# The Mesozoic Victoria Basin: Vanished link between Antarctica and Australia

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## ABSTRACT

**The Transantarctic Mountains (TAM) are the largest non-compressional mountain belt in the world. Their origin is traditionally related to crustal thickening during the Jurassic Ferrar magmatic event that was followed by episodic uplift in the Early and Late Cretaceous and since the Paleocene. This concept of a long-lived morphological high constitutes a base of virtually all Gondwana reconstructions and global climate models. Here we demonstrate that crossover age relationships between thermochronological (apatite fission track) data and stratigraphic information contradict this established interpretation. Instead these data, together with a wealth of independent thermal indicators and geological evidence require the existence of a vast intra-Gondwana basin between at least Late Triassic and Late Cretaceous times, including during the Ferrar magmatic event. Referred to here as the Mesozoic Victoria Basin (MVB), this basin formed during crustal extension across the paleo-Pacific margin of Antarctica and Australia. Uplift of the TAM with associated basin inversion commenced only with the development of the West Antarctic Rift System in Paleogene times. The recognition of the long-lived MVB has primary consequences for the general understanding of the landscape of Gondwana and the breakup between Antarctica and Australia, West Antarctic rifting and uplift of the TAM, and global long-term climate evolution and faunal radiation.**

## INTRODUCTION

The Transantarctic Mountains (TAM) are an ~3500-km-long and up to 5000-m-high mountain chain located in the climatically most sensitive region of the planet (Fig. 1). They divide Antarctica into the Precambrian East Antarctic Craton and the terrane assemblage of West Antarctica. Regional geology is characterized by variably metamorphosed basement rocks that are unconformably overlain by Devonian to Early Jurassic sedimentary rocks of the Beacon Supergroup (e.g., Barrett, 1991). The Beacon Supergroup comprises terrestrial clastic and shallow marine strata deposited on a low-relief peneplain within the Transantarctic Basin (Collinson et al., 1994). The Beacon sequence was then intruded and/or covered by Jurassic tholeiites of the Ferrar Group (e.g., Elliot and Fleming, 2008; Fig. 2). These mafic rocks, dated at ca. 180 Ma, define part of a magmatic province that extends from South Africa to Tasmania. The only preserved rocks overlying the Ferrar Group are minor deposits of Neogene volcanic rocks and shallow marine and glacial sediments.

The origin of the TAM has been related to rifting of the West Antarctic Rift System and the opening of the Ross Sea due to late Mesozoic and Cenozoic extension between East and West Antarctica (e.g., Cande et al., 2000). However, the poor regional deposition record does not allow to reconstructing the uplift and exhumation history of the TAM by means of traditional stratigraphic methods. Instead, it depends on indirect evidence, most notably apatite fission-track (AFT) analysis. This thermochronological technique is based on the accumulation of lattice defects (fission tracks) in apatites (e.g., Lisker et al., 2009). Fission tracks remain preserved in apatites below temperatures of ~110 °C. Cooling of rocks to these temperatures usually refers to exhumation or postmagmatic thermal relaxation.

Exhumation of the TAM is constrained from more than 500 AFT ages and track length data (reviewed by Fitzgerald, 2002; Lisker, 2002).

