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ANTARCTICA AND ITS NEIGHBOURS IN SUPERCONTINENT CYCLES

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The tectonic stress field evolution of Tasmania since the Cenozoic

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The separation of the Australian Plate with respect to the Antarctic Plate during the Cenozoic was the origin of the development of the Tasmania Passage. In order to better understand how the continental fragmentation and the plates drift occurred, it is important to establish the stress orientation and regime that have acted during the formation of this passage. With the aim to contribute to the knowledge of the tectonic evolution of the Tasmanian Passage, approximately 1000 faults distributed in 44 sites located in rocks of ages between the Cambrian and the Quaternary have been measured in Tasmania. The fault population analysis has been carried out using the methods of Etchecopar, y-R, Right Dihedral and Stress Inversion. The fault orientation analysis shows a predominant orientation ESE-WNW and secondary directions NE-SW, NW-SE and N-S. Considering the faults movement sense, 313 dextral, 194 sinistral, 422 normal and 62 reverse faults have been identified. Dextral faults show an ESE-WNW orientation. Sinistral faults have a predominant orientation N-S. The most of the dextral and sinistral fault planes dips are subvertical. Normal faults have a main NW-SE orientation and a NE-SW secondary direction with a modal dip value of 65°. Reverse faults have a predominant NE-SW direction with two modal dip values of 35° and 70° respectively. The σ1 orientation shows a dominant NW-SE direction. Moreover, another common stress regime is characterized by a preferentially NE-SW σ3 orientation (with σ1 vertical). The σy direction is dominantly NW-SE, although it shows a secondary mode with NE-SW orientation.

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What is Under the Antarctic Ice: An Integrated Study of U-Pb, O and Lu-Hf Isotopes

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Antarctica is a central piece in the Gondwana supercontinent jigsaw, connecting Australia, India and Africa. Bedrock exposure in Antarctica is sparse with over 98 % of the continent covered by ice. Understanding its geology can reveal the correlations between Antarctica and its neighbours and elucidate its role in the amalgamation and breakup of the Gondwana supercontinent.
Detrital zircons separated from IODP holes drilled around Antarctica have been analysed for U-Pb, O and Lu-Hf isotopes. U-Pb results show major detrital zircon crystallization peaks at ca. 70, 500, 1100 and 1750 Ma. The later three correlate with peaks in the Australian detrital zircon population. The largest ca. 500 Ma peak is interpreted to represent zircons derived from the Transgondwana Supermountain formed by the collision between East and West Gondwana. Unlike studies based on $^{40}Ar/^{39}Ar$ dating from hornblende and biotite, the ca. 70 Ma peak is significant. It was produced by extensive late Mesozoic arc magmatism in West Antarctica during the separation of South America and the Antarctic Peninsula.
$\delta^{18}O$ values of ca. 500 Ma group from Antarctica cover a large range (4.9-11‰), similar to the range of $\delta^{18}O$ in ca. 500 Ma detrital zircons from Australia. Zircons of ca. 70 Ma from West Antarctica are unusual and have $\delta^{18}O$ less than the mantle value, implying crystallization from a felsic magma by melting wet basalt. Lu-Hf isotopes of detrital zircons from Antarctica will be compared with those from the Australian continent and used to constrain the geological correlation between the Antarctica and Australia.

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Complex zircon and monazite geochronology, East Antarctica: experiments and nature

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East Antarctica is well known for rocks that exhibit complex geochronology; data spreads close to concordia over tens to hundreds of Myr. Traditionally, the oldest analyses are used to infer the age of igneous crystallisation or a high-T metamorphic event, whereas the youngest ages point toward the timing of a Pb-loss event. While the isotopic and trace element characteristics of zircon and monazite have been well characterised, clear links to microstructural patterns are often lacking. Our study presents new data for gabbroic melt-zircon and granitic melt-monazite reaction experiments and compares the compositions and textures of the reaction products to those of natural samples from East Antarctica.

The experiments resulted in a range of complex textures that are attributed to both dissolution and coupled dissolution-precipitation (CDP) processes. The microstructure and complex age patterns of natural zircon and monazite from a range of rocks of East Antarctica are comparable to the modified grains in our experiments.

