January 30, 2003

End of Cruise report NBP 03-01

Operational overview

- Science party transferred to ship at ice edge in McMurdo Sound January 4
  - Multibeam survey of MacKay Sea Valley while balancing MCS streamer January 6
  - Pick up J. Ardai and cargo at ice edge January 7
  - Head for C-19 site at Cape Crozier January 7
- Survey south part of C-19 site January 8, 9, 10
- Head east to Eastern Basin Jan 10 - turn back west to C-19 site January 11
- Survey grid at C-19 site January 11 to January 15
- Profile east across South Central High and Central Trough within B-15 site January 15 to 17
- Push through sea ice in part through B-15 site to eastern Ross Sea January 17 and 18
- Deploy east of Roosevelt Island in eastern Ross Sea January 18; head northeast along ice shelf through B-9 site.
- Geophysical profiling in far eastern Ross Sea off Edward VII Peninsula and Cape Colbeck in B-9 calving site January 19 to 21
- Profiling south to Bay of Whales January 22, head north to tie to existing NBP 96-01 lines, westward progress blocked by ice after tie-in to PD-90 seismic line. Reached farthest south at 78 35.55.
- January 22 and 23 head north along 166 W to begin transit to western Ross Sea B-15 site. Stopped in ice and fog January 23
- January 24 transit north of ice pack along 76-45 S then follow pack edge south to an area north of Ross Ice Shelf front at 77-30S, 176 E.
- January 25 to 27 geophysical profiling in C-19 site over Coulman High and Victoria Land Basin
- January 27 to 29 Deep tow side scan and chirp, plus coring, C-19 area
- January 29 to 30 transit to McMurdo Station

Data obtained:

1. 5246 kms of underway geophysical data including multibeam sonar and gravity along with 3053 kms of magnetic field data.
2. Multi channel Seismic reflection: 2253 kms
3. Single channel seismic reflection: 2500 kms approximately
4. Deep tow side scan and chirp: Five lowerings covering 4 kilometers each at C-19 calving site
5. Cores: Kasten: Five cores taken and logged

Systems performance

Navigation: No problems encountered.

Echo Sounding: The multibeam system functioned well except when pushing through ice. It acquired data over a 130-degree swath. Backscatter data was of moderate quality. Bathy 2000 functioned well but lacked detail.

Gravity: We obtained gravity data but it had noise of about 5 milligals amplitude. A filter was added to remove this, but the cause is still unknown and needs further investigation.

Magnetics: The Cesium magnetometer was deployed over the C-19 site and towed on most profiles. It acquired excellent data and functioned without problems.

Seismics: Multichannel seismic acquisition was carried out in three modes, depending on structure, ice and weather. During the first phase, JD 008 – 014, an array of five GI guns configured in 105/105 in^3 mode was deployed. The original plan had been to deploy six GI guns, but manufacturing problems with the new array umbilical left only enough intact conductor pairs (three pair required for each GI gun) for five. An unforeseen problem with the software for synchronizing the GI shooting with the Syntron GCS90 airgun controller meant that we could only fire four GI guns at a time. The fifth gun was nevertheless deployed as an in-water (or "wet") spare. This was a good choice, as by the end of shooting two of the guns had failed and we finished this phase with three GI guns firing.

As we were about to enter the deeper basins of the W. Ross Sea, the GI gun array was recovered, and the umbilical rigged for a tuned array of six Bolt 1500C Long life airguns, ranging in volume from 80 in^3 to 850 in^3 The tuning for this array seemed to be quite good, matching the modeling upon which the choice of sizes was based. This array was used from January 15 – 18, when ice conditions and bad weather dictated its recovery. From January 019 – 021, MCS and SCS were acquired simultaneously with a source consisting of a single GI airgun in 105/105 in^3 mode. This effort ceased when it became necessary to break ice during the transit from the east back to the west.

The final phase of MCS acquisition, from JD 025 – 026 saw the redeployment of the six-Bolt airgun array, acquisition ending to leave time for deep towed chirp and sidescan sonar, and sediment coring.

Days	Source	Rep. Rate	Shots recorded	kilometers
008 – 014	4 or 3 105 GI	10 sec	40,650	1,016
015 – 018	6 Bolt 1500C	15 sec	12,305	461
019 - 021	1 105 GI	10 sec	17,365	434
025 – 026	6 Bolt 1500C	15 sec	9,125	342
16 days			79,445	2253

All MCS acquisition was carried out with the S/N 48-channel analog streamer which was the subject of test and acceptance cruises in March and October, 2002. Due to non-delivery of a replacement tow leader, the streamer was towed from the shipboard end of its first active section, resulting in the loss of four useful channels. Nonetheless, the towing characteristics and data quality from the streamer were quite good.