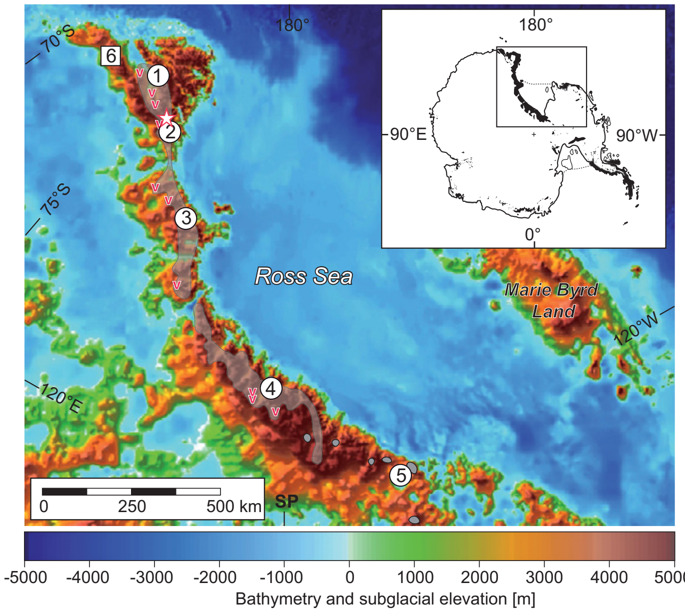


**Figure 1. Topographic and bathymetric map of part of the Transantarctic Mountains and the Ross Sea. Gray overlay shows distribution of Beacon Supergroup and Jurassic Ferrar igneous rocks; symbol "v" indicates the occurrence of Ferrar lava flows (after Elliot and Fleming, 2008). Numbered circles mark the target areas of apatite fission-track studies on basement rocks beneath Beacon/ Ferrar volcanic rocks listed in the text. 1—northern Victoria Land; 2—Terra Nova Bay (Fig. 2); 3—southern Victoria Land; 4—central Transantarctic Mountains; 5—Scott Glacier region; 6—USARP Mountains (cf. Fitzgerald, 2002, and Lisker, 2002). Red star refers to the Eisenhower Range depicted in Figure 2. SP—South Pole.**

These data are interpreted in terms of episodic cooling, related to tectonically triggered exhumation stages during the Early Cretaceous, Late Cretaceous, and Cenozoic (Fitzgerald, 2002; Fig. 3). This concept of episodic exhumation of the TAM since the Jurassic provides the base of all attempts to explain the evolution of the West Antarctic Rift System, the base of paleogeographic reconstructions, and the base of long-term climate evolution models (e.g., Sewall et al., 2000).

Though, an evaluation of the AFT data unveils a number of inconsistencies with the assumption of episodic uplift since the Early Cretaceous. These are as follows: (1) Traditional cooling histories qualitatively deduced from AFT data are not reproducible by thermal history modeling; (2) a compilation of the thermal histories from individual sample suites reveals a diachronous cooling pattern along the TAM rather than three discrete and regionally consistent cooling events (Fig. 3); (3) the postulated exhumation episodes cannot be recognized uniformly along the TAM (Fig. 3), indicating a more spatially complex uplift history (e.g., Fitzgerald, 2002; Lisker, 2002); (4) Cretaceous extension and exhumation along the axis of the TAM contrasts with coeval extension across the juxtaposed Australian margin (e.g., Willcox and Stagg, 1990); and (5) the preservation of a fluvial drainage system that developed onto a flat to subdued early Cenozoic landscape (e.g., Baroni et al., 2005).

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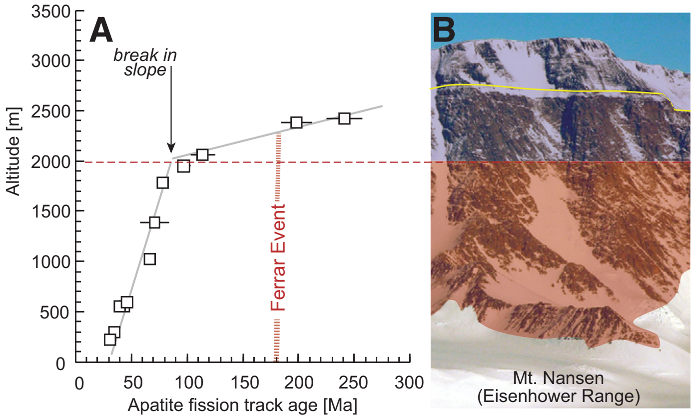


