DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
under the auspices of the
NATIONAL SCIENCE FOUNDATION

U.S. ANTARCTIC RESEARCH PROGRAM
ANTARCTIC GEOLOGIC MAP A–13

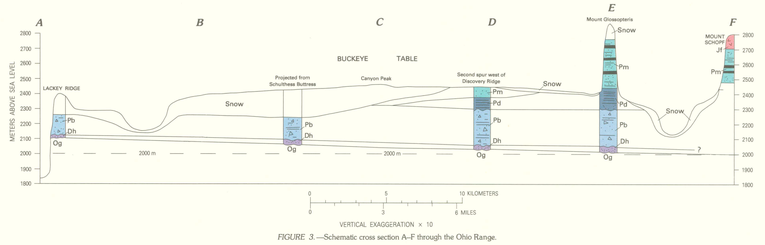
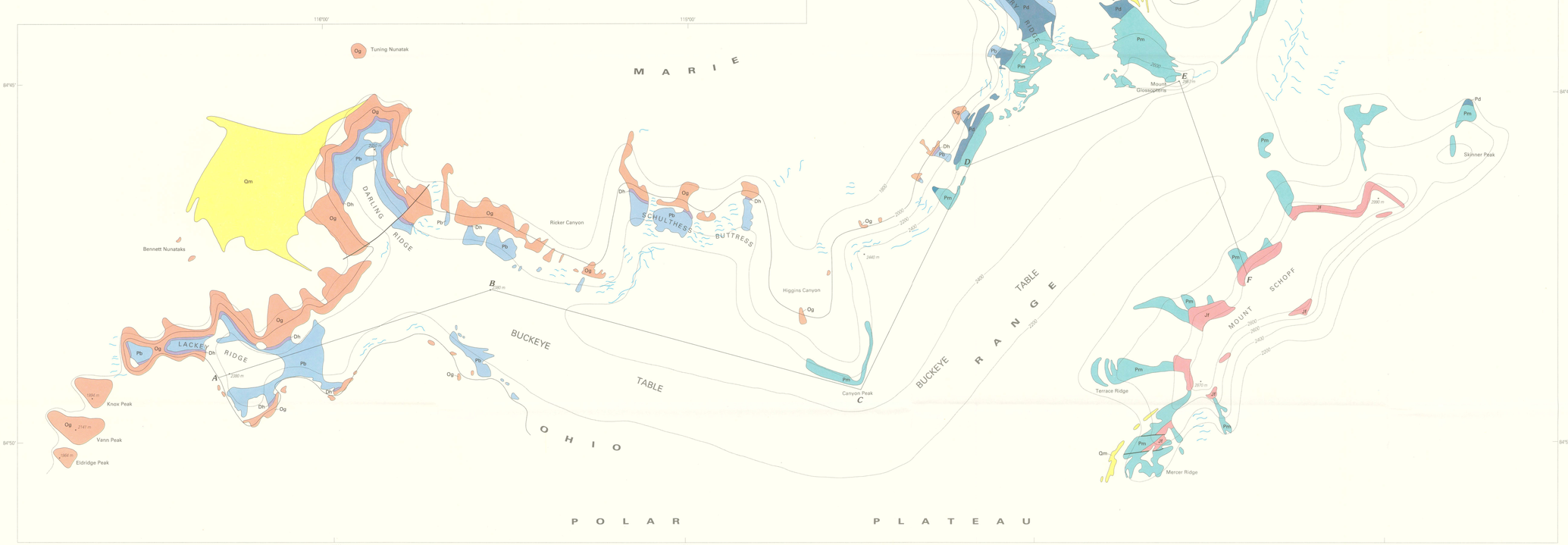


FIGURE 3.—Schematic cross section A–F through the Ohio Range.



Base from U.S. Geological Survey, 1959
Revised by authors

SCALE APPROXIMATELY 1:50,000 AT 84°45'
1 5 0 1 2 3 4 5 6 7 8 9 10 KILOMETERS
1 5 0 1 2 3 4 5 6 MILES
CONTOUR INTERVAL 200 METERS
DATUM IS MEAN SEA LEVEL
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology mapped in 1979–80

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1986—GM474

CORRELATION OF MAP UNITS

Igneous Rocks	Sediments	Sedimentary Rocks	
	Qsc Qm		QUATERNARY
	Unconformity		
Jf			JURASSIC
	Pm Pd		PERMIAN AND CARBONIFEROUS?
	Unconformity		
	Pb		
	Unconformity		
	Dh		DEVONIAN
	Unconformity		
Og			ORDOVICIAN

DESCRIPTION OF MAP UNITS

Qsc **Scree**—Rock debris with minor snow and ice matrix; only one deposit mapped, on Discovery Ridge.

