BEARDMORE GLACIER REGION PROJECTS

River-like glaciers flow through the Transantarctic Mountains towards the Ross Ice Shelf.

NSF photo by Josh Landis

Late Paleozoic-Mesozoic fauna, environment, climate, and basinal history: Beardmore Glacier area, Transantarctic Mountains.
Molly Miller, Vanderbilt University, and John Isbell, University of Wisconsin-Milwaukee.

We will investigate paleoenvironmental conditions during the late Paleozoic and Mesozoic in central interior Antarctica. The 4-kilometer-thick sequence of sedimentary rocks in the Beardmore Glacier area, known as the Beacon Supergroup, records 90 million years of Permian through Jurassic history of this high-paleolatitude sector of Gondwanaland. The sequence accumulated in a foreland basin with a rate of subsidence approximately equal to the rate of deposition. The deposits have yielded diverse vertebrate fossils, fossil forests, and exceptionally well preserved plant fossils that give a unique glimpse of glacial, lake, and stream/river environments and ecosystems and provide an unparalleled record of the depositional, paleoclimatic, and tectonic history of the area.

We plan to integrate sedimentologic, paleontologic, and ichnologic observations to answer the following focused questions:

- What are the stratigraphic architecture and alluvial facies of Upper Permian to Jurassic rocks in the Beardmore Glacier area?
- In what tectonostratigraphic setting were these rocks deposited?
- Did vertebrates inhabit the cold, near-polar Permian floodplains, as indicated by vertebrate burrows, and can these burrows be used to identify for the first time the presence of small early mammals in Mesozoic deposits?
- How did bottom-dwelling animals in lakes and streams use substrate ecospace, how did ecospace use at these high paleolatitudes differ from use in equivalent environments at low paleolatitudes, and what does burrow distribution reveal about the seasonality of river flow and thus about paleoclimate?

Answers to these questions will

- clarify the paleoclimatic, basinal, and tectonic history of this part of Gondwanaland;
- elucidate the colonization of near-polar ecosystems by vertebrates;
- provide new information on the environmental and paleolatitudinal distributions of early mammals; and
- allow semiquantitative assessment of the activity and abundance of bottom-dwelling animals in different freshwater environments at high and low latitudes.

We expect this project to contribute significantly to an understanding of paleobiology and paleoecology on a high-latitude floodplain during a time in Earth's history when the climate was much different than it is today. (G-094-M; NSF/OPP 01-26146 and NSF/OPP 01-26086)

Permian and Triassic floras from the Beardmore Glacier region: Icehouse to greenhouse?

Edith Taylor and Thomas Taylor, University of Kansas-Lawrence.

Over the past 30 years, the rocks of the central Transantarctic Mountains have been a source of outstanding plant fossil discoveries, including Permian and Triassic permineralized peat, fossil forests silicified in growth position, and compression floras with cuticular preservation. The rare juxtaposition of sites that include many different types of plant preservation, its exceptional quality, and the richness of the sites make this area unique.

We will collect Permian and Triassic plant megafossils from the Beardmore Glacier area (compression floras, especially those from Graphite Peak, and permineralized peats from Skaar Ridge and Fremouw Peak, both near Walcott Névé). Since permineralizations preserve a three-dimensional record of plant organs, they are important in understanding the basic morphology and anatomy of fossil plants, as well as detailing relationships among groups. The data provided by the juxtaposition of plant fossils preserved as permineralizations and compressions have already contributed greatly to our understanding of late Paleozoic–early Mesozoic plant evolution.

The Permian and Triassic represent an important time in plant evolution, and one about which we still know relatively little. The glossopterid seed ferns in the Permian and the corystosperms in the Triassic were the dominant plant groups in Gondwana. Since both groups had enclosed seeds, they have been proposed at one time or another as possible ancestors of flowering plants and have figured prominently in phylogenetic analyses of seed plants. Only through a combination of permineralizations and compressions is it possible to reveal a complete picture of fossil plants and, more important, to understand their position in seed plant evolution.

