Cruise Report
Nathaniel B. Palmer Cruise 0505
Chilean Inland Passage
June 23-July 14, 2005

NBP0505 Science Party

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Cruise Objectives

The objective of NBP0505 was to conduct marine geological surveys in three different fjords within the Chilean Inland Passage to determine rates of continental denudation within a broad latitudinal transect, extending from the Antarctic Peninsula to the limits of the ancestral Patagonian Ice Cap (Figure 1). A second objective is to examine the paleoclimate record using sediment cores so that continental denudation can be related to climate change. A third and final objective is to examine the paleoceanography of the region.

This is a multidisciplinary effort and post-cruise research will be carried out at three different institutions, Rice University, the University of Washington, and the University of Concepción. Rice University has responsibility for acquiring and interpreting multibeam, seismic and core data that can be used to calculate sediment flux over millennial time scales and relating sediment flux to the paleoclimatic record. The University of Washington group is focusing on the short-term (decadal) sediment flux and associated glaciological conditions. Most of their research takes place on land and was conducted during a separate field season. It is well known that the climate of southern Chile is regulated by oceanographic circulation. Dr. Carina Lange and her colleagues at the University of Concepción will focus on the paleoceanographic record and Dr. Mauricio Rondanelli Reyes, also at the University of Concepción , will analyze fossil pollen and spores for the record of climate change. This collaboration thus provides a multidisciplinary analysis of the feedbacks between ocean circulation, climate and glacial denudation of the continent. This was the first of two cruises. The second cruise to the Antarctic Peninsula region will take place in 2006.

