

Research and Education Activities

This is a collaborative project between Bruce Luyendyk at UCSB and Louis Bartek at the University of Alabama. Results of Bartek and his team are summarized in the final report for his grant (9316716)

We conducted a study of the Cenozoic glacial and tectonic history of western Marie Byrd Land (MBL), West Antarctica, in the region of the eastern Ross Sea, Edward VII Peninsula, and the Ford Ranges. The study region is located at the eastern edge of the Ross Sea and Ross Ice Shelf. The approach was an offshore geology and geophysics study of the continental margin here. This project followed a 3-year onshore geological and geophysical investigation by Luyendyk and colleagues in the northern Ford Ranges and the Edward VII Peninsula. This work included mapping, petrology, geochronology, paleomagnetism, gravity, and preliminary observations on the glacial geology in western MBL. The offshore work used the icebreaker N.B. Palmer in the first year of the project. No marine geophysical data were previously available from this large region.

We are concerned with these main problems:

- What is the history of the West Antarctic ice sheet in this region?
- What is the tectonic history in the eastern Ross Sea?
- How are the tectonic history and the glacial history related?

The offshore survey obtained multibeam echo soundings, high resolution seismic reflection data, gravity and magnetic profiles, and bottom samples. The expedition was conducted in January and February of 1996. It followed extensive work in the eastern Ross Sea by Bartek and colleagues in 1993-94 and 94-95 aimed at a fuller understanding of the glacial history in the region. Geophysical lines in our survey are tied to this survey and other Ross Sea profiles.

The expedition also completed a seismic grid offshore Cape Roberts in the western Ross Sea. This was a site survey to be used in determining the location of drill holes for the Cape Roberts Drilling Project.

In the Ross Sea region, approximately 1,402 km of 4 and 5 X 210 cubic inch Generator injector (GI) gun/multichannel seismic data, along with 1899 km of 210 cubic inch GI/single channel seismic data, and 2054 km of chirp profiler data were collected along with gravity and magnetic data, and 1 piston core. We also collected 2054 km of multibeam coverage in the Ross Sea and conducted some testing of the system. Magnetic data were collected whenever ice conditions permitted and gravity data were collected nearly continuously through the cruise (the total amount of gravity data collected is about the same as the amount of chirp sonar data acquired).

In the area west of the Edward VII Peninsula in the Colbeck Trough region, approximately 490 km of 4 and 5 X 210 cubic inch Generator Injector (GI) gun/multichannel seismic data were collected, along with 1892 km of 210 cubic inch GI/single channel seismic data, 2591 km of chirp profiler data, 2591 km of multibeam data, plus gravity and magnetic data. Nine piston cores were taken as well as two dredge hauls.

During the survey of the Sulzberger Bay area, 641 kms of 4 and 5 X 210 cubic inch Generator Injector (GI) gun/multichannel seismic data were collected, along with

797 km of 210 cubic inch GI/single channel seismic data, 1120 km of chirp profiler data, 1120 km of multibeam data, 5 piston cores were acquired, as well as gravity and magnetic data.

In the survey of the Cape Roberts area, approximately 281 km of 5 X 210 cubic inch Generator Injector (GI) gun/multichannel seismic data were collected, along with 281 km of 210 cubic inch GI/single channel seismic data, 476 km of chirp profiler data, 467 km of multibeam data, 1 piston core, as well as gravity and magnetic data.

For the entire expedition, approximately 2814 km of 4 and 5 X 210 cubic inch Generator injector (GI) gun/multichannel seismic data were collected, along with 4869 km of 210 cubic inch GI/single channel seismic data, 6241 km of chirp profiler data, 6232 km of multibeam data, as well as gravity and magnetic data. We collected a total of 16 Jumbo Piston cores.

UCSB personnel included in the project included two graduate students and seven undergraduates. Five students were women, one of these was Hispanic. The undergraduates participated in the expedition. Two of the 7 undergraduates completed REU projects, one on gravity study of the eastern Ross Sea and one on the history of sea ice coverage in western Marie Byrd Land. One undergraduate completed a bachelor's thesis on the seismic stratigraphy and structure offshore Cape Roberts.

We made eight presentations at national and international meetings. The Cape Roberts study was published as an informal report and in *Terra Antarctica*. Our studies in the eastern Ross Sea near Cape Colbeck are described in a manuscript submitted to *Tectonics* in July 1999. We are currently preparing a manuscript on the Cape Roberts study for submission to *Tectonics*.

Project Findings

Eastern Ross Sea and western Marie Byrd Land

Examination of NBP-9601 seismic and multibeam data reveals tectonic activity and glacial erosion of the shelf in the area offshore and west of Edward VII Peninsula. These same data along with core samples reveal that the inner shelf in the Marie Byrd Land region east of the Peninsula has been stripped of sediment by glacial erosion and that much of this sediment has been deposited near the shelf edge. Core samples indicate that a very different mode of glacial marine deposition is occurring in the inner shelf basins of western Marie Byrd Land as compared to other regions of Antarctica. Very little sediment is accumulating in deep silled basins in the Marie Byrd Land area. There is a lack of sediment flux here either because biologic productivity is low in the region, or that sediments are being transported beyond the basins before they can settle, or a combination of these processes. Multichannel seismic data (MCS) collected during the cruise from the central Ross Sea, where DSDP drill sites exist, provide an opportunity to correlate and provide relative ages to units to seismic stratigraphic units in the Colbeck Trough area. MCS data collected in the Eastern Basin also augment ongoing studies of glacial seismic stratigraphy/facies relationships to lithofacies.