We will collect plants and silicified logs from Graphite Peak, which is believed to contain the Permian/Triassic boundary. Silicified logs have been noted in the lower Buckley Formation at this site, and these will be collected and examined for tree rings, which can be compared with tree rings in Late Permian wood (upper Buckley) from nearby Mount Achernar. The Late Permian has been assumed to be much warmer than the Early-Middle Permian, and this should be reflected in the rings' width and structure.

Our findings should lead to significant improvements in knowledge of plant evolution and paleoenvironmental conditions during the critical Permian to Triassic interval. (G–095–M; NSF/OPP 01–26230)

Geophysical mapping of the East Antarctic Shield adjacent to the Transantarctic Mountains.

John Goodge, University of Minnesota, and Carol Finn, U.S. Geological Survey-Denver.

The East Antarctic Shield is one of Earth's oldest and largest cratonic assemblies. Interest in the evolution of the shield has been rekindled over the past decade by tectonic models linking East Antarctica with other Precambrian crustal elements in the Rodinia and Gondwanaland supercontinents. It has been postulated that the Pacific margin of East Antarctica was rifted from Laurentia during the late Neoproterozoic breakup of Rodinia; it then developed as an active plate boundary during the subsequent amalgamation of Gondwanaland. A better understanding of the geological evolution of the shield is therefore critical for studying Precambrian crustal evolution in general, as well as resource distribution, biosphere evolution, and glacial and climate history during later periods. Because of nearly complete coverage by continental-size ice sheets, however, Antarctica remains the single most geologically unexplored continent. Also, little is known about the composition and structure of the shield's interior.

Therefore, we will conduct an airborne magnetic survey (coupled with ground-based gravity measurements) across an important window into the shield where it is exposed in the Nimrod Glacier area of the central Transantarctic Mountains. Specific goals are to

- characterize the magnetic and gravity signature of the east antarctic crustal basement exposed at the Ross margin,
- extend magnetic data westward along a corridor across the East Antarctic Ice Sheet to image the crust in ice-covered areas,
- obtain magnetic data over the Ross Orogen to image the ice-covered boundary between basement and supracrustal rocks, and

- use the shape, trends, wavelengths, and amplitudes of magnetic anomalies to define magnetic domains in the shield.

Our survey (to be done in collaboration with German colleagues) will, for the first time, use geophysical methods to characterize the shield terrain in this sector. This baseline over the exposed shield will allow for a better interpretation of geophysical patterns in other ice-covered regions and can be used to target future investigations. Once the survey is done, we will then perform data reduction, interpretation, and geological correlation.

This research will lead to new basic knowledge about the antarctic continent, which in turn may help with applied research in other fields such as the glacial history of Antarctica. (G-291-M; NSF/OPP 02-30280 and NSF/OPP 02-32042)

Shackleton Glacier area: Evolution of vegetation during the Triassic.

Edith Taylor and Thomas Taylor, University of Kansas-Lawrence.

The rocks of the central Transantarctic Mountains have been a source of fossil discoveries over the past 30 years. The rare juxtaposition of sites that include many different types of plant preservation, the exceptional quality of the fossils, and the biodiversity of the sites make this area unique. The Paleozoic/Mesozoic transition is a critical time in plant evolution. A unique variety of seed plant groups existed, and several have been suggested as the ancestors of flowering plants. There was also a massive floral change from the Permian to the Triassic.

While most fossil plants occur as disarticulated leaves, stems, and reproductive organs, many in the Shackleton Glacier area are partially articulated, thus making it possible to gain a more accurate picture of the entire plant and its place in the ecosystem. We will examine Triassic floras from two sites in the Shackleton Glacier area (Collinson Ridge and an unnamed ridge southeast of Schroeder Hill). In addition to compression fossils, the latter also includes some permineralized peat and fossil stumps. The Collinson Ridge site is important because it contains fossil peat and logs in presumably Lower Triassic rocks. Preliminary analysis of petrified material collected during the 1995-1996 field season, however, suggests that perhaps it is Late Permian rather than Early Triassic, as would be expected. It is therefore important to elucidate the biostratigraphy of this area because the position of the Permian-Triassic boundary is crucial in understanding the timing of terrestrial extinctions around it. Further collecting at both of these sites and analysis of the fossil material in the laboratory will address these discrepancies and yield important new information about Triassic plant evolution.