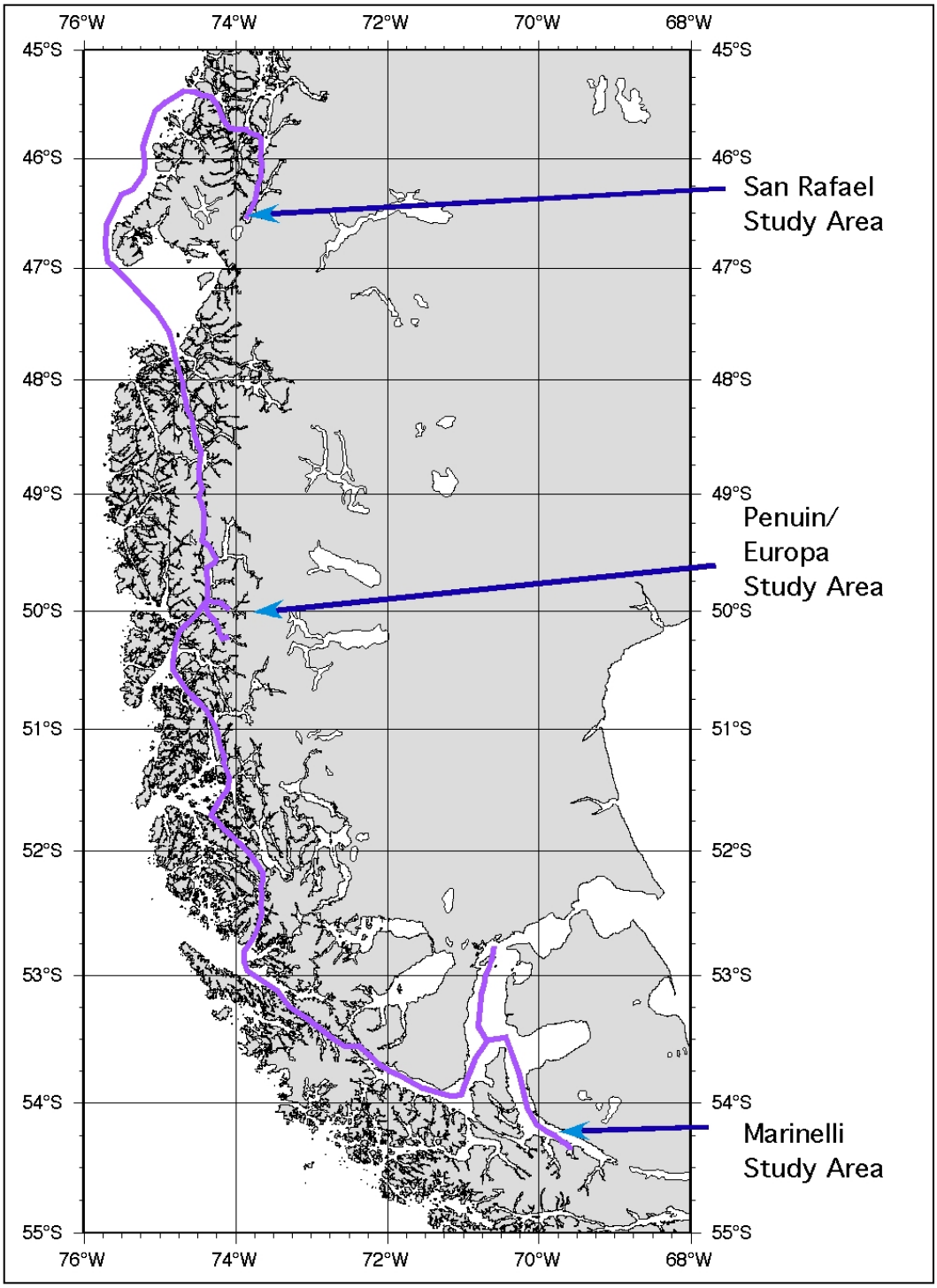

Figure 1. Location of study areas.

Preliminary Results

San Rafael Study Area

The first study was the San Rafael area, which is the northern most study area (Figure 1). The fjord consists of several small minibasins (Figure 2). A narrow and shallow pass that the *Palmer* could cross only during daylight hours connects the outer fjords and middle basin.

A total of 26 cores were attempted and twelve kasten cores and five jumbo piston cores were obtained (Figure 2). Of the nine failed core attempts, eight are attributed to a hard sandy bottom. Seismic data was collected from the *Palmer* using a fifty cubic inch air gun and then two fifteen cubic inch water guns for a higher resolution survey. Each of these surveys shows laminated sediment packages onlapping onto steep-sided bedrock walls. The final data collected at San Rafael was a short side-scan sonar survey. Despite a rocky start, the images from the side-scan system are of high quality and show what are most likely sand waves formed by strong tidal currents. No subglacial bedforms were imaged.

A six-mile long river that was accessible only by small vessels connects the middle basin and the inner basin. Small boat operations were cancelled on the first day due to extremely high winds but were resumed on the second and fourth days. A landing craft was used to acquire CTD casts along the glacier front and a zodiac was used to deploy personnel to retrieve data from a rain gauge set earlier in the year. Limited time and accessibility prevented us from deploying sediment traps near the glacier terminus.