Qm **Moraine**—Rock debris entrained in moving ice masses; occurs mainly west of Darling Ridge.

Jf **Ferrar Dolerite**—The rock is a dark-gray to black, subophitic tholeiitic basalt that shows a slight upward increase in plagioclase (labradorite and calcic andesine) and granophyre, and an upward decrease in pyroxene (pigeonite, augite, and minor hypersthene) (Treves, 1965). It occurs as a sill, at least 150 m thick, with an eroded upper contact, capping Mt. Schopf, and crops out over an area of about 2 km by 10 km (Long, 1965).

Pm **Mount Glossopteris Formation**—The Mt. Glossopteris Formation (Long, 1965) consists of two members. The upper half of the formation is dark-gray carbonaceous shale and mudstone with well-preserved fossil Glossopteris and *Gangamopteris* leaves, grading to coal in some places. Cridland (1962) has dated the leaves as Permian. A few beds contain fresh-water pelecypods (Bradshaw, 1984) and bivalved crustaceans (conchostracans; Doumani and Tasch, 1965). The lower half of the formation consists of light tan, fine- to medium-grained arkosic sandstone, with plant fragments in some beds.

The Mount Glossopteris Formation crops out east of Canyon Peak. It's lower contact is gradational with the underlying Discovery Ridge Formation; the contact has been placed arbitrarily at the base of the first massive sandstone above the black, fissile shales of the Discovery Ridge Formation (Long, 1965). The formation reaches a maximum thickness of about 350 m on Mt. Glossopteris. On Mt. Schopf, the top of the Mt. Glossopteris Formation has been intruded by a dolerite sill.

Pd **Discovery Ridge Formation**—Two members of the Discovery Ridge Formation were defined by Long (1965). The lower member, which includes the lowest quarter of the formation, is gray, platy shale, with up to 30 percent silt-size quartz. The upper member is also shale, but is darker, more fissile, and very carbonaceous. Lenses of impure, iron-bearing limestone up to 10 cm thick and 4.5 m across are present in the upper member. No body fossils are known from the Discovery Ridge Formation, but vertical and horizontal trace fossils made by mobile invertebrates are abundant in the lower member, and burrows are also present within a few meters of the contact with the overlying Mt. Glossopteris Formation. The Discovery Ridge Formation unconformably overlies the Buckeye Tillite and is exposed east of Canyon Peak. The formation is best exposed in broad steps on Discovery Ridge.

Pb **Buckeye Tillite**—The Buckeye Tillite (Long, 1965; Frakes and others, 1966) consists mainly of massive diamictite with a few beds of water-laid conglomerate, sandstone, and shale. The clasts are granite, gray siltstone and sandstone, schist, gneiss, metavolcanics, and marble. The matrix of the Buckeye Tillite is muddy even though there are many clasts up to 6 m long. More than 90% of the coarse clasts in the diamictite are subrounded to angular. Sparse pollen present in the Buckeye is Early Permian to latest Carboniferous age (Kemp and others, 1977).

The Buckeye Tillite unconformably overlies either the Horlick Formation or the granitic basement. Broad channels up to several hundred meters wide and 50 m deep mark the base of the Buckeye Tillite, completely cutting out the Horlick Formation in places. The Buckeye is more than 250 m thick at the east end of the range, and it is the uppermost exposed unit everywhere west of Canyon Peak.

Dh **Horlick Formation**—The Horlick Formation rests unconformably on the granitic basement (Long, 1965), and consists of interbedded arkosic and quartzose sandstone, chloritic mudstone and shale, and minor limestone. All clasts other than fossil fragments and intraformational mud chips could have been derived from the basement rocks. Contorted beds in the top 50 cm of the Horlick Formation on Lackey Ridge (McCartan and Bradshaw, in press), may be the result of ice override associated with Permian glaciers that deposited the Buckeye Tillite.

The formation is essentially flat-lying and because of post-Horlick erosion it thins from a maximum of about 50 m on Discovery Ridge to less than a meter on Lackey Ridge, and is absent on the first spur west of Discovery Ridge.