**Figure 2. Discordance of apatite fission-track (AFT) data and Ferrar emplacement ages. A: Tight correlation of AFT ages versus altitude from the Eisenhower Range/Terra Nova Bay (from Balestrieri et al., 1994). Note the distinctive break in slope, and the missing thermal signature of the Ferrar emplacement (dashed red line). This profile is representative for AFT studies from the Transantarctic Mountains. B: Mount Nansen segment of the Eisenhower Escarpment. Yellow-marked nonconformity separates ca. 500 Ma granitic basement from Triassic–Jurassic Beacon sediments and Ferrar volcanic rocks. Red-colored basement rocks were subjected to pre-Cenozoic temperatures >110 °C or burial depths >4 km subsequent to the Ferrar Event. Bluish-shadowed rocks above the break in slope did not experience post-Jurassic temperatures >110 °C. The thermal overprint of these rocks increases with depth.**

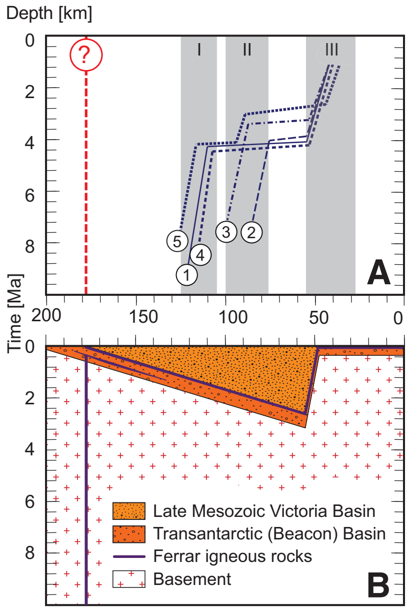


**Figure 3. Contrasting burial and exhumation scenarios of the Transantarctic Mountains. A: Traditional monotonous cooling concept (modified after Fitzgerald, 2002) comprising distinctive uplift and exhumation stages during the Early Cretaceous (I), Late Cretaceous (II), and early Cenozoic (III). Postulated exhumation paths are calibrated for samples just below the Jurassic surface; numbers of paths refer to locations in Figure 1. Question mark at 180 Ma points to the contradiction between superficial Ferrar emplacement and supposed coeval exhumation from greater depths. Note the diachronous course and the missing structural trend of the "exhumation" paths. B: Burial within the Mesozoic Victoria Basin (MVB) and Cenozoic exhumation based on the timing of Ferrar effusion (red dashed line) and apatite fission-track data. Maximum burial depth, heat flow, and timing of exhumation may vary along the MVB.**

Most striking, however, is the fundamental mismatch between the implied uplift history and the observed stratigraphic record. A comparison of thermochronological data and stratigraphic ages reveals crossover relationships between both age types. This paper highlights this contradiction, and proposes a new model for the evolution of the Antarctic-Australian sector within Gondwana that is more consistent with available thermochronologic, petrologic, and geomorphologic data.

## THE JURASSIC PALEOSURFACE AND ITS SIGNIFICANCE

A critical observation along the length of the TAM is the presence of a Jurassic paleosurface at the base of Ferrar lava flows. The subaerial nature of this surface has been established by the presence of basaltic tuffs in stratified, fossil-bearing sequences, by pillows and diatremes, and by the content of vesicles and chilled contacts of sediment suspensions in sills (e.g., Elliot and Fleming, 2008).

AFT analyses of rocks beneath the Ferrar volcanics and Beacon sandstones have been conducted from each segment of the TAM (Fig. 1): in Victoria Land including the Terra Nova Bay region (Eisenhower Range: Fig. 2), the central TAM, and the Scott Glacier region (cf., Fitzgerald, 2002 and Lisker, 2002). All age results were obtained from vertical sample profiling of high-standing escarpments. The AFT ages vary between ca. 40 and 350 Ma, and show a common and distinctive relationship with altitude (Fig. 2). Ages from the lower section of the vertical profiles are relatively young (i.e., 40–80 Ma) and display little increase with elevation. Such a steep age regression indicates complete annealing of preexisting fission tracks by heating above 110 °C some time before 80 Ma. Assuming a conventional geothermal gradient of ~25 °C/km, samples were buried to depths of 4 km or more prior to 80 Ma.