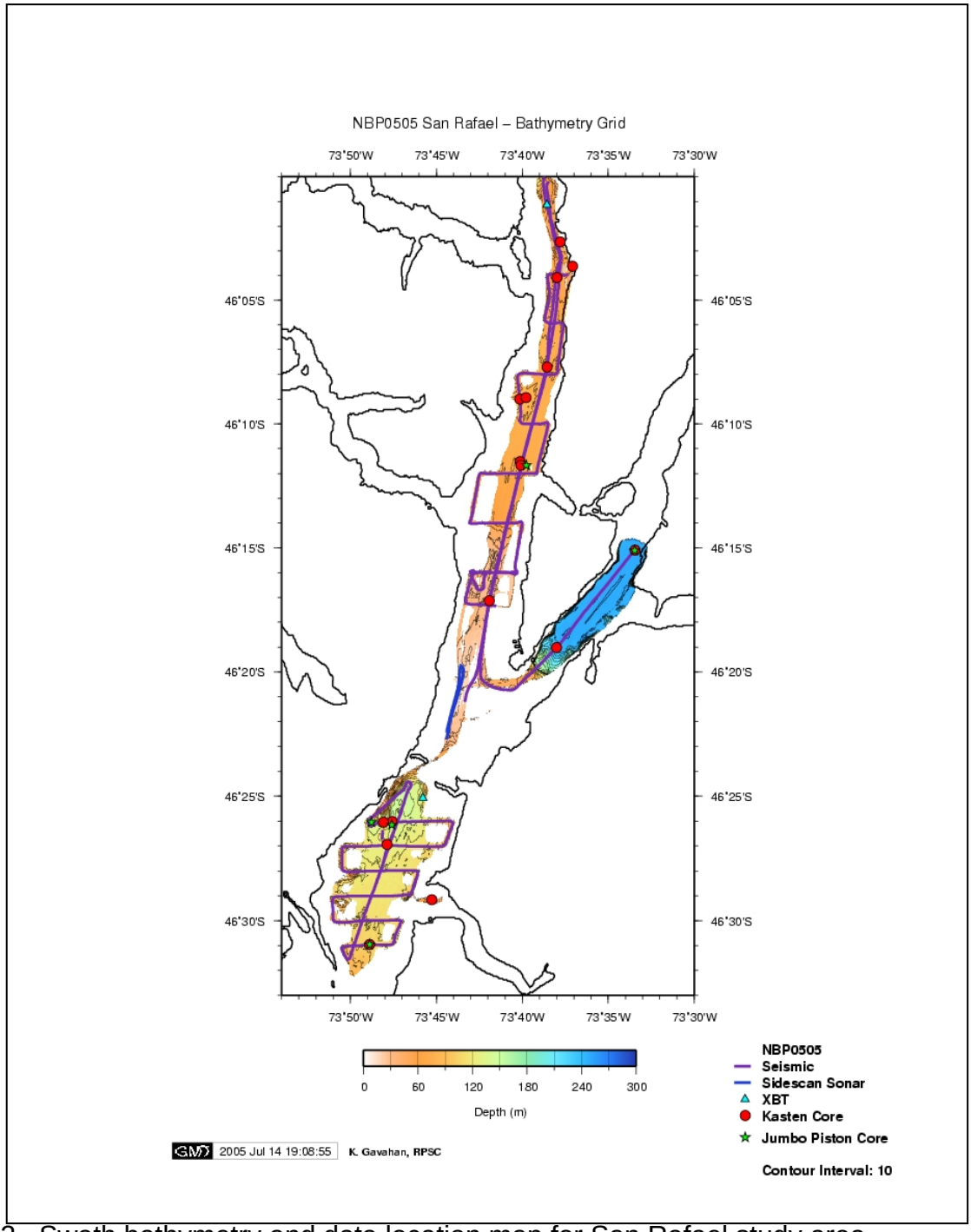

Figure 2. Swath bathymetry and data location map for San Rafael study area.

The *Palmer's* workboat, the *Cajun Cruncher*, was used for the first time in science operations to collect seismic data (Figure 3). A boomer system was used to measure sediment thickness at the glacier terminus in San Rafael Laguna. The data are of high quality and, although of limited extent, promise to

be very useful in mapping the most recent deposits. Unfortunately, the workboat became stuck in shallow water on the way back out of the river and the boat's rudder was damaged. Although it was successfully repaired, it was not available for the final day at San Rafael.

Figure 3. The Cajun Cruncher collecting seismic data in the upper lagoon with San Rafael Glacier in the background.

Surface sediments in the San Rafael area can be divided into two basic types, clean sand or gravelly lags in shallow areas and sandy or silty mud in the basins. Jumbo piston cores sampled the same basic units. Many of the cores contain abundant bioturbation, fossils, and dispersed organic material. Diatoms were observed in smear slide analysis from all cores. Assemblages consist of a mixture of marine, brackish, and freshwater species. Samples were taken for 210Pb, 14C, foram, diatom, protein, isotope, and opal analyses.

Penguin and Europa Fjords

During week 2 of the cruise, we completed our study of the Penguin and Europa fjords. This study area is around 50° S latitude and is the middle location in the transect (Figure 1). As we had feared, there was ice cover of much of the inner portion of each of these narrow fjords. Europa was somewhat less ice-choked and thus we concentrated our survey there. Neither fjord had enough open water for small boat operations.

Multibeam swath bathymetry data of the two fjords show several distinct minibasins, similar to what was observed in San Rafael (Figure 4). Unlike San Rafael, these minibasins show a distinct pattern of stepping down from the glacier front, so that each basin is deeper than the one inland from it. Overall, the multibeam bathymetry data does not show any erosional fabric. However,

further processing of the amplitude and side-scan data from the multibeam system highlights a fjord-parallel fabric that we attribute to glacial erosion.

