

AFI7/02
Geophysical exploration of a West Antarctic subglacial lake

Principal Investigator: Professor Martin Siegert (University of Edinburgh)

Co-Investigators: Hugh Corr (British Antarctic Survey)
Dr Richard Hindmarsh (British Antarctic Survey)
Dr Ed King (British Antarctic Survey)
Professor Tony Payne (University of Bristol)
Dr Andy Smith (British Antarctic Survey)
Dr John Woodward (University of Northumbria)
Professor David Vaughan (British Antarctic Survey)

Field personnel: Dr Andy Smith (British Antarctic Survey)
Dr John Woodward (University of Northumbria)
Dr Neil Ross (University of Edinburgh)
Dr Dan Fitzgerald (Field Assistant – British Antarctic Survey)

Rationale

Antarctic subglacial lakes are one of the last places on Earth where new and unique microbial life forms may be discovered. The sedimentary layers beneath these water bodies may contain important records of past climate change and long-term ice sheet evolution. To establish whether life forms and palaeo-environmental records are present, direct sampling of lake water and the underlying sediments is necessary. Before such exploration can take place, however, it is important that full physical characterisation of target lakes and their topographic setting be undertaken. Geophysical methods such as radio-echo sounding (RES) and seismic reflection are key tools for making these observations, which are necessary for constraining numerical modelling of the physical processes that operate within subglacial lakes (melting, refreezing, water circulation)

Lake Ellsworth

Lake Ellsworth is a small subglacial lake (10 km long by 2.5 km wide), which lies approximately 70 km west of the Ellsworth Mountains in West Antarctica, at an elevation of approximately 1930 m. Existing radio-echo sounding data indicate that the lake lies in the bottom of a narrow, steep-sided, fjord-like subglacial valley, 3.2 km below the ice surface.

Aims of the project

During the Austral summer 2007/08 we undertook a full geophysical characterisation of Lake Ellsworth. The aims of this fieldwork were to:

1. determine water depth and bathymetry of the lake.
2. map the outline of the lake and the subglacial topography of its catchment.
3. produce a detailed map of ice flow over the lake
4. characterise the nature of the ice-water and water-bed interfaces
5. if possible, establish sediment thickness beneath the lake floor.

Fieldwork

Personnel and equipment was deployed at Lake Ellsworth (Figure 1) from mid-November to early February. During this period, the fieldteam:

- a) completed five seismic reflection lines across the width of Lake Ellsworth. Data from these lines, complemented by a gravity survey line across the centre of the lake, is

- being used to i) map the bathymetry of Lake Ellsworth; ii) investigate the possible thickness of any sediment body beneath the lake.
- b) acquired a grid of radio-echo-sounding survey lines over the lake and its surroundings using the ground-based DELORES radar system (Figure 2). The survey was designed to define: i) the outline of Lake Ellsworth and its glaciological and topographic setting; ii) the geometry of internal layering within the overlying ice.
 - c) deployed a network of 58 aluminium poles on the ice surface above the lake. GPS surveys of these stakes during the 08/09 fieldseason will be used to produce a detailed map of the rate and direction of ice flow over the lake.
 - d) collected up to 73 days worth of continuous GPS data from four fixed stations. These data will be used: i) as base-station data to correct other GPS measurements; ii) to establish whether Lake Ellsworth has detectable tides.
 - e) drilled three shallow (20 m) ice cores near to the Lake Ellsworth camp. On-site density measurements were made on one core, whilst the remaining two were shipped back to the UK for oxygen isotope analysis (to establish surface accumulation rates) and chemical analysis.
 - f) resurveyed, using GPS, a series of stakes installed around Lake Ellsworth by Chilean scientists in January 2006. These measurements will be used to complement ice flow measurements derived from the stake network.

Data from these surveys will be used as baseline data for numerical models of ice flow, heat transfer (melt/freeze rates) and water circulation within Lake Ellsworth. 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.