Digitization was handled by the OYO DAS-1, which recorded 3490 tapes and exported shot gathers to the ship's network in real time via the new Triton Elics system. Once a number of bugs were eliminated from this pair of systems, performance was excellent, although this high level of performance was not achieved until the second half of the leg. A total of 135 3490 tapes were recorded in SEG-D 8048 [32-bit IBM Floating point) format.

Single channel seismic (SCS) data acquisition was conducted by alternately firing between the MCS shots using the gun delay timing unit obtained by Raytheon for this cruise. This unit worked extremely well in synchronizing the timing of the firing of the two systems. Three sources were used for SCS data acquisition. Sources varied between a single 25/25 cu. in. GI gun [SCS source], two 15 cubic inch water guns and a single 105/105 cu. in. GI gun. The latter was deployed for SCS work during intervals when only a single source could be towed (such as locations with high concentrations of sea ice). Analyses were conducted comparing the strength and frequency spectra of the pair of water guns and the single 25/25 GI gun to determine which would be used as the primary single channel seismic source. We found that the frequency content of data from the water guns ranged from 1.5 to 2 times as high as that from the GI gun, but the signal level was only about 0.5 the amplitude.

We determined that if we combined the data from the Bathy 2000 hull-mounted chirp sonar with the MCS data in a "nested" mode that we could do without the higher frequency of the water guns. We selected the 25/25 GI gun as the acoustic source we used for most of the single channel work. This effected a compromise where we obtained both data penetration and resolution overlap allowing us to make correlations between data sets and identify potential outcrop locations.

Two multi-element single channel streamers were used during the survey. UNC provided an orange S/N Technologies 28 element single channel streamer. It was thought to be more sensitive than the NSF ITI multi-element single channel streamer on board. Comparison of streamers was conducted to determine which streamer provided the highest data quality and which would be the back-up and bad sea ice environment streamer. Quantitative analyses of data using same sound source on the SPW software revealed that the signal to noise ratio and dynamic range was higher on UNC S/N Technologies 28 element single channel streamer than for the NSF ITI multi-element single channel streamer. Consequently the S/NT streamer was deployed as the primary single channel streamer for the survey.

Ice and Weather

Extensive sea ice cover governed our operations. Generally open water offshore eastern Ross Island at C-19 and Edward VII Peninsula at B-9 allowed us to complete a good geophysical profiling program in these locations. Gale winds during part of the eastern survey affected the quality of the seismic data there. The entire B-15 site remained ice filled for the period of our survey and only began to clear at the end of January – and then in the far-east. Persistent cloud cover meant that no visual imagery was useful and that microwave low-resolution images were the only option to guide our operations. RPSC technicians worked hard to get us the best possible ice imagery (85 MHz and NASA interpretation).

Science Results

Calving site C-19

Three sites where recent calving of giant bergs occurred were surveyed. These include the C-19 site that calved in 2001 located east of Ross Island, The B-15 site calved in 200 located in the Eastern Basin, and the B-9 site calved in 1987 northeast of the Bay

of Whales in the far eastern Ross Sea. The overall project goals were twofold: to survey new ground exposed by these calvings in preparation for drilling into the exposed sea bed from the ice shelf; and, to survey the seafloor at these sites to compare open ocean and sub ice shelf processes.

The C-19 site was the most extensively surveyed. It covers the eastern flank of the Victoria Land Basin and the Coulman High. We completed a grid of multibeam geophysical profiles at a spacing of about two kilometers covering about 6000 sq. km. We ran profiles north to tie to existing seismic lines. In addition we completed five lowerings of the SIS 1000 deep-tow side scan and chirp sub-bottom sonar system and obtained five Kasten cores at the tow sites. Our mapping revealed older glacial marine units at the sea floor above what we interpret as the RSU6 unconformity. Pre-glacial unit RSS-1 lies below RSU6. The eastern flank of the Victoria Land basin is unmistakably faulted (normal), extending to the sea floor in places, indicating a very young age of activity here.