We interpret the complex textures and age-data patterns of East Antarctic zircon and monazite grains as the result of melt-mediated coupled dissolution-precipitation reactions acting on pre-existing zircon and monazite grains. This process skews apparent ages towards the age of melt-mineral interaction. We therefore place significance on the youngest grains to date high-T anatectic events. We highlight that zircon and monazite grains modified via coupled dissolution-precipitation may not faithfully record the age or duration of metamorphism in melt-present systems and caution against relying on complex data sets for such interpretations.

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Cenozoic continental rifting in the north-western Ross Sea.

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The north-western region of the Ross Sea has been subjected to three main extensional events during the Cenozoic. The older (61 – 53 Ma) rifts of Central Basin and Central Trough occur to the east. The deep water (2000m) of the Central Basin in the north separates the Iselin Bank from the western Ross Sea continental margin, and gravity modelling indicates a thin crust (basement ~8km) with sharp margins, probably oceanic, underlying its central part. The rift continues south into the continental Central Trough graben. A stage pole of rotation was derived for this extension based on limited magnetic data and estimates of extension for the basin/trough. The Transantarctic Mountains form the western rift margin of the Ross Sea and traverse Antarctica, separating East from West Antarctica. They were primarily uplifted about 55 – 45 Ma, between the times of the extension episodes forming Central Basin and Northern Basin, along a major lithospheric boundary, but no extension estimates are available. New ocean crust formation (43 – 26 Ma) in the Adare Basin off north-western Ross Sea can be traced using magnetic data directly into the Northern Basin underlying the adjacent continental shelf, implying a continuity of emplacement of oceanic crust. Steep gravity gradients along the margins of the Northern Basin suggest that little extension and thinning of continental crust occurred before it ruptured and new oceanic crust formed, unlike other continental rifts. Estimates of extension enables the restoration of Iselin Bank back to the Transantarctic Mountains.

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The AIRLAFONIA survey: new plate kinematic constraints on Mesozoic tectonics in west Antarctica

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We present the results of a recent aeromagnetic survey over the Falkland Plateau Basin. Magnetic reversal isochrons in the east of the basin reveal Jurassic-onset seafloor spreading. The basin's thick igneous crust further west also formed in Jurassic times, but in a subaerial setting. These isochrons can be reconstructed to likely conjugates in the southwestern Weddell Sea, suggesting the Falkland Plateau Basin and earliest Weddell Sea formed in a back-arc setting by divergence of a newly-recognized plate, named after the Skytrain Ice Rise, from West Gondwana. The growth of this Weddell-Falkland Plateau ocean at the Skytrain-West Gondwana plate boundary generated a barrier of oceanic lithosphere across what was to become the Drake Passage gateway, adding to previous observations that suggest correlation-based interpretations of the South Georgia microcontinent's Eocene-and-later translation from the Pacific margin of Gondwana should be regarded as untenable. Further south in the Weddell Sea Embayment, aeromagnetic and outcrop evidence for rifting confirms the plate circuit's requirement for Skytrain to have diverged from East Gondwana in mid-to-late Jurassic times. The circuit requires Skytrain and East Gondwana to have subsequently collided early in the Cretaceous. This setting contextualizes and more precisely constrains the timing of post-Cambrian paleomagnetic rotations from the Ellsworth mountains, as well as thermochronological and structural observations of their Cretaceous uplift and post-Permian oblique-dextral collision. In contrast, the Skytrain Plate concept does not allow for large-scale rotation of the Falkland Islands during Gondwana breakup, as has long been proposed on the basis of paleomagnetic and geological correlation studies.