Geophysical data allowed us to map half grabens in the continental shelf of the eastern Ross Sea adjacent to Edward VII Peninsula, and in Sulzberger Bay offshore from the southern Ford Ranges. These structures trend NNW and NNE subparallel to the ranges onshore. A 1000-meter high escarpment trending NNW mapped on the east side of the Colbeck Trough, defines the west side of Edward VII Peninsula. The trough is bare of sediments near the Ross Ice shelf edge but farther offshore it is cut into glacial marine sediments. Faulting of the shelf apparently routed the flow of outlet glaciers and carved the Colbeck Trough in Miocene and later time. This trough is the most prominent bathymetric feature of the eastern Ross Sea. Farther east offshore from the Ford Ranges, Sulzberger and Saunders Basin are fault-controlled structures that also may have been conduits for glaciers during previous glacial maxima. These faults may have down-to-the-east displacement. Our correlations to seismic lines farther west in the Ross Sea have identified known prominent seismic stratigraphic units in the Colbeck Trough region. We traced a late Oligocene-early Miocene unit here that is not disrupted by faulting in the Colbeck area; therefore, faulting here is largely pre-Ross Sea glaciation. We propose that the faulted units we mapped in the eastern Ross Sea correspond to the seismic sequence RSS1 and a sequence below this one. This lowermost unit may correspond to a rift breccia that was sampled in DSDP hole 270. Fission track studies by other workers found a Late Cretaceous cooling age for this unit at DSDP 270. Dredge hauls we made on the innermost Colbeck Trough retrieved mylonites. Fission track studies on these rocks show Late Cretaceous cooling. Therefore, we hypothesize that faulting in the easternmost Ross Sea is predominantly of this age. Late Cretaceous faulting may have occurred along low angle detachments faults to produce the mylonitic textures.

Site survey for Cape Roberts drilling project

During Palmer 9601 we completed a site survey for the Cape Roberts Drilling Project. This comprises a 250 line-km grid of 16 SCS and MCS lines. We have fully processed through FK filter multiple reduction, and velocity analyses every 1 km, of all the MCS lines. Our lines covered Roberts Ridge, the site of the drill holes, and the V-shaped basin to the west.

We made two significant findings here. One finding is that the N-S trough separating Roberts Ridge and the coast is defined on the west by a major normal fault and on the east by east-tilted fault blocks on the west side of Roberts Ridge. The trough apparently formed as a result of rift basin subsidence at the front of the Transantarctic Mountains. Based on preliminary interpretation, block tilting ceased or decreased during mid-Tertiary time. A fault zone with at least 4 kilometers of separation on acoustic basement bounds the basin to the west. This fault has been found north and south of the study region by other researchers. We propose it represents the master fault for uplift of the Transantarctic Mountains. We named it the McMurdo Sound fault zone.

We have interpreted several west-side-down faults between the locations of drill sites CRP1 and CRP2 and the proposed location of CRP3. These faults vertically separate Oligocene strata by a few tens of meters. A younger sub-vertical fault with a larger separation was mapped in the south that projects between the drill sites.

A correlation with basin-wide seismic sequences from other geophysical surveys conducted in the Victoria Land basin, indicates that units V3-V5 rise to the sea floor along the bathymetric high of Roberts Ridge. V3 and V4 have been reached by drilling;

V4 is Oligocene in age. We subdivided unit V4 into 4a and 4b. V3 and V4a dip gently and thicken towards the east. Unit V4a onlaps the more-steeply east-dipping top reflector of V4b. The angular unconformity between V4a and V4b may represent the transition from the main phases of uplift of the Transantarctic Mountains.

Training and Development

Seven undergraduates from UCSB participated in the expedition. Two of the 7 undergraduates completed REU projects, one on gravity study of the eastern Ross Sea and one on the history of sea ice coverage in western Marie Byrd Land. One undergraduate completed a bachelor's thesis on the seismic stratigraphy and structure offshore Cape Roberts. All student participants completed term projects on data obtained on the expedition.

Outreach

Sandra Markle participated in the expedition and developed teaching materials for grade school students. This was done as part of a separate project awarded to her by NSF OPP. She conducted real-time exchanges with school children in North America during the expedition.

Contributions within Discipline

Cape Roberts Project

Our site survey was a critical component to siting the drill holes for this project. In addition, our data provide a meaningful context for the drilling results. By our interpretation we have identified a major fault zone along the Transantarctic Mountains front. And, we have shown structural evidence for the timing of uplift of these mountains during Oligocene time.

Tectonics of eastern Ross Sea

Our study was the first of its kind on the eastern side of the Ross Sea rift. We identified a new Ross Sea unconformity, RSU7 and a new syn-rifting unit, RSS1-lower. Our work demonstrates that deformation here is largely restricted to pre-RSU6 time, which is mid-Tertiary in age. It also shows that detachment faulting likely extended throughout the Ross Sea prior to Cenozoic time. The results of our work mesh nicely with the onshore work in the Ford Ranges where we determined Late Cretaceous cooling ages that suggest crustal deformation here at that time, synchronous with the Ross Sea.

Contributions to Other Disciplines

Our project is a significant contribution to the Cape Roberts Project. The Cape Roberts Project has a potential to make an impact on global climate models and paleoclimate.

Contributions to Human Resources Development

Personnel included in the project included two UCSB graduate students and seven undergraduates from UCSB. Five students were women, one of these was Hispanic. The undergraduates participated in the expedition. Two of the 7 undergraduates completed REU projects, one on gravity study of the eastern Ross Sea and one on the history of sea

ice coverage in western Marie Byrd Land. One undergraduate completed a bachelor's thesis on the seismic stratigraphy and structure offshore Cape Roberts.