Multibeam mosaic mapping revealed a generally undulating sea floor that is grooved with several meters of relief. Deep side scan tows were made both in open water and at sites recently covered by C-19. These revealed both scalloped and furrowed sea floor as well as sites with grooves that are partially buried. One site was completely smooth and undisturbed. Initial comparisons of the deep-tow and multi-beam data suggest that the multi-beam produces an aliased version of the sub-glacially generated sea floor topography. The sea floor patterns do not bear any obvious relation to the former ice shelf cover. Kasten cores at the tow sites yielded stiff gray clay overlain by green diatomaceous (?) mud. Cores also contained glacially derived pebbles of volcanic, plutonic, and metamorphic origin. Again, the core samples do not bear a strong correlation to the former ice shelf cover. More subtle relations need to be investigated in the laboratory.

Our survey of the new ground exposed by the calving of C-19 provides numerous targets for drilling from the Ross Ice Shelf once it moves north and covers this area once again.

Central Trough and Eastern Basin profiles, calving site B-15

We completed a MCS airgun and SCS profile eastward across the Central Trough, Central High and west Eastern Basin into the B-15 site. MCS data show the basin fill of the Central Trough exhibits unconformities deep into the section. These may be RSU6 and RSU7. Examination of the profiles we have collected indicates that strata from units RS-5 (Middle Miocene), RS-4 (Early Miocene), RS-3 (Early Miocene), and RS-2 (Early Miocene to Late Oligocene) sub-crop in this area and may be accessible with piston coring. Within the Eastern Basin keystone faulting in basin fill was found over basement highs extending up to the highest unconformity seen on MCS data. These faults could be either tectonic or due to differential compaction. If tectonic they indicate activity in Late Tertiary time, younger than previously recognized. At the western inside corner of the B-15 site we observed a crevassed region into the Ross Ice Shelf that is on the order of 100 meters wide that apparently extends westward. This crack can also be seen in satellite imagery.

We were able to complete these profiles over the western B-15 site one kilometer north of the new ice shelf front. Our plan was to add more profiles at the site when we

returned to the west. Our objective is to better image the spatial variability of glacial seismic and lithofacies associated with waxing and waning of the West Antarctic Ice Sheet, to assess the timing of the onset of sub-glacial deposition in this area, and to identify potential drill sites. However, the sea ice advanced toward the ice shelf closing the gap of open water needed for surveying. This area remained closed for the rest of the cruise, and later more sea ice advanced west to cover the area over the Central Trough and the C-19 area that we planned to survey.

Calving site B-9

Geophysical profiling in the eastern Ross Sea was conducted over a site formerly occupied by giant iceberg B-9 that calved off in 1987. Basement crops out in the far south near Roosevelt Island and the Bay of Whales. Magnetic anomalies of several hundred nanotesla were profiled over basement that appear to be related to discrete sources. Deeper stratigraphic layers reach upward to the sea floor at the borders of the basement outcrops. Off the basement high these dipping layers are deeper and uncomfortably capped by flat lying units. The deeper layers are possibly the Early Tertiary – Cretaceous RSS1. Near the basement high they are within easy reach of modern ship-based or ice shelf-based drilling systems. Profiling to the north we tied the upper seismic units to those on PD 90 line 22.

On our profile into the Bay of Whales we reached farthest south of 78° 35.55’ S, 163° 23.32’ W.

Tie to NBP 96-01

To the north of the B-9 site we acquired profiles that tie to lines NBP 96-01 11, 25, and 26. These lines and our tie lines cross a raised plateau on the shelf that we postulate could be related to a Neogene marine transgression. Our new lines extend the mapped boundaries of the plateau.

Other studies

MacKay Sea Valley, western Ross Sea

We added multibeam coverage to that we obtained off Cape Roberts on NBP 96-01 and to the seismic survey that Bartek and S. Henrys conducted over the site in 1994. The objective of the mapping was to examine the morphology of the subglacial delta that is active during major ice sheet expansions. We observed the extension of the erosional trough of the Mackay sea valley and the beginning of the transition to a more depositional lobate morphology. The new mapping also located a moraine in the eastern valley.

Map of Ross Ice Shelf front

During our surveys and transit from the west to east we took regular radar range and bearings to the new edge of the Ross Ice Shelf front and computed its outline from this. Later we will compare this outline with satellite observations to check registry and future ice shelf northward movement.

Iceberg scours and Mud volcanoes

Along 166° E and westward along 76° 45’ S numerous iceberg sea floor scours were revealed in high detail. The scours are found in 500 meters or more of water and show several generations and directions. Direction changes are often sharp; in one instance over 90 degrees. At two locations along the 166° E track sea floor craters were mapped. They are a few hundred meters in diameter and tens of meters high. These we interpret as mud volcanoes from past fluid discharges.

Marine Mammals

These were observed and logged continually during the cruise. A report is attached as an Appendix.

