Episodic Rifting of Phanerozoic Rocks in the Victoria Land Basin, Western Ross Sea, Antarctica

Abstract. *Multichannel seismic-reflection data show that the Victoria Land basin, unlike other sedimentary basins in the Ross Sea, includes a rift-depression 15 to 25 kilometers wide that parallels the Transantarctic Mountains and contains up to 12 kilometers of possible Paleozoic to Holocene age sedimentary rocks. An unconformity separates the previously identified Cenozoic sedimentary section from the underlying strata of possible Mesozoic and Paleozoic age. Late Cenozoic volcanic rocks intrude into the entire section along the eastern flank of the basin. The Victoria Land basin is probably part of a more extensive rift system that has been active episodically since Paleozoic time. Inferred rifting and basin subsidence during Mesozoic and Cenozoic time may be associated with regional crustal extension and uplift of the nearby Transantarctic Mountains.*

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The Victoria Land basin is the westernmost of several north-south trending sedimentary basins of the Ross Sea, Antarctica (Fig. 1), that are actively being studied for their crustal structure and potential mineral resources. This basin is tectonically active and lies parallel with the Transantarctic Mountains and extends at least from McMurdo Sound to Cape Washington. Previous seismic and gravity studies in the western Ross Sea (*1–4*) suggested that the Victoria Land basin contained up to 3.5 km of Tertiary age sedimentary rocks that were underlain by high-velocity (4.8 to 5.6 km/sec) Paleozoic and Precambrian igneous and metamorphic rocks. In earlier surveys, reflections from depths generally greater than 1 to 2 km could not be traced because of highly reverberant seafloor multiples. Sedimentary strata seen at great depths (up to 12 km) in the new multichannel seismic reflection data, were not previously known.

Rocks in the Victoria Land region of the Transantarctic Mountains are predominantly Proterozoic and Early Paleozoic metamorphic and silicic intrusive rocks of a basement complex that is overlain by flat-lying shallow-water sedimentary rocks of the Beacon Supergroup, Devonian to Triassic in age (*5–7*). The Beacon Supergroup is widely invaded by tholeiitic intrusives of Jurassic age and is uplifted 4 to 5 km by vertical displacements (*8*). A substantial hiatus in the geologic record appears between Jurassic and Paleogene time, as rock outcrops of these ages are not found in Victoria Land (*8, 9*). Uplift of the Transantarctic Mountains was initiated during Mesozoic time, and rapid uplift (90 m per million years) is postulated during the past 50 million years (*10*) for southern Victoria Land. The uplift history elsewhere in the Victoria Land region, however, is poorly documented and older (Paleozoic and Mesozoic) episodes of vertical motions also have been postulated (*11, 12*).

In February 1984, multichannel-seismic (24-fold, 2400 m) reflection and other geophysical data were recorded in the western Ross Sea (*13, 14*) (Fig. 1). Tracklines of the U.S. Geological Survey connect, in the east, with a 1980 West German multichannel seismic survey of the central and eastern Ross Sea (*15*). The 1984 data reveal several new features of the structure and tectonics of the Victoria Land basin and central rift.

1) The Victoria Land basin can be traced as a bathymetric and structural depression north from Ross Island to Cape Washington. In the north, the basin terminates somewhere between the onshore late Cenozoic volcano Mt. Melbourne and Coulman Island. In the south, however, the basin may continue beneath the moat-like depression (*1, 2*) that surrounds Mt. Erebus, another late Cenozoic volcano.

2) The axial part of the basin is a 15- to 25-km-wide rift depression (Fig. 2) that is bordered on both sides by zones of predominately normal faults. In most lines across the basin, these faults dip toward the basin axis and are most highly concentrated along the eastern side of the central rift; however, in at least one part of the basin's eastern side (line 407 in Fig. 2), the faults dip eastward away