Paleobotany is ideally suited to education and outreach. Workshops and temporary exhibits on antarctic science have been developed through programs sponsored by the University of Kansas Natural History Museum and Biodiversity Research Center, and we will continue this activity. Student involvement has also been extensive and will be continued. (G-293-M; NSF/OPP 02-29877)

Terrestrial paleoecology and sedimentary environment of the Meyer Desert Formation, Beardmore Glacier, Transantarctic Mountains.

Allan Ashworth, North Dakota State University.

Terrestrial fossils recovered from the Meyer Desert Formation are providing paleoclimatic information about the interior of Antarctica before the growth of the great ice sheets. The site is located on the Upper Beardmore Glacier, about 500 kilometers from the South Pole. Southern beech wood and leaves were discovered many years ago, but since 1995, the fossils have included the seeds of several species of vascular plants, including buttercups; the stems and leaves of several species of mosses; body parts of beetles; a puparium of a higher fly; shells of freshwater mollusks; valves of an ostracod; and a fish tooth. The largest fossils at the site are cushions of vascular plants buried in their growth positions by sediments of glacial outwash.

These sediments were deposited in stream channels and shallow pools associated with moraines that had been colonized by tundra-like vegetation harboring insects and mollusks. The fossils provide the best evidence so far of how much heat the atmosphere near the South Pole can hold.

Although the fossils are fragmentary, they are more closely related to living terrestrial and freshwater organisms than any other fossils found in Antarctica. They are most probably the direct descendants of an ancient biota that was part of Gondwanaland. Until the discovery of the Meyer Desert Formation, no fossils of terrestrial organisms, except for pollen and spores, were available to answer questions about the evolutionary relationships between organisms distributed in southern South America, Australia, New Zealand, and the subantarctic islands.

We will revisit the Meyer Desert Formation to locate and sample new fossiliferous horizons, construct an accurately scaled and correlated cross-section of the complex facies, and collect samples for a pilot project to date the deposits directly. Collectively, these studies will provide information that should help address larger questions about the size and dynamics of the East Antarctic Ice Sheet during the Neogene.

There is extensive public interest in Antarctica, in part because of the romance of exploration but also because of the threat of global warming and the potential instability of the West Antarctic Ice Sheet. Because Antarctica exerts a huge influence on the Earth's climate, oceanic circulation, and sea level, knowledge about warmer climates during the Neogene is vital. (G-294-M; NSF/OPP 02-30696)

Paleobiology and taphonomy of exceptionally preserved fossils from Jurassic lacustrine deposits, Beardmore Glacier area and southern Victoria Land, Antarctica.

Loren Babcock, Ohio State University.

Sedimentary interbeds of the Kirkpatrick Basalt represent unusual, exceptionally well preserved deposits, characterized by the presence of a variety of non-biomineralizing (so-called soft-bodied) organisms. Fieldwork in previous decades resulted in the discovery of abundant remains of conchostracans (bivalved arthropods having non-mineralized exoskeletons) and fishes; less common remains of various arthropods such as insects, syncarids, and isopods; and plant fragments. The arthropod and fish fossils range in preservational quality from disarticulated pieces to articulated remains comparable to the finest in the fossil record.

Present indications are that the Kirkpatrick lake deposits offer important windows into the evolutionary history of high-latitude, freshwater ecosystems of the middle Mesozoic. Paleoecologic and taphonomic study of these deposits can be expected to provide additional clues to the general conditions under which exceptional preservation of non-mineralized skeletal parts, and perhaps soft parts, occurred in the geologic past. This is significant because nearly all of our current understanding of conditions surrounding exceptional preservation has been derived from studies of marine deposits, marginal-marine deposits, or freshwater deposits from low to middle paleolatitudes.

Our principal objectives are to

- collect and systematically document the biota of the sedimentary interbeds of the Kirkpatrick sites in the Beardmore Glacier area and southern Victoria Land;
- document and interpret taphonomic information on the Kirkpatrick sites, including diagenetic alteration of fossils;
- describe and interpret trace fossils that are associated with the body fossils; and
- document and interpret the stratigraphic and sedimentologic context of exceptional preservation.