Recommendations and suggestions

Ice imagery

Considering the extreme ice conditions this season we found ourselves at a disadvantage in planning to deal with this. Consistent cloud cover rendered satellite visual coverage not useful. Microwave coverage lacks resolution for track planning (15 x 15 km pixels) and is contaminated by weather systems containing ice.

Radarsat coverage is essential to plan future expedition in the Ross Sea especially the eastern part. Satellite radar penetrates clouds and weather and resolves floes on a kilometer scale or less. The U.S. Coast Guard had intermittent access to this. The USAP needs to investigate ready access in real-time to this system on its ships.

MCS Streamer Lead

The lead-in for the MCS streamer is of uncertain integrity. This required towing it with the first group wound on the reel and shortened the maximum offset. The lead-in needs to be reconstructed so it can be used with confidence.

MCS Gun Umbilical

The umbilical for the large high volume multi-gun array was delivered to Raytheon in substandard condition from the manufacturer. Due to tight time constraints, Raytheon elected to make repairs to the umbilical to get to nearly full function capability. When we started the cruise it had enough air electric lines to operate 5 GI guns or 6 air guns. During the cruise function of the umbilical declined to 4 GI guns or 6 air guns. This situation limited our choice of seismic source for the MCS component of the survey and the umbilical either needs to be modified to accommodate 6 GI guns or 6 standard air guns or be replaced by one that does have this capability.

MCS Gun Controller

The Syntron gun controller for the MCS system has hardware and software problems that limit it to firing only 4 GI guns. This is a significant problem because it limits scientists with interest in deep penetration with MCS systems to an array of 6 standard air guns. Six standard air guns in a tuned array is a fine way to acquire deep penetration data, but if just one of the guns stops functioning for some reason, the entire array is out of tune and produces a long noisy source signature. Whereas, when using 6 GI guns for the same purpose in a survey, if one gun goes down, you are simply down $1/6^{th}$ of your power and still have an array that produces a sharp tuned pulse. The outcome is that one has more options when deciding when to do maintenance on guns and less down time during the survey. The gun controller and umbilical issues need to be resolved prior to future seismic surveys.

Airgun array

One significant problem with the towed array is the need to develop a better way of hanging the 850 cubic inch gun. The shackles used to suspend it from the umbilical broke on a frequent basis and this terminated use of the array until it was repaired

resulting in relatively short, but significant intervals of down time and less that prime quality MCS data.

Second Gun Controller and High Resolution Digital Acquisition System

We demonstrated during this survey is that is possible to acquire both deep penetration MCS data and higher resolution single channel (SCS) data simultaneously from the *Palmer* in polar environmental conditions. The gun delay timing unit obtained by Raytheon for this cruise worked extremely well in allowing us to alternate firing a shallow towed, small volume GI gun or water gun array and the large MCS gun array. Bartek provided the second gun controller as well as the high-resolution digital acquisition system required to do this type of survey. Other investigators who may desire to optimize their survey and acquire a spectrum of seismic reflection data simultaneously may not have access to these systems and therefore will not be able to do this type of work. This then limits the pool of people who can do this type of work to those who have access to this type of equipment and this is not a fair situation for potential PI's. Therefore, Raytheon should acquire a second gun controller and high-resolution digital acquisition system or make it very clear in proposal documentation that these pieces of equipment will be leased if the PI needs it.

Sonobuoy acquisition system

There is a nagging and variable crosstalk observed when recording either sonobuoys or signals from the SCS streamers on the OYO auxiliary channels. This behavior is not typical of other OYO DAS systems in our experience, and seems to be related to the power and signal circuitry in the 48-chanel S/N analog MCS streamer.

MB Backscatter

The backscatter function is marginal at present. It is unclear whether this is a system issue or more operator training is needed. RPSC needs to investigate this.

Helicopter fuel

We learned that the *Palmer* does not carry fuel for helicopters. This precludes emergency helo operations at long distances from McMurdo. Carrying fuel will allow for landings and refueling and therefore a wider range of emergency access. NSF needs to authorize the *Palmer* to carry a full load of fuel for helicopters.

Hand held radios for MPCs

Finding MPCs on board could at times be frustrating since their duties require them to be at a variety of locations. It should be standard procedure for the MPC to carry hand held radios like the marine technicians so that they can stay accessible to the science party.

Acknowledgments

We gratefully acknowledge the skill and cooperation of the ECO crew and thank in particular Captain Joe Borkowski III for an efficient and safe passage. Raytheon Polar staff provided excellent and cheerful support. This is greatly appreciated. We also thank

students from UC Santa Barbara and the University of North Carolina, Chapel Hill for enthusiastic help with the science program.

