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Supporting Information for

Tectono-stratigraphic Evolution of the Kerguelen Large Igneous Province: the Conjugate William's Ridge - Broken Ridge Rifted Margins

L. Magri[1,2], J. M. Whittaker[1], M. F. Coffin[1,3,4], K. Hochmuth[1,2], D. Gürer[1,5], S. Williams[1], G. Bernardel[6], G. Uenzelmann-Neben[7]

[1]Institute for Marine and Antarctic Studies, University of Tasmania, Battery Point, Tasmania 7004, Australia
[2]Australian Centre for Excellence in Antarctic Sciences, University of Tasmania, Battery Point, Tasmania 7004, Australia.
[3]School of Earth and Climate Sciences, University of Maine, Orono, Maine 04469-5790, USA
[4]Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, USA
[5]School of the Environment, The University of Queensland, St. Lucia, Queensland 4072, Australia
[6]Geoscience Australia, Symonston, Australian Capital Territory 2609, Australia
[7]Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Am Alten Hafen 26, 27568 Bremerhaven, Germany

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Introduction

The supporting information encompasses technical descriptions of multichannel seismic (MCS) data acquisition and processing undertaken for three different datasets acquired during research voyages IN2020_V01 (RV *Investigator*), SO272 (RV *Sonne*), and Geoscience Australia Survey 179 (RV *Rig Seismic*) voyages. In addition, we show a plate kinematic model of the Australian and Antarctic tectonic plates since ~100 Ma (Figure S1), four MCS profiles collected on IN2020_V01 (Figures S2, S4, S5, S6), two MCS profiles acquired on SO272 (Figures S3, S7), and a conceptual model showing how William's Ridge-Broken Ridge developed apparent symmetry (Figure S8).

Text S1

1. MCS Data Acquisition and Processing

1.1 RV *Investigator* MCS dataset

Multichannel seismic reflection (MSC) data were acquired during RV *Investigator* IN2020_V01 in 2020. The seismic acquisition system consisted of two Sercel GI-airguns with a total volume of 3.6 l deployed 25 m behind the vessel, 5 m deep, and fired every 25 m (~12.5 s at a survey speed of ~4 knots). The record length of the data is typically 10 s, and the sample rate is 1 ms. At the same depth of 5 m, a 500 m long Geometrics GeoEel streamer, configured for 40 channels with a 12.5 m hydrophone group spacing, was deployed ~65 m behind RV *Investigator*.

MCS data processing was undertaken using Globe Claritas (version V7.1.1). Data were initially imported as SEG-D format files. The initial processing consisted of a static correction (50 ms bulk shift), assignment of geometry and relative CDP (Common Depth Point) sorting (10 traces per CDP), trace balancing, band pass filtering (tapering parameters 10/15-200/400 Hz), and AGC (Automatic Gain Control) filtering (100 ms). We later performed a stacking velocity analysis (every 50 CDP), normal moveout correction, stacking, and Kirchhoff time migration (maximum horizontal displacement: 320 m; maximum migration dip: 45°; minimum stretch mute: 20%). We completed a seabed pick and top mute, assigned the navigation to the shotpoints, and exported the processed lines in SEG-Y format.

1.2 RV *Sonne* MCS dataset

MCS data were acquired during RV *Sonne* SO272 in 2020. Four Sercel GI-guns with a total volume of 9.6 l were towed 20 m behind the vessel, 2 m deep, and fired every 25 m (~10 s at a survey speed of ~5 knots). The record length of the data is 9.5 s, and the sample rate is 1 ms. Acquisition was undertaken by a streamer consisting of a 240-channel hydrophone array, consisting of 20 active sections of 12 channel each, for a total active length of 3000 m. The hydrophone group spacing was 12.5 m (Uenzelmann-Neben & Westerhold, 2020).