In contrast, AFT ages from upper profile sections show a shallow regression with topographic altitude (Fig. 2). Apatites from samples there contain a large portion of short, partially annealed tracks indicating pre-Cenozoic temperatures below 110 °C that decrease systematically toward the base of the Ferrar volcanics. This indicates that these rocks were buried prior to the Paleocene, but not to the depths required to completely anneal preexisting fission tracks in apatites. Because the overlying Ferrar lavas were at the surface in the Jurassic (e.g., Elliot and Fleming, 2008), the data collectively indicate that the Jurassic surface was buried by up to ~4 km between 180 Ma and at least 80 Ma.

Burial of the Ferrar paleosurface is consistent with a number of independent studies. Ballance and Watters (2002) and Bernet and Gaupp (2005) described diagenetic features in Beacon sandstones, which indicate post-Ferrar temperatures of 200–300 °C. Fleming et al. (1992) recognized low-temperature Cretaceous alteration within Ferrar lava flows, while Rb-Sr, K-Ar, and Ar/Ar ages between 90 and 175 Ma reflect post-Ferrar perturbation of the respective isotopic systems (e.g., Faure and Mensing, 1993; Molzahn et al., 1999). Similar alteration temperatures were inferred from secondary mineral parageneses, such as secondary micas in lava flows and zeolite assemblages (e.g., Hornig, 1993; Elliot and Fleming, 2008). Paleomagnetic studies document varying virtual geomagnetic pole positions in northern Victoria Land that were related to a Cretaceous thermal event with temperatures of 150–250 °C (e.g., Faure and Mensing, 1993).

## BURIAL OF THE TRANSANTARCTIC BASIN

Diachronous heating of a Jurassic surface is not compatible with the established model of thickened continental crust uplifted episodically since the Jurassic (e.g., Fitzgerald, 2002) or with a Cretaceous thermal event affecting undisturbed basement (Molzahn et al., 1999). It similarly cannot be explained with the effusion of thick, hot lava flows as suggested by Jacobs and Lisker (1999) for a similar setting in Dronning Maud Land because AFT annealing increases from the surface toward the lower section of the vertical profiles, and any potential kilometer-thick lava flow would be far too weathering-resistant to account for rapid early Cenozoic erosion.

Instead, paleotemperature distribution requires burial by a post-Ferrar sedimentary pile that was eroded long after any thermal effects from the basalt emplacement. This now-removed rock section was deposited within a sedimentary Gondwana basin that likely initiated as the Transantarctic Basin since the Devonian (cf., Collinson et al., 1994). The emplacement of the Ferrar suite did not mark the termination of subsidence, nor did it cause any significant crustal thickening. Instead, this magmatic event occurred as part of an ongoing process of long-lasting crustal thinning, subsidence, and sediment accumulation.



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First-order estimates of basin depth can be derived from the change of the AFT age regression with altitude (Fig. 2), which indicates a relatively stable thermal regime with basal basin temperatures of ~100 °C prior to Cenozoic cooling/exhumation. A geothermal gradient of ~25 °C/km (Lisker et al., 2006) refers to maximum basin depths of 2.5–5 km. The Paleocene cooling stage is consistently observed along the TAM and is clearly related to exhumation. As argued by earlier studies, this most probably was tectonically induced by rifting of the West Antarctic Rift System and associated uplift of the TAM. High erosion rates of up to 1 km/m.y. suggest that most of the removed overburden likely consisted of poorly consolidated sedimentary rocks. Exhumation stagnated with the re-exposure of the much more competent Ferrar or basement rocks beneath the Beacon deposits, and was then compensated isostatically by basement uplift along the TAM.

In the context of this concept, locally observed elevated paleotemperatures and cooling stages throughout Cretaceous times represent local heat flow variation and short-term heat spikes rather than exhumation stages.