Submitted by Bruce Luyendyk, Lou Bartek, and John Diebold

APPENDIX

Marine Mammals and Penguins NBP 0301

J. Rosenburg

The January 2003 cruise of the Nathaniel B. Palmer began at the edge of the fast ice north of McMurdo Station on Ross Island, then proceeded northeast and south along the eastern edge of the B-15 iceberg. From there a survey was performed in the C-19 area of the western Ross Sea; the survey continued eastward along the Ross Ice Shelf in the area from where the B-15 iceberg calved. The ship proceeded from the south central Ross Sea to the Bay of Whales and Edward VII coast. During the cruise, the ship encountered many areas of dense pack ice, as well as areas of open sea in McMurdo Sound, the C-19 area, and the Bay of Whales. Wildlife sightings included whales, seals, and penguins. Their patterns of distribution and behavior are discussed below.

By far, adelie penguins were the most plentiful species sighted. They were seen in abundance in McMurdo Sound, the C-19 area, and all along the Ross Ice Shelf. There were sightings of adelies on floes in the central eastern Ross Sea some distance north of the Ross Ice Shelf. Colonies of up to 100 penguins were spotted on areas of the western shelf where the ice edge was low allowing access to the sea. In addition, in several instances, groups of up to 8 adelie penguins were noted swimming alongside the ship in areas of open water. In general, the adelies seem to be present anywhere there is ice allowing them a surface upon which to stand and a plenteous supply of food in the water.

In contrast, emperor penguins were seen less frequently, and when sighted, were usually alone or in pairs. They were mainly sighted in the eastern regions of the cruise, along the shelf, in the Bay of Whales, and on the ice floes of the central eastern Ross Sea. An exception to the above was a flock of 10 emperor penguins on the sea ice of the central eastern Ross Sea. The emperors were usually seen standing, walking, or sliding on the floes. Curiously, although there is a known emperor colony on Cape Crozier near the C-19 site where she ship did an extensive survey, no emperor sightings were reported in this area.

Minke whales comprised the majority of sightings of marine mammals; orcas were also seen, and three whale sightings were of undetermined type. Minke whales traveled alone or in groups of up to 8, and were seen swimming across the ship's path in all regions of the cruise. At times they were reported to be breaching, diving, and feeding.

A pod of orcas was spotted in the Bay of Whales swimming along the bow of the ship. On three occasions whales of undetermined type were spotted. One pair was swimming in the Bay of Whales, and a group of four whales swam across the ship's path in the south central Ross Sea. The third whale of undetermined type was swimming in the pool behind the propeller as the ship was anchored in the fast ice in McMurdo sound; it swam in a circle, dove and blew several times, then disappeared under the ice, presumably to return to the open sea.

Seals were spotted sleeping on ice throughout the Ross Sea . One seal of undetermined type was seen as far east as the Bay of Whales. Most identified seals were leopard seals, and one crabeater seal was recognized. In all occasions the seals were solitary and stationary, lying on ice floes without much activity.

Cruise reports from previous NBP trips were consulted in an attempt to determine if similar patterns of marine mammal and penguin distribution had been observed. Unfortunately, most of the earlier trips that had kept track of wildlife sightings had done so in a different region of Antarctica than the current cruise in the Ross Sea from McMurdo Sound to the Edward VII coast. Additionally, as one of the goals of this cruise was to map the B-15 and C-19 sites which had previously been under the ice shelf, any patterns of wildlife behavior in these areas would have no precedent.

The only data that overlapped in position with our trip was a portion of the NBP 99-09 APIS cruise. A major focus of this trip was to study the distribution and genetics of seals and penguins with the assistance of helicopter flights from the ship into the pack ice. The western edge of their data collection corresponds to the eastern boundary of our cruise. Briefly, they reported 17 weddell seals in the Bay of Whales, with observations of weddell and crabeater seals along the Edward VII coast, with the majority of sightings closer to the ice edge. On our cruise, only one seal of undetermined type was spotted in the Bay of Whales, and none reported along Edward VII coast. The 99-09 trip monitored penguins populations in the pack ice of the Ross Sea, with an overlap of position in the mid-central Ross Sea. They recorded mostly emperor penguins, and noted that their populations increased southward. Adelie penguins were more likely to be found on large floes. Our observations in this area were similar. No mention was made in their data regarding whales.

Although the observations of marine mammals and penguins on our cruise represent only a portion of the numbers of these animals present in this area of the Ross Sea, hopefully our samples can be applied to the populations as a whole.