Pre-processing of the MCS profiles consisted of defining the geometry and merging with navigation data. CDPs were sorted with a spacing of 25 m, and stacking velocity analysis (every 50 CDP) was carried out for normal moveout correction. Spherical divergence correction was applied before stacking. The stacked data have been further processed

implementing an Omega-X time-migration (Yilmaz, 2001) and a bandpass filter with a Hanning window taper, with boundaries of 5-30 Hz and 200-250 Hz and no AGC applied (Uenzelmann-Neben & Westerhold, 2020).

1.3 RV *Rig Seismic* MCS dataset

MCS data were acquired during RV *Rig Seismic* 179 in 1997. The source array consisted of 20 sleeve airguns with volume of 49.2 l, fired at a shot interval of 50 m, at a survey speed of ~5 knots. The data were acquired at a sample rate of 2 ms and a record length of 16 s. The streamer was 3000 m long, with 240-channels and a group spacing of 12.5 m. Processing of the MCS data consisted of interval velocities stacking and the use of the consequent depth-velocity functions for depth-conversion, augmented by core and sonic velocities from ODP sites.

Figure S1. GEBCO 2023 gridded bathymetric map (GEBCO, 2023) showing the Australian and Antarctic tectonic plates reconstructed at time steps representing different phases of relative motion: ~100-83 Ma, ~83-44 Ma, and after ~44 Ma (Whittaker et al., 2013). Black arrows indicate the direction of relative motion between the Australian and Antarctic tectonic plates (Whittaker et al., 2013). Contour interval is 500 m. Antarctic plate is fixed. Purple lines show the boundaries of the Australian and Antarctic tectonic plates (Whittaker et al., 2013); blue lines show the boundaries of the Southern Kerguelen Plateau (SKP), Central Kerguelen Plateau (CKP), Northern Kerguelen Plateau (NKP), and Broken Ridge (BR) (modified after Whittaker et al., 2015).

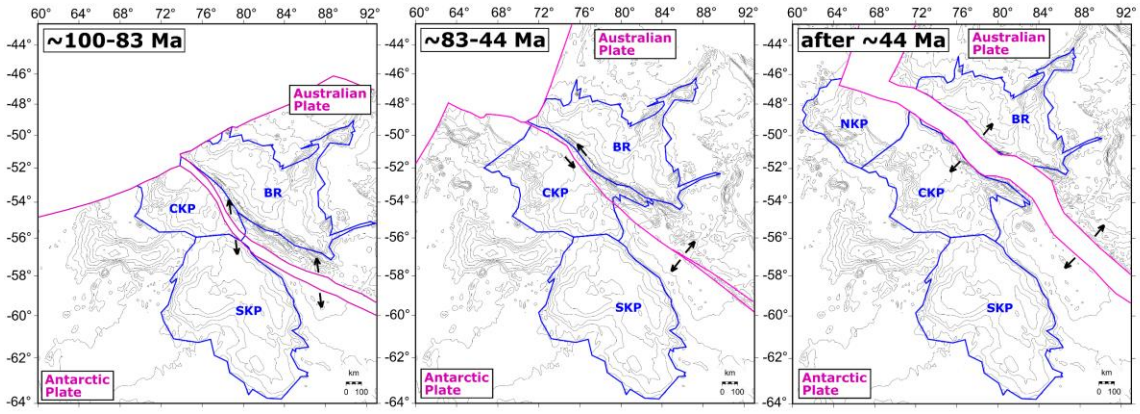


Figure S2. *RV Investigator* MCS profile IN2020_V01-0001 across William's Ridge. Uninterpreted (top) and interpreted (bottom) seismic showing the main unconformities (solid colored lines), pre-rift faults (dark purple lines) and syn-rift faults (black lines). Blue lines represent pre-rift unconformities; orange lines indicate syn-rift unconformities. See Table 1 for key to seismic units and boundaries. Black dotted line: intersection with MCS profiles AWI-20200002 and AWI-20200001.LIPC, Large Igneous Province (LIP) crust; PAB, pull-apart basin. Vertical exaggeration: ~5. Angles displayed in the upper panel show vertically exaggerated values on the left, and true-to-scale values on the right.