Og **Granitic Basement**—Most rocks of the granitic basement are medium-grained, massive to prophyritic granodiorites to monzogranites. Treves (1965) reported K-Ar (biotite) and Rb-Sr (feldspar) ages of about 470 m.y. (Middle Ordovician) from a pink quartz monzonite that intrudes gray granodiorite of unknown age. Rock samples from the second spur west of Discovery Ridge are biotite monzogranite with roughly equal proportions of plagioclase, potassium feldspar, and quartz. Samples form Discovery Ridge have about 44 percent quartz and 20 percent potassium feldspar, and plagioclase ranges from andesine (An35) to oligoclase (An27) (McCartan and Bradshaw, in press).

EXPLANATION OF MAP SYMBOLS

Contact

Fault—Displacement shown where known. U, upthrown side; D, downthrown side

Crevasse

INTRODUCTION

The Ohio range is a north-facing, east-trending escarpment at the edge of the Polar Plateau (fig. 1). The range is about 45 km long, and the highest point is on Mt. Schopf (2990 m above sea level). Southward, ice overriding most of the Ohio Range merges with that of the Polar Plateau; large ice falls occur along the southeastern side of Mount Schopf. Northward, ice of the extensive Buckeye Table falls an average of 400 m through wide canyons along the escarpment to merge with the ice of southern Marie Byrd Land. Summer air temperatures are always below freezing, although dark rock surfaces occasionally rise above freezing. Winter temperatures have not been recorded.

This map is derived in part from Long's (1965) geologic map of the Ohio Range but also includes field work done in the austral summer of 1979–1980 by a four-person expedition sponsored by the New Zealand Antarctic Research Programme and the National Science Foundation. The main purpose of the 1979–1980 project was to study the paleoecology and sedimentology of the Horlick Formation (Bradshaw and McCartan, 1983; McCartan and Bradshaw, in press), but the contacts and character of other formations were examined briefly. The base map (U.S.G.S., 1963) and contacts were revised in the field using a Brunton Pocket Transit and vertical and oblique aerial photographs (fig. 2). Previously measured sections (Long, 1965) were found to be as much as several hundred meters too thick when compared with the most reliable topographic reference points on the base map (U.S.G.S., 1963). Schematic stratigraphic columns presented herein (fig. 3) lack many details contained in Long's (1965) publication but probably reflect the thickness of units more accurately. The datum for the cross section (fig. 3) is the top of basement, which appears to be an almost flat surface tilted less than 1° downward toward the east.

GEOLOGIC HISTORY

Little is known about the geologic history of the Ohio Range prior to the emplacement of a granitic batholith in Middle Ordovician time. The granitic basement was eroded to a flat peneplain before deposition of the overlying Horlick Formation. The granitic basement forms sheer cliffs as much as 300 m high that extend the length of the Ohio Range (fig. 4), and wind-scoured pavements that are especially well exposed on Discovery Ridge and Darling Ridge. The eroded surface of the basement is about 100 m higher on the west end of the range than on the east end. Clasts of basement rock in the Horlick Formation are all granitic, and so provide no clues about rocks in the area older than the granite batholith.

The Horlick Formation is considered to be of Early Devonian age based on the presence of stratigraphically diagnostic marine fossils (Boucout and others, 1963; Doumani and others, 1965). Marine fossils were present at all of the sections studied, except at one untick/fetrus reef section on the west spur of Schultheiss Buttress. That section is composed of coarse arkosic sandstone with festoon and antidune crossbeds and very rare mudstone beds; textures and structures suggest that this unit was formed by fluvial deposition. The distribution of lithologies and fossils suggests deposition in 2 to 30 m of water on a broad, unbarred coast that experienced low to moderate tides (1–2.5 m), such as occur at German Bay in the North Sea (Dörjes and others, 1970; Wunderlich, 1970). A Lower Devonian landmass lay to the north, and sediment transport was predominantly towards the west, probably reflecting a longshore current (Long, 1965; McCartan and Bradshaw, in press). The sequence at west Schultheiss Buttress probably was deposited by a river that supplied sediment to the coast.

After deposition and consolidation of the Horlick Formation, gentle eastward tilting created a western highland. Both Long (1965) and Frakes and others (1966) concluded that the Buckeye Tillite, which overlies the Horlick Formation, is primarily of glacial origin with minor intercalated waterlaid deposits. From studies of the striations on faceted boulders and pavements, as well as crossbedding at several levels in the formation, Long (1965) interpreted ice movements as toward the northeast and east; however, Frakes and others (1966) came to the opposite conclusion—that ice and water currents had moved toward the southwest and west. Later in the Permian, the sandstones and shales of the Discovery Ridge and Mt. Glossopteris Formations were deposited by east-flowing streams and in large lakes.