Preliminary results

Preliminary results based on the initial analysis of the field data reveal the following:

Seismic reflection:

- The lakebed is visible within each of the five seismic reflection profiles (see example, Figure 3).
- Using the lakebed reflectors it has been possible to establish the depth of Lake Ellsworth (> 100 m in places) and approximate the volume of water within it (~2 km³).
- The strong, uninterrupted reflection generated from the lake surface suggests a 'clean' ice-water interface with no evidence for accreted ice.
- The morphology of the lake floor is suggestive of the presence of sediments, but estimates of sediment thickness have not yet been possible using the processing strategies currently applied to the dataset.

Radio-echo-sounding (RES):

- The ice-water interface is clearly imaged as a bright, smooth, gently sloping reflector within the RES data (Figure 4).
- The RES data demonstrates considerable variation in subglacial relief (in the order of 1500-2000 m) in the Lake Ellsworth catchment, with the lake located within a deep, narrow, fjord-like subglacial trough (Figure 4).
- Strong internal reflecting horizons are clearly identifiable throughout the RES dataset to depths of 2000 m, although deep internal reflections are not apparent within the 1000 m of ice above the lake surface.
- Localised buckling of internal reflecting horizons is apparent over the lake, which may be indicative of i) variations in surface accumulation rates; ii) palaeo-iceflow regimes. These internal reflecting horizons will be used for modelling iceflow and rates of basal melting over the lake.

Global positioning systems (GPS):

- Processing of the GPS data is currently ongoing.



Figure 1: Lake Ellsworth field camp during the 2007-08 season, with the Ellsworth Mountains in the background.

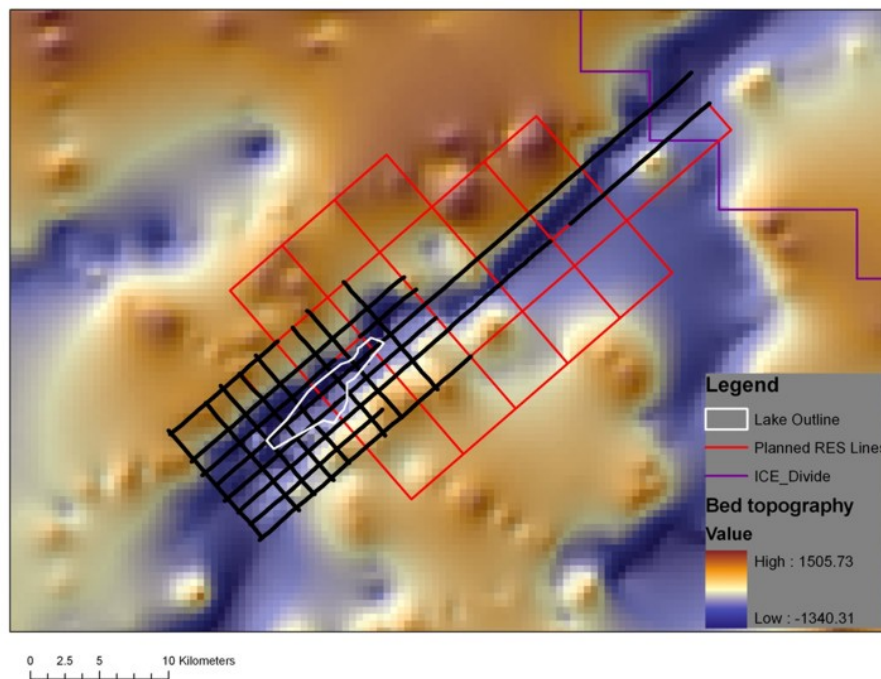


Figure 2: Map of the radio-echo sounding survey lines acquired during the 2007/08 season (acquired lines shown in black), overlaid on the subglacial topography.