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Comparing the build-up of East Antarctica to its former Gondwana neighbours

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Numerous unresolved issues exist regarding the lithosphere of (East) Antarctica, especially in terms of density, temperature, and compositional structure. Estimates of total lithospheric thickness often involve assumptions on the depth of the Moho discontinuity, which is subject of high uncertainty in Antarctica. Recent estimates of the Moho depth from different geophysical methods show significant discrepancies of up to 10-20 km. While seismological methods suffer from a limited station coverage and ice reverberation, potential field methods, such as gravity studies, are inherently non-unique.
Here, we compare recent global lithospheric models that account for thermodynamically stable mineral phases of rocks under in-situ pressure and temperature conditions, for East Antarctica and its formerly adjacent Gondwana neighbours. The integrated modelling compensates for the sparseness of data in Antarctica and reduces inconsistencies and ambiguities of separate geophysical methods to a large extent. We compare the global models with a dedicated Antarctica model, where gravity gradient data from ESA's satellite mission GOCE have been used to constrain the density distribution within the lithosphere in an integrated 3D model. The presented model includes new estimates of the crustal and the total lithospheric thickness of Antarctica.
Furthermore, we make use of newly processed aeromagnetic surveys to describe the crustal structure in a Gondwana setting. This approach helps to describe the tectonic setting in order to derive parameters like geothermal heat-flow, especially if combined with statistical methods like machine learning.

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Unveiling cryptic imprints of rifting, magmatic arcs and accretion in East Antarctica linked to subduction of Nuna's oceans

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East Antarctica is a key missing piece of the puzzle to reconstruct global supercontinent cycles. However, what happened to East Antarctica during the assembly and growth of the Nuna supercontinent between the Paleoproterozoic and the Mesoproterozoic remains particularly poorly understood. To address this major knowledge gap, we present and interpret new continental-scale aeromagnetic and aerogravity data compilations, and satellite gravity and satellite magnetic imaging, complemented by passive seismic and geological data and modelling. This enables us to re-define the extent and the architecture of several major crustal provinces in interior East Antarctica. We delineate a narrow and elongated Archean ribbon microcontinent (proto-Mawson) that connects exposures of Archean basement in Terre-Adélie and the Central Transantarctic Mountains. We propose that proto-Mawson is flanked by a rifted Paleo to early Mesoproterozoic Wilkes Terrane to the east, and several distinct Paleo to Mesoproterozoic magmatic arcs of inferred continental margin and oceanic affinity respectively to the west. By incorporating geophysical, geological, geochronological and paleomagnetic constraints, we then embed our new geophysical views for East Antarctica into GPlates to obtain a new kinematically evolving Nuna plate reconstruction. Several key aspects of our Nuna reconstruction have variable degrees of speculation attached, but we contend that our hypotheses could be further tested by targeted future studies, including drilling. Overall, our new interpretations support the hypothesis that a large tract of East Antarctica was built during long-lived subduction of Nuna's exterior ocean, following the closure of a smaller interior ocean that separated proto-East Antarctica and Australia from Laurentia.

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Crustal architecture of a large pull-apart basin in East Antarctica unveiled

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Here we combine aeromagnetic, aerogravity, land-gravity and bedrock topography imaging to help constrain the extent, architecture and kinematics of the largest Cenozoic pull-apart basin recognised so far in East Antarctica, the Rennick Graben (RG).
Enhanced potential field imaging reveals the extent of part of a Jurassic tholeiitic Large Igneous Province preserved within the RG and the inherited structural architecture of its basement, including remnants of uplifted ca 530-500 Ma arc basement in the northern Wilson Terrane and a ca 490-460 Ma subglacial thrust fault belt that separates the Cenozoic western flank of the RG from the eastern margin of Wilkes Subglacial Basin (WSB).
The RG is interpreted here as a major composite right-lateral pull-part basin that extends from the Oates Coast to the Southern Cross Mountains block. We propose that Cenozoic strike-slip deformation kinematically connected the RG with the western edge of the West Antarctic Rift System and the eastern margin of the WSB.
We conclude that the RG is part of a wider and more distributed region of the continental lithosphere in East Antarctica that was deformed in response to an evolving Cenozoic transtensional tectonic setting that may have also affected enigmatic sub-basins such as the Cook Basins within the adjacent WSB.

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New magnetic and gravity views of Precambrian and Pan-African age crustal features between Dronning Maud Land, Shackleton Range and South Pole

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By analysing aeromagnetic, aerogravity and satellite gravity and satellite magnetic images we investigate crustal architecture and identify some of the key tectonic and magmatic features within the basement located between Dronning Maud Land, Shackleton Range and South Pole. Our findings provide a new glimpse into the tectonic and geodynamic processes that affected East Antarctica from Nuna, Rodinia and Gondwana times.