A period of extension and injection of dolerite sills (Ferrar Dolerite) during Jurassic time characterizes much of the Transantarctic Mountains (McDougall, 1963; Long, 1965; Treves, 1965). In the Ohio Range, a thick dolerite sill intruded the rocks of the Mt. Glossopteris Formation. The thermal effect of the sill is evident in the alteration of sandstone to quartz-sericite hornfels immediately below the sill, and in the change of coal rank in the Mt. Glossopteris Formation. The rank ranges from semianthracite near the base of the formation through anthracite to coke just below the sill at the top of the formation (Schapiro and Gray, 1966). Estimates of coal rank by vitrinite reflectance from coal samples collected on Discovery Ridge suggest that these samples were also within the thermal aureole of an igneous intrusion (R. W. Stanton, U.S. Geological Survey, personal communication, 1983).

High angle faults, possibly related to Jurassic rifting, partly controlled subsequent glacial erosion.

Sedimentary rocks of the Ohio Range dip less than 1° to the east. Paleozoic rocks in Victoria Land are also relatively undeformed (Allen, 1962), although the Paleozoic rocks of the Pensacola Mountains, east of the Ohio Range, record multiple orogenic episodes (Schmidt, 1963).

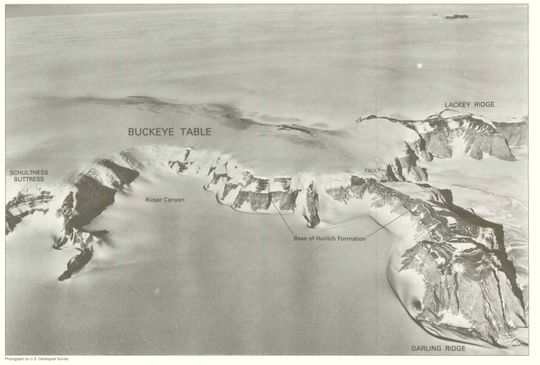
The maximum temperature and depth of burial attained in the Horlick Formation on Darling and Lackey Ridges have been estimated by analyzing the color of phosphatic fish plates, or ichthyoliths (A. G. Harris, U.S.G.S., written communication, 1983; see also Epstein and others, 1977). Assuming that a 200-m-thick Jurassic sill was about 500 m stratigraphically above the Horlick Formation on Darling and Lackey Ridges (a realistic projection from the large sill on Mt. Glossopteris), a maximum temperature as high as 150°–200° C would have been reached during a short-term (less than 1000 years) thermal pulse. If the sill did not extend as far as the area of Darling and Lackey Ridges, and the subtle alteration of fish plates from the Horlick Formation is due entirely to long-term burial, then the maximum temperature attained did not exceed about 100°. This latter temperature can be used to estimate the maximum amount of overburden by comparison with a realistic geothermal gradient (Hacquebard, 1975); a value of 4000 to 5000 m of overburden is thus obtained. Most likely, a combination of thermal and burial metamorphism affected the rocks of the Horlick Formation.

ACKNOWLEDGEMENTS

This project was generously supported by the Antarctic Division of the New Zealand Division of Scientific and Industrial Research, the Canterbury Museum Trust Board, the National Science Foundation, and the U.S. Geological Survey.

FIGURE 1.—Location diagram. E, East Antarctica; W, West Antarctica; V, Victoria Land; T, Transantarctic Mountains.

FIGURE 2.—Aerial photographs used in revision of base map.



Photograph by U.S. Geological Survey

FIGURE 4.—Oblique aerial photograph of the west end of the Ohio Range, looking south.

REFERENCES CITED

Allen, A. D., 1962, Geological investigations in southern Victoria Land, Antarctica, Part 7—Formations of the Beacon Group in the Victoria Valley region: New Zealand Journal of Geology and Geophysics, v. 5, p. 278.

Boucout, A. J., Coster, K. E., Ives, D., and Talent, J. A., 1963, Relationships of a new Lower Devonian Terebratuloid (Brachiopoda) from Antarctica: Bulletin of American Paleontology, v. 46 (207), p. 77–151.

Bradshaw, M. A., 1984, Permian nonmarine bivalves from the Ohio Range, Antarctica: Alcheringa, v. 8, p. 305–309.

Bradshaw, M. A., and McCartan, Lucy, 1983, The depositional environment of the Lower Devonian Horlick Formation, Ohio Range, in Oliver, R. L., James, P. R., and Jago, J. B., eds., Antarctic Earth Science: Canberra, Australian Academy of Science, p. 238–241.

Cridland, A. A., 1963, A *Glossopteris* flora from the Ohio Range, Antarctica: American Journal of Botany, v. 50, p. 186–195.