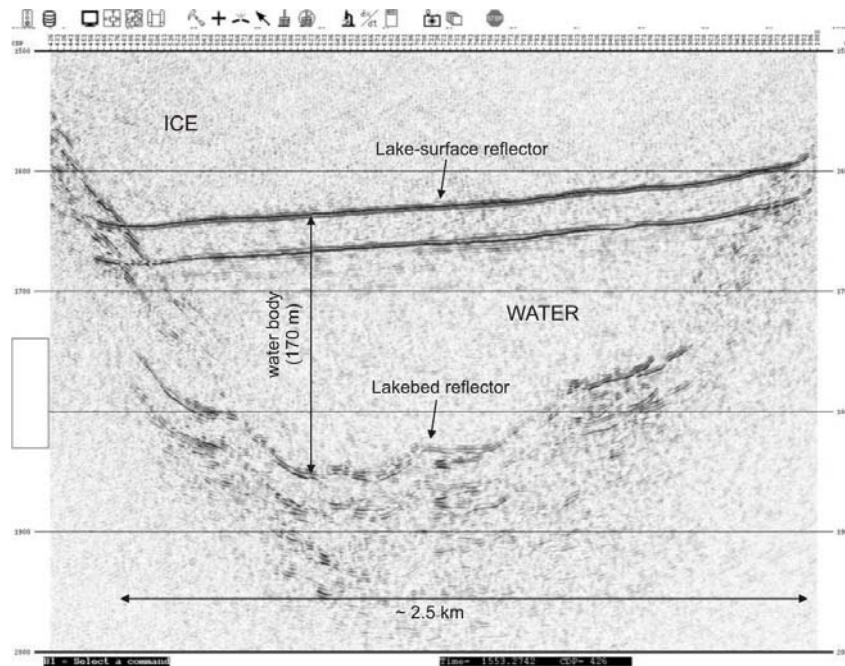


Figure 3: Seismic reflection profile across Lake Ellsworth. A significant part of the profile from the ice surface to just above the lake surface has been cropped, and the vertical scale exaggerated ($\sim \times 10$), to aid visualisation of the lake.

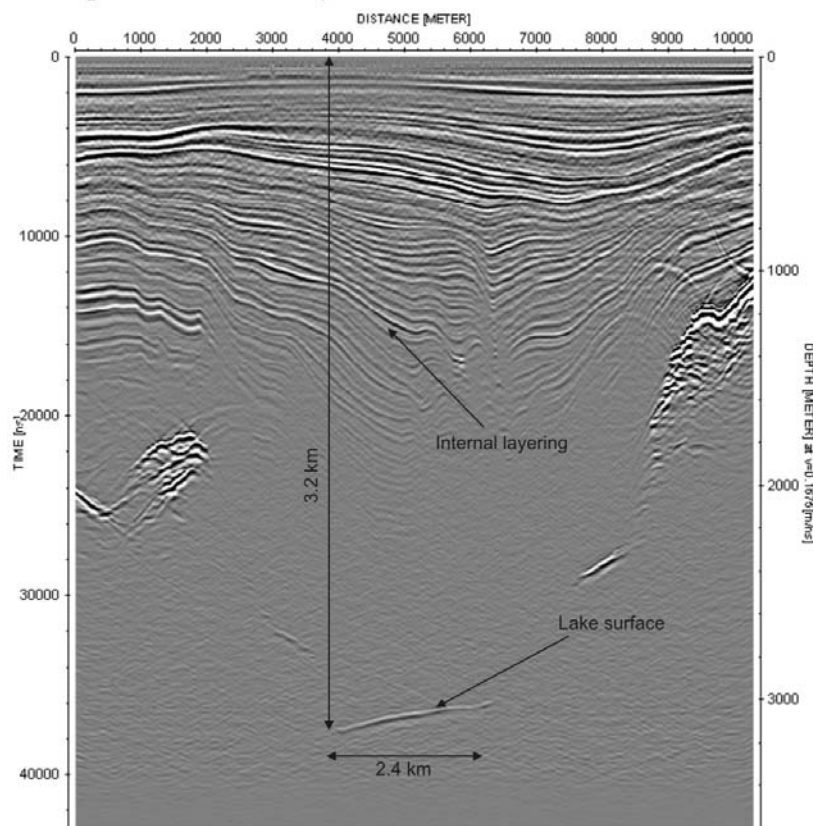


Figure 4: Example of DELORES radio-echo-sounding data from across Lake Ellsworth. Note significant vertical exaggeration.