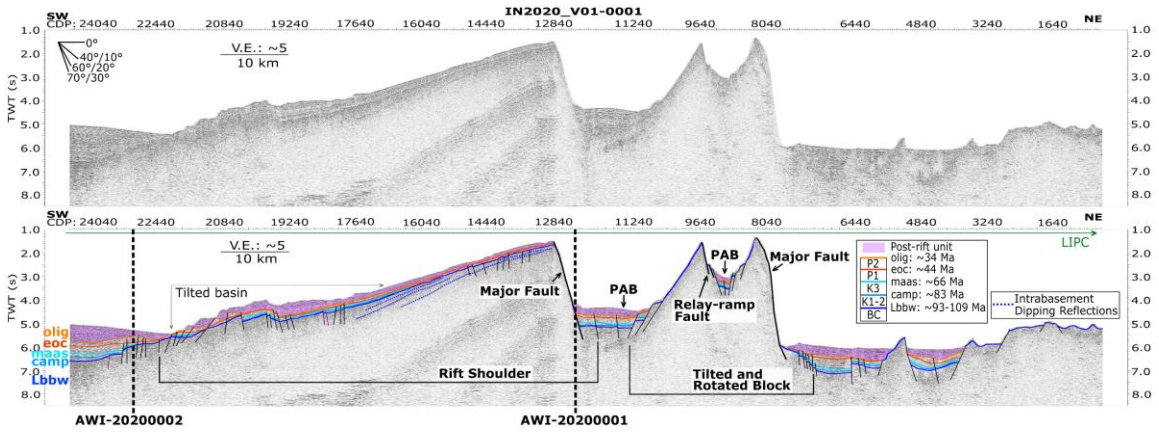


Figure S3. *RV Sonne* MCS profile AWI-20200001 across William's Ridge. Uninterpreted (top) and interpreted (bottom) seismic showing the main unconformities (solid colored lines), pre-rift faults (dark purple lines) and syn-rift faults (black lines). Blue lines represent pre-rift unconformities; orange lines indicate syn-rift unconformities. See Table 1 for key to seismic units and boundaries. Black dotted line: intersection with MCS profile IN2020_V01-0001. LIPC, Large Igneous Province (LIP) crust; PAB, pull-apart basin. Vertical exaggeration: ~5. Angles displayed in the upper panel show vertically exaggerated values on the left, and true-to-scale values on the right.