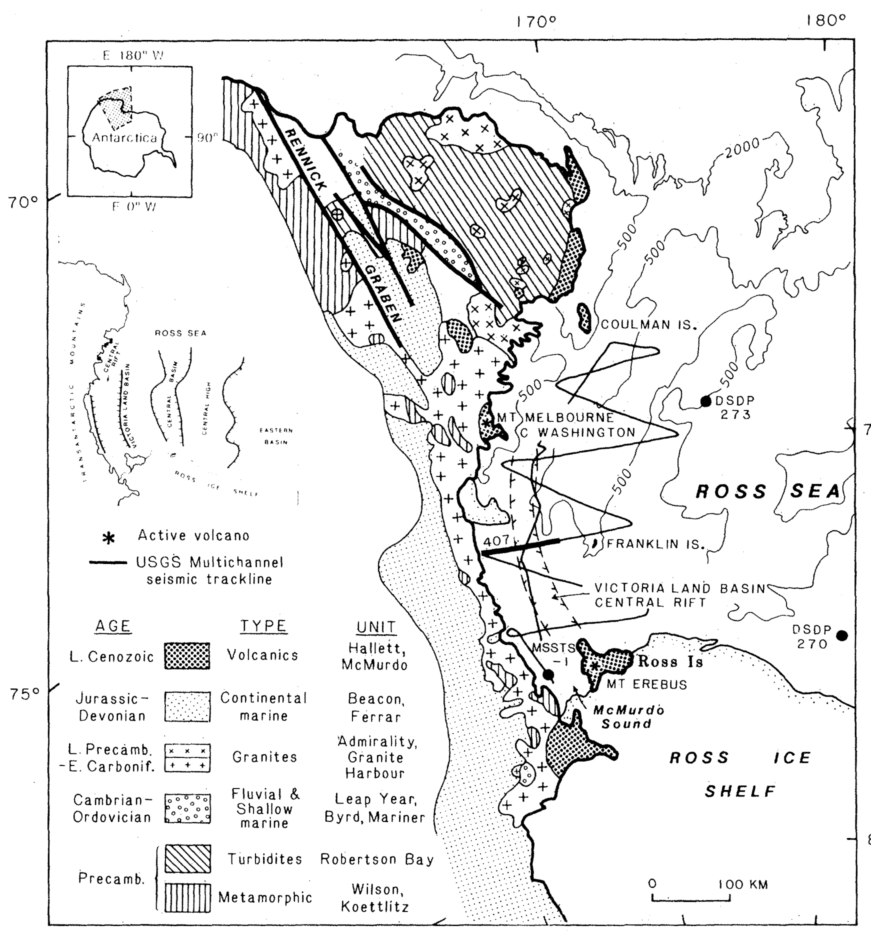

Fig. 1. Index map of the western Ross Sea region showing onshore geology of Victoria Land (*5, 9*), offshore location of the U.S. Geological Survey multichannel seismic-reflection tracklines, and location of seismic line 407 (Fig. 2).

from the axis and toward nearby intrusions of magmatic rocks. The faults appear to cut sedimentary rocks near the seafloor and to show an increasing displacement with depth.

3) The deformational style differs beneath the eastern and western flanks of the Victoria Land basin. The eastern flank is characterized by a highly faulted sedimentary section, with locally irregular bathymetric relief, and by intrusions of igneous rocks, presumably correlatives of the late Cenozoic volcanic rocks found on Coulman Island, Franklin Island, and in the McMurdo Sound region. In contrast, the western flank of the basin is relatively undeformed. Laterally continuous sedimentary rocks are gently uplifted above an inclined block-faulted acoustic-basement surface, and intrusive volcanic rocks are not observed except locally near Cape Washington and Ross Island.

4) In the central rift of the Victoria Land basin, the stratified sedimentary section reaches thicknesses of up to 12 km. The upper part (seafloor to horizon B, Fig. 2) is 5 to 6 km thick and has seismic velocities from 1.7 to 4.9 km/sec (sonobuoy S-29, Fig. 2). A deeper, and previously unknown, stratified sequence lies beneath the basin's bedrock horizon (horizon B, seismic velocity about 5.6 km/sec, Fig. 2) and fills the lower parts of the basin with an additional 5 to 7 km of presumed sedimentary rock. An angular unconformity separates the upper and lower sedimentary sections along the western flank. The eastward extension of this unconformity is difficult to trace into the central and eastern parts of the basin.

5) Gravity data show a prominent negative (−60 mgal) free-air anomaly, with locally steep gradients, over the central rift of the basin. The gradients correspond with the fault zones that border the central rift (Fig. 2). Negative gravity values over shallow basement (horizon C, Fig. 2) rocks at the western edge of the basin can be explained by a westward increase in crustal thickness beneath the Transantarctic Mountains (*3*, *16*).