## THE MESOZOIC VICTORIA BASIN

Persistent Mesozoic sedimentation in the TAM region is supported by various geological evidence between western Ross Sea and southeastern Australia. The paleontological record of the Cenozoic deposits on the Pacific Antarctic shelf and the Ross Sea is dominated by recycled Cretaceous and Paleocene spores and pollen (e.g., Truswell and Drewry, 1984; Fig. 4). The occurrence of such a common palynomorph assemblage at both shelf sections, and provenance indications within Ross Sea deposits, require substantial Cretaceous overburden on the present TAM.

Juxtaposed to the Ross Sea margin of Antarctica is a series of Mesozoic depocenters aligned along the southern Australian shelf, with Bremer Basin, Great Australian Bight, Duntroon Basin, and Otway–Bass–Gippsland basins being the most important ones (Fig. 4). These basins contain up to 15 km of Jurassic and Early Cretaceous sediments on crystalline basement. The deposition of these rocks during Late Jurassic–Early Cretaceous transtension along the present Australian-Antarctic margins (Willcox and Stagg, 1990) suggests the existence of a similar sediment package on the Antarctic coast.

AFT data and vitrinite reflectance contours also imply the existence of a kilometer-scale cover of Jurassic–Cretaceous sediments between southern Victoria Land and southern Queensland (e.g., Kohn et al., 2002).

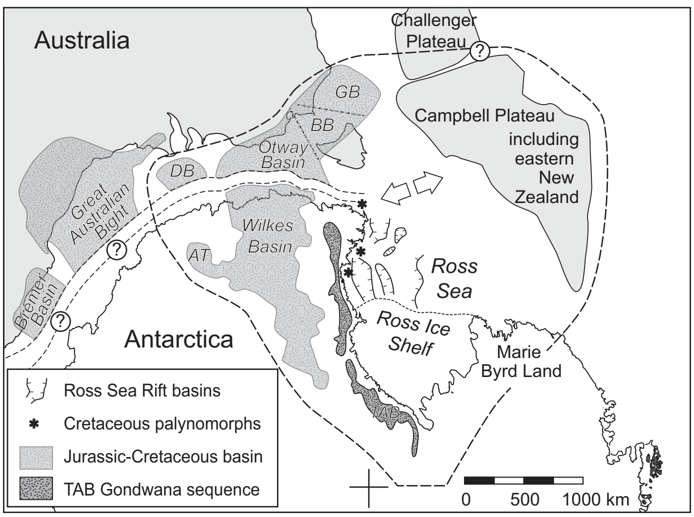


**Figure 4. Outline of the extent of the Mesozoic Victoria Basin between Antarctica and Australia (dashed line), compiled after Ferraccioli et al. (2009) and Boger (2011). AT—Aurora Trench; BB—Bass Basin; DB—Duntroon Basin; GB—Gippsland Basin; TAB—Transantarctic Basin.**

In proximity to the Ross Sea, Tasmania hosts a suite of Jurassic dolerites equivalent to the Antarctic Ferrar rocks. Secondary zeolite assemblages within these dolerites (Sutherland, 1977) and AFT data of host rocks (O'Sullivan et al., 2000) imply regional burial to depths of 1.6–2.2 km subsequent to Jurassic extrusion.

The observations described here suggest the existence of an extensive Jurassic to Cretaceous basin that covered large areas of Pacific Gondwana. The basin stretched from the interior of southeastern Australia along the whole length of the Ross Sea embayment. In the west, it extends beyond the Wilkes Basin / Aurora Trench, which are filled with Permian to Cenozoic sediments (Ferraccioli et al., 2009; Fig. 4). A structural high between Wilkes Basin and the TAM was also covered by more than 2 km of post-Jurassic overburden (Lisker et al., 2006). Toward the east, the basin likely comprised Marie Byrd Land, where a West Antarctic Erosion Surface (Le Masurier and Landis, 1996) may represent the former basin floor. There, it may have also incorporated parts of the large submarine terranes underlying New Zealand (Campbell and Challenger plateaus; Fig. 4). Given that the published literature uses the term "Transantarctic Basin" to describe the relatively thin pre-Jurassic Beacon sequence of the TAM, we define the overlying but now largely vanished intra-Gondwana basin as the "Mesozoic Victoria Basin" (MVB).