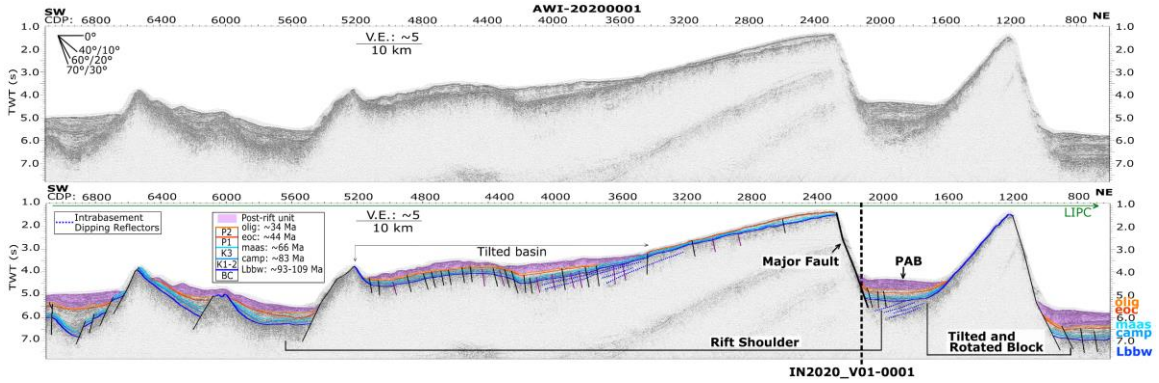


Figure S4. *RV Investigator* MCS profile IN2020_V01-0008 across William's Ridge. Uninterpreted (top) and interpreted (bottom) seismic showing the main unconformities (solid colored lines), pre-rift faults (dark purple lines) and syn-rift faults (black lines). Blue lines represent pre-rift unconformities; orange lines indicate syn-rift unconformities. See Table 1 for key to seismic units and boundaries. Red dotted box shows a characteristic positive flower structures within the seismic sequences. LIPC, Large Igneous Province (LIP) crust; OC, oceanic crust. Vertical exaggeration: ~5. Angles displayed in the upper panel show vertically exaggerated values on the left, and true-to-scale values on the right.

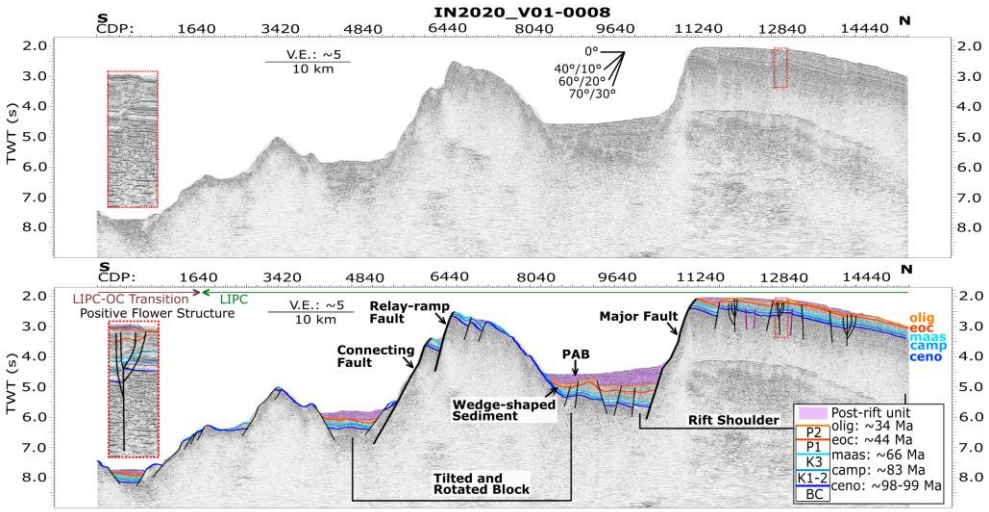


Figure S5. *RV Investigator* MCS profile IN2020_V01-0004 across Broken Ridge. Uninterpreted (top) and interpreted (bottom) seismic showing the main unconformities (solid colored lines), pre-rift faults (dark purple lines) and syn-rift faults (black lines). faults (black lines). Blue lines represent pre-rift unconformities; orange lines indicate syn-rift unconformities. See Table 1 for key to seismic units and boundaries. Red dotted box shows a characteristic positive flower structures within the seismic sequences. LIPC, Large Igneous Province (LIP) crust. Vertical exaggeration: ~5. Angles displayed in the upper panel show vertically exaggerated values on the left, and true-to-scale values on the right.

