to enable the 3D dynamic visualisation of these data are also requested.

*RES.* Funds for the components and development costs for the bespoke RES system are requested. These have been based on recent BAS experience developing an airborne RES system.

*Seismic.* None of the collaborating institutes have a seismic recorder suitable for the project, nor does one appear to be available elsewhere within the UK community. Hence we request funds for a 24-channel recorder (Geometrics Geode, or equivalent) and an appropriate cable. BAS can supply geophones and the necessary testing, shooting and safety equipment. A small hot-water drill will be required to drill the shot holes. On completion of the project, the seismic recorder will be offered to the NERC Geophysical Equipment Facility (see Letter of Support 3, from the Steering Committee chair).

*Ice surface measurements.* A small number of items are required for the acquisition of ancillary surface measurements. These include a shallow ice core drill, a strain-rate sensor and 40 aluminium poles.

*Meetings.* Funds are requested for PIs and the PDRA to meet on a regular basis; to meet with the collaborator (Jakobsson); and to disseminate our work to the international community (including SALE members). The RES engineer will be required to make one visit to the USA for consultation on design and specifications. This is a complex project and we have specifically allowed for regular visits between the various institutes to ensure successful progress.

*Miscellaneous.* If successful, we are aware that BAS might request that we purchase and ship some items a year in advance, for operational- and cost-efficiency reasons. If so, we would expect to make an Advance Purchase request, so that hazardous and heavy items can be deployed to Rothera in advance.

### **Management of the project and dissemination of results.**

This is an ambitious project, which aims to accomplish a complete understanding of the boundary environment (and some internal processes) of a subglacial lake within 3 years. The project is achievable given the experience of the PI and co-Is, and their respective areas of expertise in RES, seismic survey, data analysis and numerical modelling. As the work involves multiple researchers it is essential that the project is managed effectively. This will be the responsibility of the PI, who will conduct formal meetings with the PDRA and co-Is (as required) on at least a monthly basis. This will ensure progression of the work according to the timetable provided in Table 1. Data will be archived at the collaborating institutes and made available to the wider community via the NERC Antarctic Environmental Data Centre.

It is the policy of our respective institutions to publish research in peer-reviewed international journals. We expect a number of publications in major journals as a result of our work. In recent years, there has been significant public interest in Antarctic subglacial lakes (e.g. Lake Vostok). Our proposal has already received a high level of UK media interest (e.g. Times Higher Education Supplement, 17 Sept 2004; BBC Radio 4 Material World, 21 Oct 2004; The Guardian, 21 Oct 2004; National Geographic, 1 November 2004). We expect this interest to increase as results become available, allowing the dissemination of our work to a wide audience. A WWW site is already constructed ([www.ggy.bris.ac.uk/ellsworth](http://www.ggy.bris.ac.uk/ellsworth)), allowing students at schools and colleges, and the media, to follow the plans and progress of our work.

### **Expected outcome of the project and future plans**

The outcome of this project will be the first detailed characterisation of a subglacial lake, and the completion of the first stage towards the full exploration of Lake Ellsworth. The next stage will be to measure and sample the lake water and sediment. A consortium from ten UK universities and research institutions has undertaken a series of meetings in the past year to plan the *in situ* exploration of Lake Ellsworth (for details see [www.ggy.bris.ac.uk/ellsworth](http://www.ggy.bris.ac.uk/ellsworth)). Funding discussions have been initiated with UK research councils and a 'cross-council' proposal is scheduled to be submitted in 2005.

## Relation to international activities: IPY and SALE

This proposal is relevant to two international research programmes that will take place around its lifetime.

1. The International Polar Year (IPY) is planned for 2007-8. Given that the geophysical survey of Lake Ellsworth is planned from 2006-7, it is possible that the exploration of the lake can take place within the lifetime of IPY. Such exploration is ideally suited to IPY theme #4 “To investigate the unknowns at the frontiers of science in the polar regions”. MJS will submit ‘The exploration of Lake Ellsworth’ as a project to the IPY ISCU-WMO joint committee on 14<sup>th</sup> January 2005.

2. The SCAR Subglacial Antarctic Lakes Environments (SALE) programme (which MJS is a member) will begin on 1<sup>st</sup> January 2005. “*The three scientific objectives of the SALE project will be to: (1) understand the origin of subglacial environments and their impact on the origins, evolution and maintenance of life beneath ice sheets; (2) determine the form, distribution, and functioning of biological, chemical and physical systems in subglacial environments including the sediments, the water, and the overlying ice; and (3) decipher climatic information and limnological history of the lakes through analysis of the sediment record. The scientific objectives will be addressed through a series of projects which form a comprehensive research program for the exploration of subglacial environments. Each research project will be defined by its own scientific objectives and requirements for logistics and technology*” (SALE, 2003). This proposal represents one such research project and is, thus, central to SALE’s plans. Importantly, in its submission to the IPY, SALE recommended that Lake Ellsworth, as a small subglacial lake, could be the first to be explored directly. SALE is essential to this proposal because it ensures that results will be disseminated directly to the international community via meetings and symposia. In addition, the *in situ* exploration of Lake Ellsworth, planned to follow the proposed work, will benefit hugely from the international multidisciplinary collaboration the SALE group offers.

## Relation to NERC strategy

Subglacial lakes are likely to contain microbes and sediments. Future analysis of this content is the driving force behind our proposal and is directly relevant to two of NERC’s priority areas: Earth’s life-support systems, and Climate Change. Several of NERC’s research questions within these priority areas are particularly pertinent to subglacial lakes. For example NERC asks “What previously unexplored sources of biodiversity can we find within the deep ocean, ice, soils, rocks and clouds?”. The exploration of life within subglacial lakes will certainly contribute to answering at least part of this question. Further, NERC enquires “What are the... consequences of climatic perturbations on the world’s ice sheets?”. The extraction of sediments from a West Antarctic subglacial lake could potentially provide a unique record of ice sheet stability, which would make a key contribution to this important question. This proposal is a first step towards the *in situ* measurement of Lake Ellsworth and the answers to two of NERC’s research questions. We are, thus, confident that the proposal relates well to NERC’s long-term strategy and plan.

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