Considerable importance attaches to the Jurassic sites in the Transantarctic Mountains, because few sites from aqueous ecosystems of high-paleolatitude areas are known to contain non-biomineralized fossils. Completion of this study will result in a more complete understanding of the biota and paleoecology of high-latitude lake ecosystems of the middle Mesozoic. The Kirkpatrick sites will also provide information useful for interpreting Jurassic biotas in a global context. Data from this study are expected to provide information on the fundamental question of why exceptional preservation of organisms has occurred in freshwater, high-latitude settings. (G-297-M; NSF/OPP 02-29757)

Vertebrate paleontology of the Triassic to Jurassic sedimentary sequence in the Beardmore Glacier area of Antarctica.

William Hammer, Augustana College.

During a 3-year study, we will investigate fossils from Triassic and Jurassic dinosaurs and other vertebrates in the central Transantarctic Mountains. A field program to search for Upper Triassic to Jurassic fossil vertebrates in the Beardmore Glacier region will be carried out in the 2003-2004 austral summer. Initially, we will concentrate our efforts on the Hanson Formation, which has produced the only Jurassic dinosaur fauna in Antarctica. We will then further excavate the Hanson dinosaur locality on Mount Kirkpatrick and will follow that with an extensive search of other exposures of the Hanson, Falla, and Upper Fremouw Formations in the Beardmore area.

Our field party will operate for 3 to 4 weeks out of a small helicopter camp in the Beardmore area. The field party will consist of six persons, to allow two groups of three to work independently at different sites. One group will excavate the Mount Kirkpatrick site, while the other reconnoiters. In addition to collecting new specimens, we will interpret the depositional settings for each of the vertebrate sites. Our second and third years will be dedicated to preparing and studying the vertebrates.

Antarctic vertebrates provide a unique opportunity to study the evolutionary and biogeographic significance of high-latitude Mesozoic fauna, and this project should result in significant advances in knowledge. (G-298-M; NSF/OPP 02-29698)

Permian-Triassic mass extinction in Antarctica.

Gregory Retallack, University of Oregon; Luann Becker, University of California-Santa Barbara; and Hope Jahren, Johns Hopkins University.

We will study fluvial sediments in Antarctica for evidence of what caused the greatest mass extinction in the history of life on Earth. The Permian-Triassic boundary was, until recently, difficult to locate and thought to be unequivocally disconformable in Antarctica. New studies, however (particularly those using carbon isotopic chemostratigraphy, and paleosols and root traces as indicators), together with improved fossil plant, reptile, and pollen biostratigraphy, now suggest that the precise location of the boundary might be identified; these studies have also led to local discovery of iridium anomalies, shocked quartz, and fullerenes with extraterrestrial noble gases. These anomalies are associated with a distinctive claystone breccia bed, similar to strata known in South Africa and Australia, and accepted as evidence of deforestation.

There is already much evidence from Antarctica and elsewhere that the mass extinction on land was abrupt and synchronous with extinction in the ocean. What led to such death and destruction? Carbon isotopic values are so low in these and other Permian-Triassic boundary sections that there was likely to have been some role for catastrophic destabilization of methane clathrates. Getting the modeled amount of methane out of likely reservoirs would require such catastrophic events as a meteor impact, flood-basalt eruption, or collapse of the continental-shelf, which have all been implicated in the mass extinction and for which there is independent evidence. Teasing apart these various hypotheses requires careful reexamination of beds that appear to represent the Permian-Triassic boundary and search for more informative sequences, as was the case for the Cretaceous-Tertiary boundary.

Our research on the geochemistry and petrography of boundary beds and paleosols; on carbon isotopic variation through the boundary interval; and on fullerenes, iridiums, and helium is designed to test these ideas about the Permian-Triassic boundary in Antarctica and to shed light on the processes that contributed to this largest of mass extinctions. We will conduct our fieldwork in the central Transantarctic Mountains and in southern Victoria Land, with an initial objective of examining the stratigraphic sequences for continuity across the boundary. Such continuity is critical for the work to be successful. If fieldwork indicates sufficiently continuous sections, a full analytical program will follow. (G-299-M; NSF/OPP 02-30086, NSF/OPP 02-29917, and NSF/OPP 02-29136)