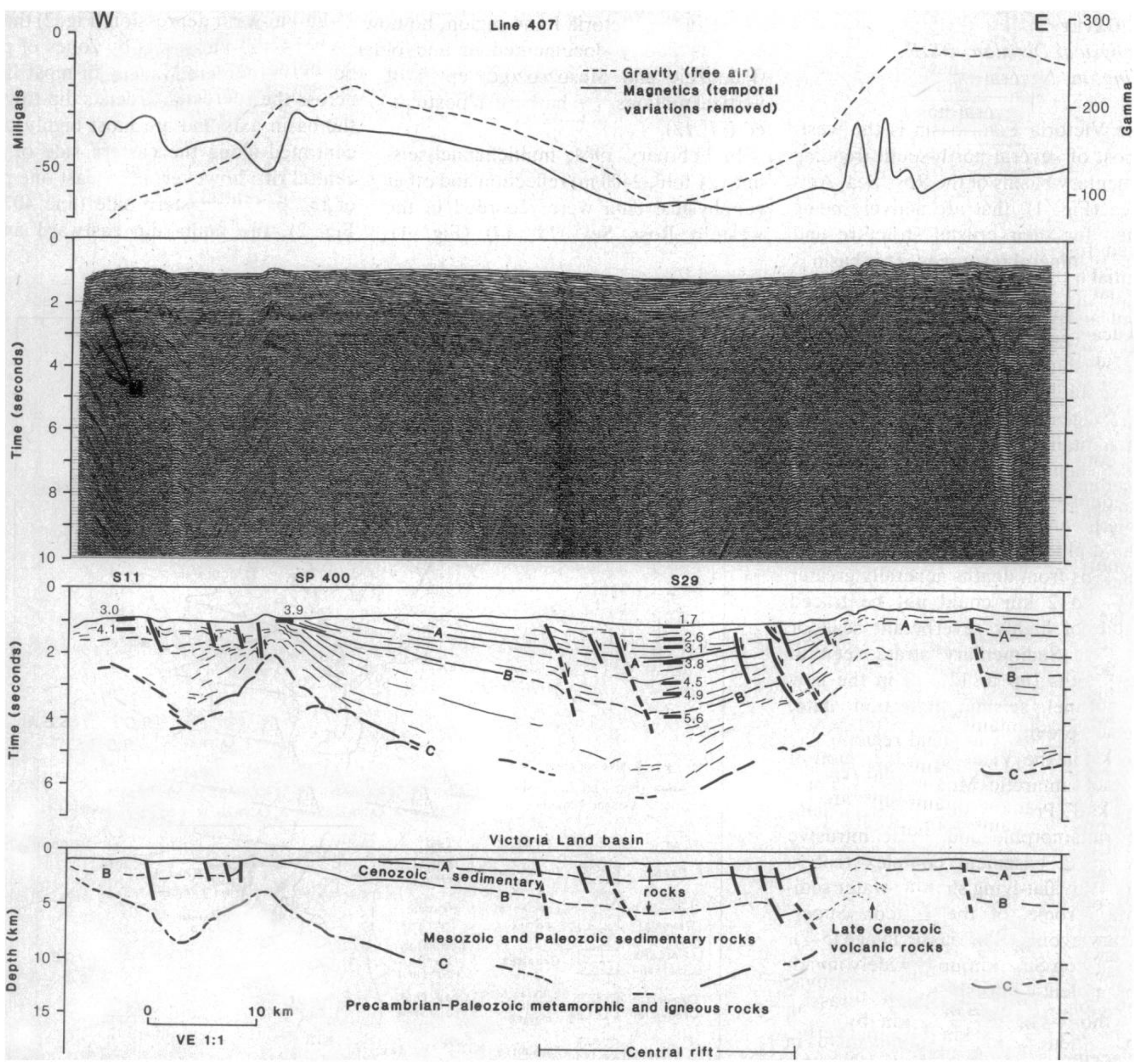

Fig. 2. Multichannel seismic-reflection and other geophysical data for line 407 in the Victoria Land basin. Refraction velocities (in kilometers per second) from sonobuoys (S11 and S29) and multichannel seismic field-gathers (SP400) were used in making the interpretive depth section. The multichannel seismic data have numerous seafloor multiple-reflections (M), but many layered reflection events at depths up to 12 km (6 seconds) are real and are interpreted as sedimentary rocks. Reflection horizons: A is a reference horizon of about late Oligocene age; B is sedimentary bedrock, formerly called basement, and may be a late Mesozoic to early Cenozoic unconformity; and C is the top of igneous and metamorphic basement.

6) Magnetic-gradiometer data, which have had magnetic temporal variations removed (*17*), show narrow large-amplitude anomalies above seismically deformed zones that lie beneath the eastern edge of the basin's central rift. These magnetic anomalies are evidence that local magmatic intrusive bodies lie at shallow subsurface depths.

The age of sedimentary rocks in the Victoria Land basin is poorly constrained because of the absence of offshore rock samples. By projection of seismic horizons from MSSTS-1 drill site (western McMurdo Sound, Fig. 1) to the center of McMurdo Sound, the upper 800 m of the sedimentary section is probably late Oligocene or younger near the southern end of the basin (*18, 19*); near line 407 in the central basin, the upper 1000 to 2000 m may be of equivalent age (above horizon A, Fig. 2). Projection of the late Oligocene and younger horizons from DSDP sites 270 and 273 (Fig. 1) (*20*) into the basin's central rift is not possible because of intervening basement highs and sedimentary structures.