## IMPLICATIONS OF THE MESOZOIC VICTORIA BASIN

The recognition of the long-lived MVB has primary consequences for the general understanding of (1) the landscape of Gondwana and the breakup between Antarctica and Australia, (2) West Antarctic rifting and uplift of the TAM, and (3) the global long-term climate evolution and faunal radiation.

(1) The longevity of the MVB implies the presence of a relatively stable regional stress field dominated by east-west extension, which probably results from the clockwise rotation of Gondwana and the sheared breakup between Antarctica and Australia. In such a setting, the emplacement of Ferrar rocks across Antarctica at ca. 180 Ma does not represent an extraordinary event, but only an episode during a long-lasting extension process.

(2) Persistent extension and crustal thinning below the MVB provides a stringent evaluation criterion for models explaining the evolution of the TAM. For example, the MVB excludes a TAM as a remnant of a Mesozoic Ross Sea highland (e.g., Bialas et al., 2007) because this scenario requires long-term Mesozoic exhumation instead of the accumulation of a kilometer-thick sedimentary sequence. The stable paleotemperature pattern also does not support models confining TAM uplift to mainly thermal processes (e.g., Smith and Drewry, 1984), while models involving mechanically driven uplift (e.g., Salvini et al., 1997) may be generally compatible. The transition from the MVB to the present-day Ross Sea can then be described by diffuse extension beneath the West Antarctic Rift System followed by focused rifting near the East-West Antarctic boundary without any significant change in the general tectonic regime (e.g., Huerta and Harry, 2007).

(3) Published long-term climate models usually rely on a permanent Antarctic topography resembling the present-day one. Our scenario provides a much more realistic base for future paleoclimate models. A direct consequence of the MVB refers to the probability of late Mesozoic glaciations. Behrendt and Cooper (1991) argued that the uplift of the TAM significantly contributed to early Cenozoic climate deterioration. Similarly, substantial Cretaceous uplift of a mountain chain or highland at polar latitudes, as assumed by traditional scenarios, would very likely trigger climate cooling and glaciation within Gondwana. In contrast, a stable MVB deposited in subaerially exposed lowlands, potentially including shallow seas, would have enabled marine communication between East and West Antarctica, providing a source for heat transport to the polar center of Antarctica. An additional crucial aspect is the high efficiency of mountains as barriers to faunal radiation, that does not apply to basin settings.



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## REFERENCES CITED

Balestrieri, M.L., Bigazzi, G., Ghezzo, C., and Lombardo, B., 1994, Fission track dating of apatites from the Granite Harbour Intrusive Suite and uplift-denudation history of the Transantarctic Mountains in the area between the Mariner and David Glaciers (northern Victoria Land, Antarctica): Terra Antartica, v. 1, p. 82–87.

Ballance, P.F., and Watters, W.A., 2002, Hydrothermal alteration, contact metamorphism, and authigenesis in Ferrar Supergroup and Beacon Supergroup rocks, Carapace Nunatak, Allan Hills, and Coombs Hills, Victoria Land, Antarctica: New Zealand Journal of Geology and Geophysics, v. 45, p. 71–84, doi:10.1080/00288306.2002.9514960.

Baroni, C.N., Ciccacci, V., Righini, S., Giovanni, S., and Cristina, M., 2005, Fluvial origin of the valley system in northern Victoria Land (Antarctica) from quantitative geomorphic analysis: Geological Society of America Bulletin, v. 117, p. 212–228, doi:10.1130/B25529.1.

Barrett, P.J., 1991, The Devonian to Triassic Beacon Supergroup of the Transantarctic Mountains and correlatives in other parts of Antarctica, *in* Tingey, R.J., ed., The Geology of Antarctica: Oxford, UK, Oxford University Press, p. 120–152.