Several Precambrian terranes outcrop within the Shackleton Range, namely the Southern, Northern and Eastern terranes. The Southern Terrane in particular includes an exposed belt of juvenile Paleoproterozoic crust and a prominent aeromagnetic and satellite magnetic anomaly is interpreted as reflecting the roots of a Paleoproterozoic arc-related ribbon terrane.

Completely different magnetic and gravity signatures occur north of the Shackleton Range suture over the Coats Land Block, which are broadly comparable e.g. to the Paleoproterozoic Yavapai Province in Laurentia. Rift-related Keweenawan-age (ca 1.1 Ga) igneous rocks are exposed in small coastal outcrops within this crustal block but our new aeromagnetic images suggest they are widespread also further in the interior.

Arcuate magnetic anomaly belts extend from Dronning Maud Land to the northern margin of the Coats Land Block and also further south beneath the Recovery catchment. These anomalies may reflect belts of accreted Grenvillian-age arc crust, similar to remnants entrained in the Namaqua-Natal and Maud orogenic belts. These and other Precambrian terranes appear to have deformed into complex orocline-like structures bounded by major shear zones, likely linked to Pan-African age orogenic processes associated with protracted East- West Gondwana amalgamation.

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The active triple junction in the NE Antarctic Peninsula: new insights from NE Bransfield Strait and Elephant Island recent tectonic evolution

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The northern margin of the Antarctic Peninsula is affected by the most recent tectonic activity related to the last stage of the opening of the Drake Passage. The subduction along the South Shetland Trench of the Former Phoenix Plate, now belonging to the Antarctic Plate, contributes to the detachment of the continental South Shetland Block from the Antarctic Peninsula and the development of the Bransfield Basin. The underthrusting of the active transpressive sinistral Shackleton Fracture Zone below this continental block shaped the active triple junction that determined the NE tip of the South Shetland Trench and the uplift of Elephant Island. This geological context produced changes in tectonic regime along the NE Antarctic Peninsula, including transcurrence associated to the Shackleton Fracture Zone, compressive deformations with reverse faults and large open folds related to subduction in the northern part of South Shetland Block and Elephant Island and extensional processes in Bransfield back arc basin and the southern part of Elephant Island. The analysis of the recent structures from multichannel seismic profiles, detailed bathymetric data, seismicity including earthquake focal mechanisms and paleostresses determined from mesofault population analysis, improves the knowledge of the recent tectonic evolution of the triple junction and highlights implications on the latest palaeoceanographic evolution of the Drake Passage.

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Results of ground magnetic surveys and petrophysical studies in the Bunger Hills, East Antarctica

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Ground surveys during 2017-20 seasons in the Bunger Hills completed by PMGRE and VNIIOkeangeologia acquired more than 320 line-km of magnetic data. The petrophysical data set representing the study area comprises c. 600 samples, collected for the follow-up of magnetic anomalies during field trips, and also in situ susceptibility measurements were made in selected areas. The major goal of these studies was to clarify the magnetic image of the Paz Cove batholith at its boundary with basement rocks.
The banded magnetic patterns with high-gradient zones throughout the boundary of the Paz Cove batholith are mainly associated with a finely interlayered sequence of orthopyroxene-bearing tonalitic orthogneiss and predominantly garnet–cordierite ± sillimanite gneiss, with minor psammitic gneiss and other rocks. This was verified by susceptibility measurements, when migmatized and mylonitised orthogneiss and schists have high magnetizations with the average susceptibility value of about 34.3×10-3 SI, whereas paragneiss of roughly 0.32×10-3 SI. Among metagabbroic rocks of the compositionally varied Paz Cove batholith monzodiorites, diorites and gabbrodiorites yield modal susceptibility value of the order of 25.1×10-3 SI, and monzogabbroids and gabbroids are less magnetic with susceptibilities of about 4.04×10-3 SI, when blastomylonitic gabbroids show susceptibilities in the range 1.1-103×10-3 SI with modal value 11.6×10-3 SI. High magnetization of the Paz Cove plutonic rocks does not correlate with the observed magnetic anomaly pattern which exhibit predominantly negative anomalies with amplitude up to –1490 nT and possibly affected by their strong remanent magnetization. The most intense negative anomalies are associated with quartz-bearing monzodiorites and granodiorites.