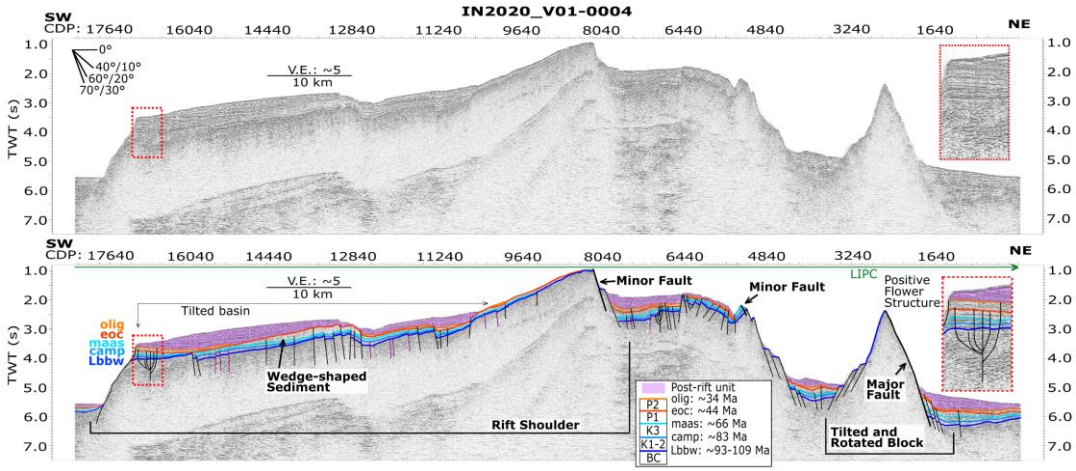


Figure S6. *RV Investigator* MCS profile IN2020_V01-0007 across Broken Ridge. Uninterpreted seismic at the top and interpreted seismic showing the main unconformities (solid colored lines), pre-rift faults (dark purple lines) and syn-rift faults (black lines). Blue lines represent pre-rift unconformities; orange lines indicate syn-rift unconformities. See Table 1 for key to seismic units and boundaries. Red dotted box shows a characteristic negative flower structures within the seismic sequences. LIPC, Large Igneous Province (LIP) crust; OC, oceanic crust. Vertical exaggeration: ~5. Angles displayed in the upper panel show vertically exaggerated values on the left, and true-to-scale values on the right.

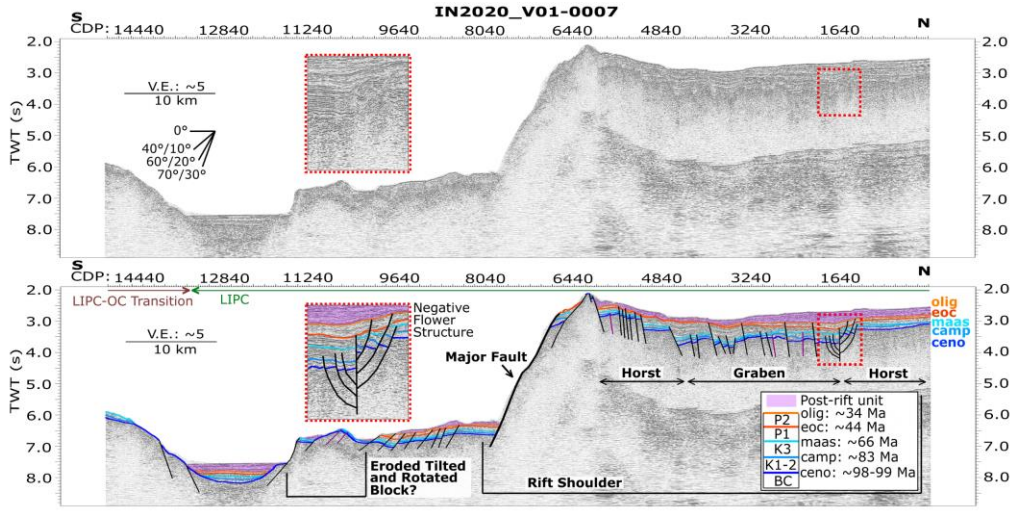


Figure S7. *RV Sonne* MCS profile AWI-20200003 across William's Ridge. Uninterpreted (top) and interpreted (bottom) seismic showing the main unconformities (solid colored lines), pre-rift faults (dark purple lines) and syn-rift faults (black lines). Blue lines represent pre-rift unconformities; orange lines indicate syn-rift unconformities. See Table 1 for key to seismic units and boundaries. Red dotted box shows a characteristic negative flower structures within the seismic sequences. LIPC, Large Igneous Province (LIP) crust; PAB, Pull-apart basin. Vertical exaggeration: ~5. Angles displayed in the upper panel show vertically exaggerated values on the left, and true-to-scale values on the right.