Dörjes, J., Gadow, S., Reineck, H-E., and Singh, I. B., 1970, Sedimentologie und makrobenthos der Nordergründe und der Aseriade (Nordsee): Senckenbergiana Maritima, v. 2, p. 31–59.

Doumani, G. A., and Tasch, P., 1965, A lealid Conchostracan Zone (Permian) in the Ohio Range, Horlick Mountains, Antarctica, in Hadley, J. B., ed., Geology and paleontology of the Antarctic, Antarctic Research Series, VOLUME 6: Baltimore, American Geophysical Union (and Garamond/Pridemark), p. 229–240.

Doumani, G. A., Boardman, R. S., Rowell, A. T., Boucout, A. J., Johnson, J. G., McAlester, A. L., Saul, J., Fisher, D. W., and Miles, R. S., 1965, Lower Devonian fauna of the Horlick Formation, Ohio Range, Antrectica, in Hadley, J. B., ed., Geology and paleontology of the Antarctic, Antarctic Research Series, VOLUME 6: Baltimore, American Geophysical Union (and Garamond/Pridemark), p. 241–281.

Epstein, A. G., Epstein, J. B., and Harris, L. D., 1977, Conodont color alteration—an index to organic metamorphism: U.S. Geological Survey Professional Paper 995, 27 p.

Frakes, L. A., Matthews, J. L., Neder, I. R., Crowell, J. C., 1966, Movement directions in Late Paleozoic glacial rocks of the Horlick and Pensacola Mountains, Antarctica: Science, v. 153, p. 746–749.

Hacquebard, P. A., 1975, Pre-and postdeformational coalification and its significance for oil and gas exploration, in Alpern, B., ed., Pétrographie de la matiele organique des sédiments, relations avec la paleotemperature et le potential pétrolier, Colloque International, Paris, 1973, published by Centre National de la Recherche Scientifique, Paris, p. 225–241.

Kemp, E. M., Balme, B. E., Helby, R. J., Kyle, R. A., Playford, G., and Price, P. L., 1977, Carboniferous palynostratigraphy in Australia and Antarctica: a review: Bureau of Mineral Resources Jour. of Australian Geol. and Geophysics, v. 2, p. 177–208.

Long, W. E., 1965, Stratigraphy of the Ohio Range, Antarctica, in Hadley, J. B., ed., Geology and paleontology of the Antarctic, Antarctic Research Series, VOLUME 6: Baltimore, American Geophysical Union (and Garamond/Pridemark), p. 71–116.

McCartan, Lucy, and Bradshaw, M. A., Petrology and sedimentology of the Horlick Formation (Lower Devonian), Ohio Range, Transantarctic Mountains, Antarctica, in press.

McDougall, I., 1963, Potassium-argon age measurements on dolerites from Antarctica and South Africa: Journal Geophysical Research, v. 68, p. 1535–1545.

Schapiro, N., and Gray, R. J., 1966, Physical variations in highly metamorphosed Antarctic coals, in P. H. Given, ed., Coal science: The American Conference on Coal Science proceeding, 1964, University Park, Pa., p. 196–210.

Schmidt, D. L., 1983, Proterozoic to Mesozoic mobile-belt geology, Pensacola Mountains, Antarctica: U.S. Geological Survey Circular 911, p. 12 and 13.

Treves, S. B., 1965, Igneous and Metamorphic Rocks of the Ohio Range, Horlick Mountains, Antarctica, in Hadley, J. B., ed., Geology and paleontology of the Antarctic, Antarctic Research Series, VOLUME 6: Baltimore, American Geophysical Union (and Garamond/Pridemark), p. 117–126.

United States Geological Survey, 1963, Topographic map of the Ohio Range, 1:250,000.

Wunderlich, Friedrich, 1970, Genesis and environment of the "Nellenköpfchenschichten" (Lower Emsian, Rheinian Devon) at Locus Typicus in comparison with modern coastal environment of The German Bay: Journal of Sedimentary Petrology, v. 40, p. 102–130.

RECONNAISSANCE GEOLOGIC MAP OF THE OHIO RANGE, TRANSANTARCTIC MOUNTAINS, ANTARCTICA

By
Lucy McCartan, U.S. Geological Survey, Reston, Va.
Margaret A. Bradshaw, Canterbury Museum, Christchurch, New Zealand
Karl S. Kellogg, U.S. Geological Survey, Denver, Co.

1986

For sale by Branch of Distribution, U.S. Geological Survey,
1200 South Eads Street, Arlington, VA 22202