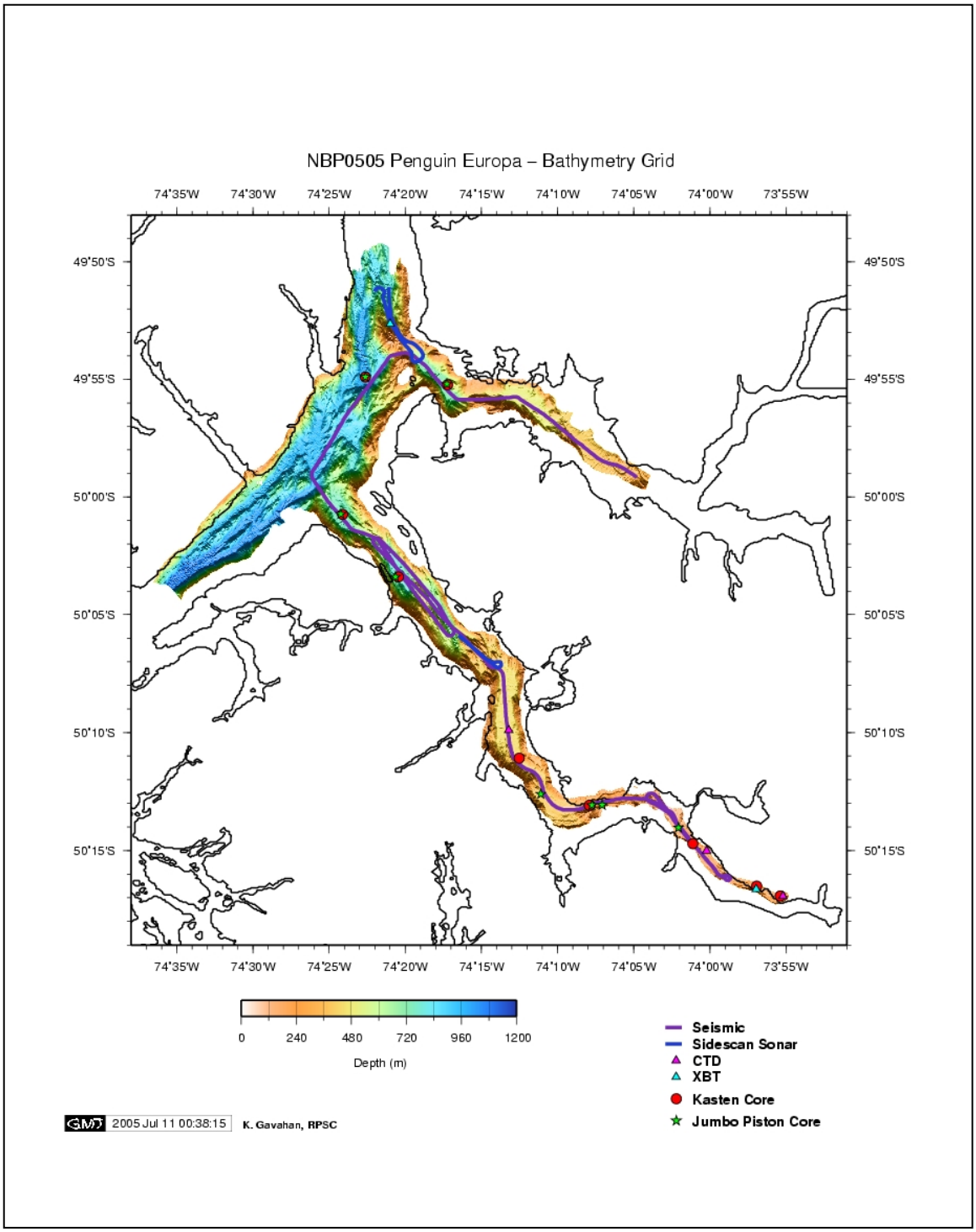

Figure 4. Swath bathymetry and data location map for Europa Fjord.

We made a total of 20 attempts at coring in this area. Of 12 kasten cores collected, one was discarded due to over-penetration and the other 11 were described, sampled, and archived on board. Eight jumbo piston cores were collected and nearly all of them were full. Five of these were cut on board but three were left uncut. The sediments consisted primarily of either silty/sandy mud or mud. Cores from the ice front sampled mud with very high water content, indicating high sedimentation rates at the ice front. Smear slides were made from samples from each core and diatoms were observed in all slides; assemblages are composed by marine, brackish, and some freshwater species. Coccoliths, silicoflagellates, and foraminifera were also observed in cores from three sites. Decreasing biogenic material was observed with increasing proximity to the ice front.

Seismic data were collected using a 50 cubic inch air gun. This larger seismic source was needed due to the deeper water in Europa and Penguin fjords. The seismic survey shows very thick, laminated sediments in each of the basins; the sediment is somewhat thicker in Penguin fjord.