In the central rift, nearly 4 to 5 km of high-velocity (3.1 to 4.9 km/sec) sedimentary rock lies beneath the postulated late Oligocene horizon and above the bedrock unconformity (horizon B, Fig. 2). These velocities are typical of marine Paleogene rocks (*21*) as well as nonmarine Devonian to Jurassic Beacon Supergroup rocks (*21, 22*). Hence, the age of sedimentary rocks in the Victoria Land basin cannot be established solely on the basis of velocity. We favor a Paleogene and possible Cretaceous age for the upper part of the sedimentary section (above horizon B, Fig. 2) because the acoustic characteristics of this part of the section [subparallel reflection horizons (Fig. 2) and a smooth increase in velocity with depth suggest continuous deposition] and uniform compaction (*4, 23*). Also, Paleogene and Cretaceous glacial erratic rocks are found in surrounding areas (*8, 19, 24*).

The bedrock unconformity (horizon B, Fig. 2) marks a hiatus that may be equivalent in places with the Jurassic to Tertiary hiatus noted onshore (*8, 9*). This interpretation implies that the lower 6 to 7 km of the stratified section contains Beacon Supergroup and possibly older Paleozoic layered sedimentary rocks. An alternative interpretation, which cannot be ruled out, is that this lower section also contains Cretaceous rocks that were deposited in a rift-depression related to the breakup of Gondwana.

We favor a pre-Cretaceous age for most of the lower sedimentary section because, onshore near the western end of line 407 (Fig. 1), the Cretaceous and Paleogene sedimentary sections are missing, whereas regionally extensive flat-lying Beacon rocks are present and overlie Paleozoic granitic basement. In this area, Beacon rocks may have been continuous with the offshore section before the uplift and erosion of the eastern flank of the Transantarctic Mountains. Onshore, the Beacon rocks reach a thickness of only 2.5 km (*7*), consequently the thicker offshore section may also include earlier Paleozoic and possibly Late Mesozoic rocks.

The new geophysical data from the Victoria Land basin show features that are commonly associated with areas of active crustal extension and rifting—such as tilted and block-faulted basement and sedimentary rocks, intrusion of volcanic rocks along narrow fault zones, high heat-flow (*14*), and a narrow graben beneath the axis of the basin. The late Cenozoic volcanics found on Ross Island, at Cape Washington, and inferred to occur in the Victoria Land basin, lie along a north-south trend and appear to be part of a more extensive rift zone located along the eastern side of the Transantarctic Mountains.

The Rennick graben of north Victoria Land is a major extensional structure that lies 150 km to the northwest of the Victoria Land basin. The basin and Rennick graben exhibit some geometric similarities (Fig. 1), yet the relations between these two features are unclear. Kyle and Cole (*25*) suggest that the Rennick fault, on the western side of the Rennick graben, may continue south to run along the eastern side of the Transantarctic Mountains of southern Victoria Land. However, the southern extension of this fault may form the western margin of the central rift of the basin. The faulting in the Rennick graben is believed to be Late Jurassic to Early Cretaceous in age, with possible neotectonic reactivation (*12*). In the Victoria Land basin, the faulting extends up to the late Cenozoic in age. The region between the basin and Rennick graben, however, is high-standing granitic basement, and there is at present no apparent structural connection between them.

The most recent episode of rifting in the basin may have commenced in Early to Middle Tertiary time; this interpretation is based on the observation that growth faults displace the upper 5 to 6 km of the sedimentary section (Cenozoic). The initial part of this rifting episode predates the earliest emplacement of the Cenozoic volcanism [15 million years ago (*26*)] and thereby indicates that the early part of the faulting episode is not related to igneous activity but is probably associated with early periods of Cenozoic extensional tectonics and uplift of the Transantarctic Mountains.

In the multichannel seismic data, vertical offsets on faults in the Victoria Land basin central rift appear to increase with depth throughout the sedimentary section, which suggests that faulting has been active episodically in Paleogene, Mesozoic, and possibly earlier times. These earlier periods of faulting in the basin may be similar to those suggested for the Rennick graben and the two structures may be part of the same rift system. We suggest, therefore, that at least part of the older sedimentary section in the Victoria Land basin may have been deposited in a Mesozoic rift zone that was once continuous with the Rennick graben and that this rift zone has subsequently been segmented near Cape Washington by the Tertiary uplift of the Transantarctic Mountains.

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