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Investigating Princess Elizabeth Land Provinces with new magnetic compilation.

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The total amount of the Russian high-quality aeromagnetic data recently collected over Princess Elizabeth Land (PEL) exceeded more than 70,000 line-km. They clearly depict the extent of tectonic belt characterised by low amplitude, linear/curvilinear NE-SW-trending magnetic anomalies that is extremely straightforward relative to the other regions of East Antarctica. At the eastern shoulder of the Lambert Rift they are associated with orthogneissic Pickering Series and paragneissic Manning Series. Based on U-Pb zircon ages and chemical comparisons, these rocks are nearly identical to those of the Beaver Complex. The most outstanding Robertson anomaly is reflected by amphibolite-facies rocks only occur in Robertson Nunatak where mafic schists and orthogneiss crop out. Isotopically juvenile rocks from the Fisher Terrane and Robertson Nunatak may represent a small-scale oceanic arc extending eastward across the Lambert Rift. Two fragments of this oceanic arc displaced approximately 50-60 km along dextral strike-slip system of faults are most likely related to Cretaceous transtensional tectonics. At the Manning Nunataks, mafic granulites can be related to metamorphism of island arc basalts, whereas the felsic volcanic arc orthogneisses have no obvious relation to subduction of oceanic crust. Protolith ages range from ca. 1347 to 1020 Ma, indicating the Rayner continental arc was a long-lived site of crustal accretion. Thus, aeromagnetic surveying over PEL has imaged a distinctive Stenian-aged accretional orogen in East Antarctica. The orogen can be traced uninterruptedly from the Clemence Massif to the southern margin of the Rauer-Vestfold Hills crustal block and further eastwards to coastal areas at 88° E.

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Post ADMAP-2 surveys – new results and achievements

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Since the release of ADMAP-2 map in 2017, the Antarctic geomagnetic community has been very active acquiring more than 550 000 line-km of new air- and shipborne data. Many of these new data sets were obtained by multidisciplinary projects that also acquired airborne laser altimetry, radio echo sounding, and gravity anomaly data for comprehensive studies of the surface, thickness, and internal features of the ice sheets and the subglacial geology and hydrology. Major target of the new surveys was ADMAP-2 gaps coverage such as over Princess Elizabeth Land, the Recovery Basin, the Ross Ice Shelf, the South Pole region, and over other poorly explored Antarctic areas. At present many of new surveys are not publicly available and cannot be combined with previous datasets, but potentially they may provide most important new data for improving the ADMAP compilation and as a result give new views into the large-scale crustal architecture of East Antarctica and its supercontinental linkages. For instance, the Russian aeromagnetic surveying over Princess Elizabeth Land has imaged the extent of distinctive Stenian-aged accretional orogen in East Antarctica. Whereas new aeromagnetic data collected by AWI/BGR surveys from southern and eastern Sør Rondane and their integration with surface geology offer new insights regarding the southern and eastern extents of the Tonian Oceanic Arc Super Terrane. Mapping of magnetic anomalies by the ROSETTA-Ice survey reveals a key break between cratonic East Antarctica and accreted crust of West Antarctica.

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Antarctica in Supercontinent evolution - Rodinia to Gondwana Breakup