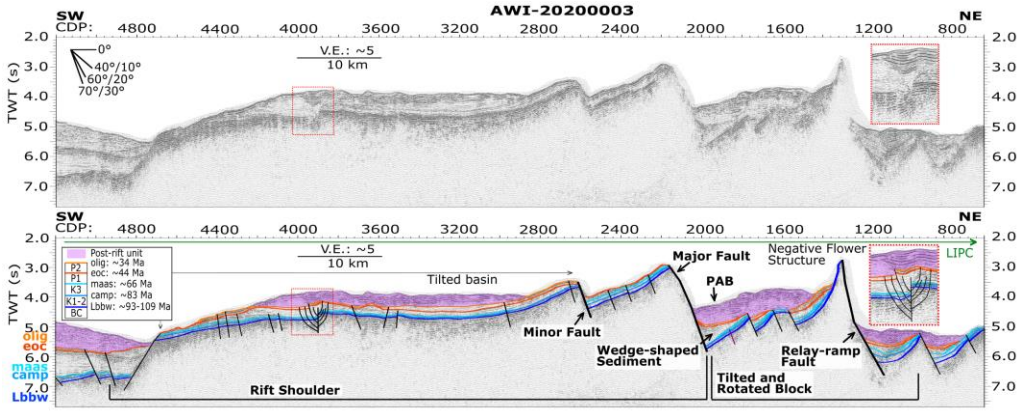
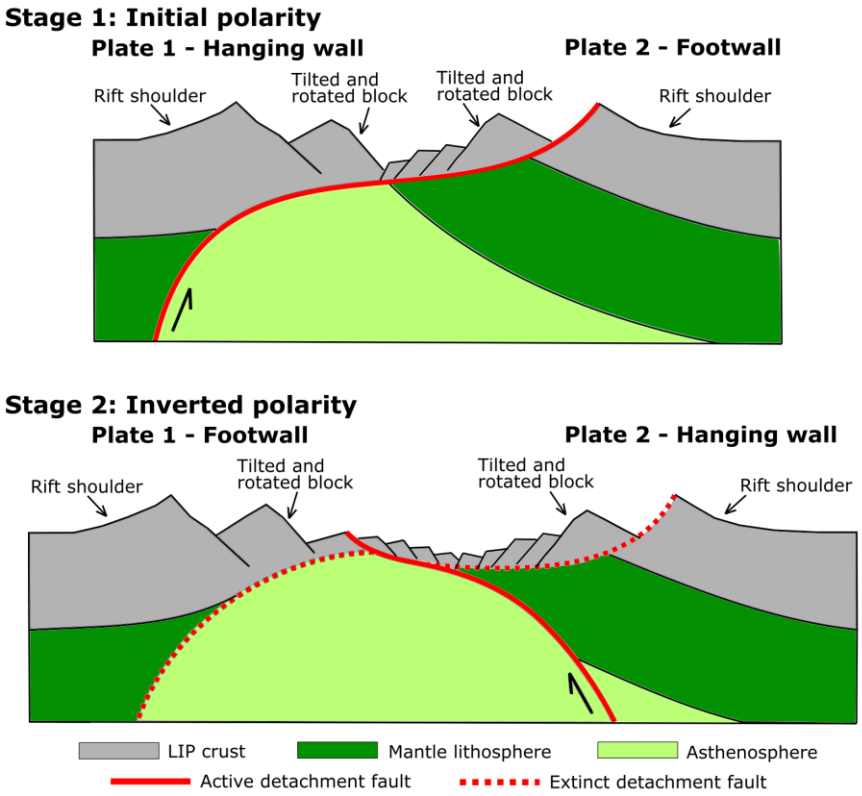


Figure S8. Conceptual model showing apparent symmetry in the morphology of Plate 1 and Plate 2, which represent William's Ridge and Broken Ridge, respectively. The system evolves by asymmetric processes.



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