Behrendt, J.C., and Cooper, A., 1991, Evidence of rapid Cenozoic uplift of the shoulder scarpment of the Cenozoic West Antarctic rift system and a speculation on possible climate forcing: Geology, v. 19, p. 315–319, doi:10.1130/0091-7613(1991)019<0315:EORCUO>2.3.CO;2.

Bernet, M., and Gaupp, R., 2005, Diagenetic history of Triassic sandstone from the Beacon Supergroup in central Victoria Land, Antarctica: New Zealand Journal of Geology and Geophysics, v. 48, p. 447–458, doi:10.1080/00288306.2005.9515125.

Bialas, R.W., Buck, W.R., Studinger, M., and Fitzgerald, P.G., 2007, Plateau collapse model for the Transantarctic Mountains–West Antarctic Rift System: Insights from numerical experiments: Geology, v. 35, p. 687–690, doi:10.1130/G23825A.1.

Boger, S.D., 2011, Antarctica—Before and after Gondwana: Gondwana Research, v. 19, p. 335–371, doi:10.1016/j.gr.2010.09.003.

Cande, S.C., Stock, J.M., Müller, R.D., and Ishihara, T., 2000, Cenozoic motion between East and West Antarctica: Nature, v. 404, p. 145–150, doi:10.1038/35004501.

Collinson, J.W., Isbell, J.L., Elliot, D.H., Miller, M.F., Miller, J.M.G., and Veevers, J.J., 1994, Permian-Triassic Transantarctic Basin: Geological Society of America Memoir 184, p. 173–222.

Elliot, D.H., and Fleming, T.H., 2008, Physical volcanology and geological relationships of the Jurassic Ferrar Large Igneous Province, Antarctica: Journal of Volcanology and Geothermal Research, v. 172, p. 20–37, doi:10.1016/j.jvolgeores.2006.02.016.

Faure, G., and Mensing, T.M., 1993, K-Ar dates and paleomagnetic evidence for Cretaceous alteration of Mesozoic basaltic lava flows, Mesa Range, northern Victoria Land, Antarctica: Chemical Geology, v. 109, p. 305–315, doi:10.1016/0009-2541(93)90077-V.

Ferraccioli, F., Armadillo, E., Jordan, T.A., Bozzo, E., and Corr, H., 2009, Aeromagnetic exploration over the East Antarctic Ice Sheet: A new view of the Wilkes Subglacial Basin: Tectonophysics, v. 478, p. 62–77, doi:10.1016/j.tecto.2009.03.013.

Fitzgerald, P.G., 2002, Tectonics and landscape evolution of the Antarctic plate since the breakup of Gondwana, with an emphasis on the West Antarctic Rift System and the Transantarctic Mountains: Royal Society of New Zealand Bulletin, v. 35, p. 453–469.

Fleming, T.H., Elliot, D.H., Jones, L.M., Bowman, J.R., and Siders, A.M., 1992, Chemical and isotopic variations in an iron-rich lava-flow from the Kirkpatrick Basalt, north Victoria Land, Antarctica: Implications for low-temperature alteration: Contributions to Mineralogy and Petrology, v. 111, p. 440–457, doi:10.1007/BF00320900.

Hornig, I., 1993, High-Ti and Low-Ti Tholeiites in the Jurassic Ferrar Group: Antarctica, *in* Danske, D., and Fritsch, J., eds., German Antarctic North Victoria Land Expedition, 1988/89, Ganovex V: Geologisches Jahrbuch, Reihe E, v. 47, p. 335–369.

Huerta, A.D., and Harry, D.L., 2007, The transition from diffuse to focused extension: Modeled evolution of the West Antarctic Rift system: Earth and Planetary Science Letters, v. 255, p. 133–147, doi:10.1016/j.epsl.2006.12.011.