We completed two side-scan sonar surveys. Both surveys were accomplished despite the difficult towing conditions (irregular bottom, sea ice, narrow fjords that don't leave much room for turns). The two surveys show similar results of what appear to be bedrock knobs sticking out of an otherwise very smooth bottom. No other distinct geomorphic features were observed.

Lastly, we conducted a series of CTDs casts intended to help constrain meltwater input into the fjord. Unfortunately, the sea ice prevented us from collecting these data as close to the glacier terminus as we would have liked.

Marinelli Study Area

Marinelli Glacier is located in the southern part of the study area on the island of Tierra del Fuego and drains into Bahia Ainsworth (Figure 1). The glacier has retreated significantly since the mid 1960s to expose an inner lagoon that is separated from the main fjord by a prominent set of recessional moraines (Figure 5).

The *Palmer* was unable to cross the shoal formed by the moraines, so small boats were used to carry out seismic data acquisition, CTD
casts and to deploy sediment traps.

Data collected includes water gun seismic lines from the *Palmer*, boomer and sparker seismic lines collected from the *Cajun Cruncher*, three side-scan sonar surveys, over 30 cores, sediment traps and CTDs from the glacier front, full multibeam coverage of the area, and a dense grid of 3.5 kHz data.

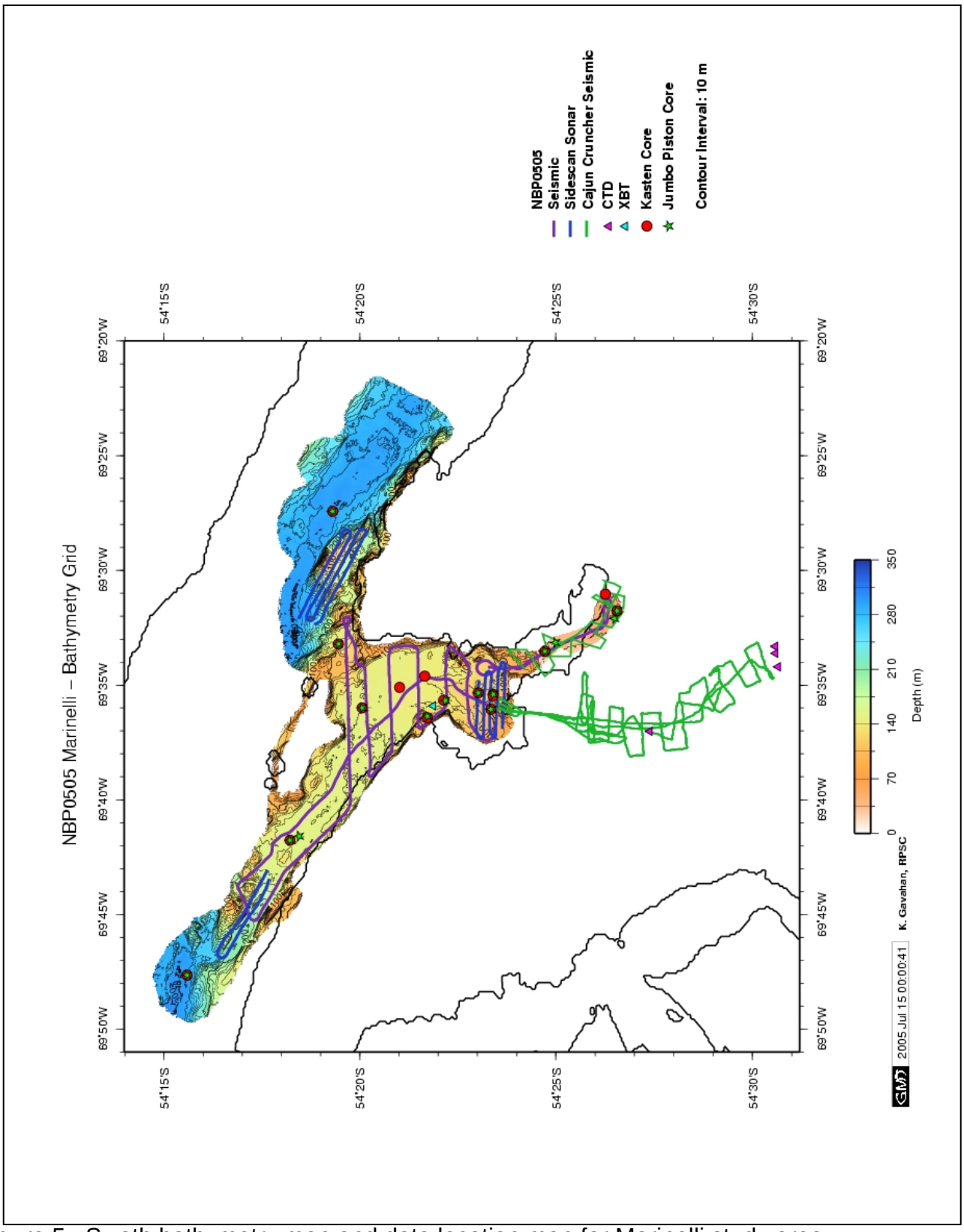

Figure 5. Swath bathymetry map and data location map for Marinelli study area

Unlike the other two study areas, the Marinelli study areas consists of a single basin that is closed at its seaward end (Figure 5). Prominent linear features, most notably drumlins, mark the flow directions of the ice cap as it flowed out of the fjord and into the straits. The seismic data from Bahia Ainsowrth show a thick sediment package, which implies high rates of sedimentation. This is supported by observations from sediment cores within the basin that sampled massive silts with high water content at the surface and dewatering structures down-core. Living starfish were found as deep as 20 cm in core. 210Pb and 14C dating will allow us to constrain the sedimentation rate. Overall, the sediments are much sandier than those of the other two study areas and diatoms are scarce. The side-scan sonar, although working perfectly, generally revealed a very smooth sea floor. This is another sign that the sedimentation rate must be quite high. The lack of small-scale geomorphic features formed by glacial erosion, even within drumlin fields, is in part due to the thickness of sediment but is also interpreted as indicating that during the expansion of the ice sheet in this area, the ice was still too warm-based to form grooves in the bedrock. We used our last afternoon of the cruise to go ashore on the 1960s moraine to collect samples and hold a short course on glacial processes (Figure 6).

Figure 6. Science party field trip to terminal moraine

Cruise Accomplishments

During a prior cruise to the Chilean Inland Passage in 1993, we were not able to acquire sufficient data to map the basins, thus sediment volume calculations could not be made. Furthermore, smaller diameter sediment cores collected during the 1993 cruise yielded very little carbonate and organic material for radiocarbon dating. During the NBP0505 cruise we were able to map the basins and their sediment fill. All three-study areas proved to be relatively closed sedimentary basins, which means that we will be able to make reasonable volume calculations. High quality seismic data with a range of stratigraphic resolution will enable volume calculations over different time intervals.

The abundance of calcareous and plant material will enable us to obtain a robust radiocarbon stratigraphy for each study area so that sediment volumes can be converted to sediment flux rates. Furthermore, the sediment cores contain rich fossil remains, ranging from marine to terrestrial, and sampled a wide range of sediment types. This means that we should be able to extract a good paleoclimatic and paleoceanographic record from the cores. So, we are all very excited about the chances for achieving our cruise objectives. All of the scientists agreed that this had been a very successful and enjoyable cruise.

We would like to thank all of the ECO and RPSC personnel who have put in so much effort to keep science operations happening on multiple platforms. As in the past, they did their jobs with skill and without complaint. Their efforts have made this cruise a success and it was a pleasure to work with each of them.

Future Needs

Given the number of individual investigators requiring samples material, and the need to examine cores on the spot to look for datable material, cores were split, photographed, described and sampled onboard. This proved to be hard work, but it paid off time and time again considering the opportunity for the scientists to communicate and reflect as a group (Figure 7). However, the Palmer has no suitable core splitting capability and we had to cut core with a skill saw. A better core splitting capability is needed before our next cruise. Also, it would have been great to have a digital logging system onboard so that cores could be logged and photographed as soon as they were collected. This would also be a great asset for the SHALDRIL cruise. The seismic data acquisition system on Palmer is not suitable for high-resolution work. The minimum firing time is 5 seconds and should be capable of digitizing data at ½ second. Finally, the hull-mounted Bathy sub-bottom imaging system does not record digital data in a usable format. As a result, these data can not be analyzed using seismic interpretation software. The Knudsen system does record digital data but does not provide as good resolution as the Bathy system. It would be good to upgrade the Bathy system so that it will acquire digital data in a useful format.

Figure 7. Group discussion over kasten core