Jacobs, J., and Lisker, F., 1999, Post Permian tectono-thermal evolution of western Dronning Maud Land, E-Antarctica: An apatite fission-track approach: Antarctic Science, v. 11, p. 451–460, doi:10.1017/S0954102099000589.

Kohn, B.P., Gleadow, A.J.W., Brown, R.W., Gallagher, K., O'Sullivan, P.B., and Foster, D.A., 2002, Shaping the Australian crust over the last 300 million years: Insights from fission track thermotectonic imaging and denudation studies of key terranes: Australian Journal of Earth Sciences, v. 49, p. 697–717, doi:10.1046/j.1440-0952.2002.00942.x.

LeMasurier, W.E., and Landis, C.A., 1996, Mantle plume activity recorded by low relief erosion surfaces in west Antarctica and New Zealand: Geological Society of America Bulletin, v. 108, p. 1450–1466, doi:10.1130/0016-7606(1996)108<1450:MPARBL>2.3.CO;2.

Lisker, F., 2002, Review of fission track studies in northern Victoria Land—Passive margin evolution versus uplift of the Transantarctic Mountains: Tectonophysics, v. 349, p. 57–73, doi:10.1016/S0040-1951(02)00046-X.

Lisker, F., Läufer, A., Rossetti, F., Olesch, M., and Schäfer, T., 2006, The Transantarctic Beacon Basin: New insights from fission track data and structural data from the USARP Mountains and adjacent areas (northern Victoria Land, Antarctica): Basin Research, v. 18, p. 497–520, doi:10.1111/j.1365-2117.2006.00301.x.

Lisker, F., Ventura, B., and Glasmacher, U.A., 2009, Thermochronological methods: From paleotemperature constraints to landscape evolution models: Geological Society of London Special Publications, v. 324, p. 181–192.

Molzahn, M., Wörner, G., Henjes-Kunst, F., and Rocholl, A., 1999, Constraints on the Cretaceous thermal event in the Transantarctic Mountains from alteration processes in Ferrar flood basalts: Global and Planetary Change, v. 23, p. 45–60, doi:10.1016/S0921-8181(99)00050-8.

O'Sullivan, P.B., Mitchell, M.M., O'Sullivan, A.J., Kohn, B.P., and Gleadow, A.J.W., 2000, Thermotectonic history of the Bassian Rise, Australia; Implications for the breakup of eastern Gondwana along Australia's southeastern margins: Earth and Planetary Science Letters, v. 182, p. 31–47, doi:10.1016/S0012-821X(00)00232-6.

Salvini, F., Brancolini, G., Busetti, M., Storti, F., Mazzarini, F., and Coren, F., 1997, Cenozoic geodynamics of the Ross Sea region, Antarctica: Crustal extension, intraplate strike-slip faulting and tectonic inheritance: Journal of Geophysical Research, v. 102, p. 24,669–24,696.

Sewall, J.O., Sloan, L.C., Huber, M., and Wing, S., 2000, Climate sensitivity to changes in land surface characteristics: Global and Planetary Change, v. 26, p. 445–465, doi:10.1016/S0921-8181(00)00056-4.

Smith, A.G., and Drewry, D.J., 1984, Delayed phase change due to hot asthenosphere causes Transantarctic uplift?: Nature, v. 309, p. 536–538, doi:10.1038/309536a0.

Sutherland, F.L., 1977, Zeolite minerals in the Jurassic dolerites of Tasmania: Their use as possible indicators of burial depth: Journal of the Geological Society of Australia, v. 24, p. 171–178, doi:10.1080/00167617708728977.

Truswell, E.M., and Drewry, D.J., 1984, Distribution and provenance of recycled palynomorphs in surficial sediments of the Ross Sea, Antarctica: Marine Geology, v. 59, p. 187–214, doi:10.1016/0025-3227(84)90093-8.

Willcox, J.B., and Stagg, H.M.J., 1990, Australia's southern margin: A product of oblique extension: Tectonophysics, v. 173, p. 269–281, doi:10.1016/0040-1951(90)90223-U.

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