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The definition of lithologies typically associated with plate margins in Rodinia and Gondwana permits the definition of continuous geological provinces contributing to the recognition of continental crustal blocks within and pre-dating reconstructed Gondwana.
These data along with aerogeophysical data from Antarctica, combined with geochronological and structural data permit the recognition that the Kuunga and Ross Orogenies define two broadly parallel plate margins involved in the amalgamation of Gondwana between ca. 650Ma and ca. 480Ma.
The Ross Orogeny is recognised as involving an arc subduction setting stretching from South America, through the Cape (Southern Africa), Transantarctic Mountains to eastern Australia.
In contrast the Kuunga Orogeny involved a continent-continent collision setting (post dating the East African Orogeny) between North and South Gondwana extending from the Damara Belt (Namibia), through the Zambesi and Lurio Belts (Zambia and Mozambique), through Sri Lanka into East Antarctica. Further extensions are possible south of Enderby Land through the Prince Charles Mtns area to Princess Elizabeth Land to western Australia. This orogeny has contibuted to much of East Antarctica being underlain by a block of double-thickened crust, reflected in gravity studies, which contains a broadly uniform aeromagnetic linear fabric extending from western Dronning Maud Land to the Gamburtsev Mtns and beyond.
The central Antarctic crustal block formed during the Kuunga Orogeny would provide a relatively proximal source for the extraordinary extensive sandstone sequence extending from the Cape Fold belt in the west, via the Transantarctic Mountains to eastern Australia.

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Neoproterozoic to Cambrian granitoids of northern Mozambique and Dronning Maud Land Antarctica: Implications for the assembly of Gondwana during the Kuunga Orogeny.

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The field relationships, petrography, whole rock major, trace element and radiogenic isotope chemistry and geochronology of Cambrian Granites from the Nampula Terrane (NT) Mozambique are reported. These data are compared with published data from Neoproterozoic to Cambrian granites from Central Dronning Land (CDML) and the Cabo Delgado/Namuno Terrane of northern Mozambique (CDNT). The CDML and Nampula terranes are contiguous in reconstructed Gondwana. Whereas there is significant overlap in the chemistry and ages of the granites from the Nampula Terrane compared to those from CDML and CDNT, indicating their probable genesis within the same broad orogenic event, subtle differences in distribution, mineralogy, chemistry and age are seen. These differences include subsolvus peraluminous mica-dominated granites with ages <~530 Ma in all three areas but concentrated in the Nampula Terrane. This in contrast to the dominantly metaluminous hypersolvus charnockitic syenogranites with ages >~530 Ma restricted to CDML and CDNT terranes. The differences between the two granite varieties are inferred to reflect differences in tectonic setting during orogenesis and genesis with the marginally older CDML and CDTNM granites resulting from decompression dehydration melting of amphibole in an extensional setting restricted to the hanging wall of a mega-nappe. In contrast the marginally younger granites were generated from dehydration melting of mica in the footwall of a to-to-SE directed mega-nappe structure during the Kuunga Orogeny but emplaced into both floor and roof complexes.

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The Kuunga Nappe of Sverdrupfjella, western Dronning Maud Land, Antarctica.

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The geology of Sverdrupfjella, western Droning Maud Land, Antarctica comprises three complexes. The ~1140Ma Jutulrora Complex consists mostly of arc-related TTG orthogneiss with evolved Sr/Nd isotopic signatures with TDm ages >2by. The Fuglefjellet Complex, structurally overlying the Jutulrora Complex, comprises supracrustal (~800-900Ma) carbonates intercalated with ~1100-1200Ma quartzo-feldspathic gneisses with ca. 500Ma metamorphic overprints. The Rootshorga Complex, structurally overlying the Fuglefjellet Complex, contains paragneisses with minor ~1100-1200Ma orthogneisses, intruded by granitic orthogneiss of similar age. Sr/Nd isotopic signatures from the Fuglefjellet and Rootshorga Complexes have TDm ages <1.8by. D1 and D2 deformation verges top-to-NW. In contrast D3 deformation verges top-to-the-SE. In the Jutulrora Complex, D3 is characterized by ~100m scale folds with NW dipping axial planes cut by SE dipping dilational granite sheets. In the Rootshorga Complex D3 is characterised by syntectonic dilational granite sheets with extensional and compressional displacements with top-to-the SE shear. Zircon ages of the granitic sheets are 490-500Ma. Sr/Nd isotopic signatures of the granitic sheets which intrude all complexes, are consistent with melting of crust similar to the Jutulrora Complex with Archaean and Mesoproterozoic xenocrysts seen in some samples. P-T-t studies from the Rootshorga Complex yield an ITD path with decompression from ~1.4Gpa at ~570Ma to ~0.7Gpa at ~500Ma whereas P-T-t estimates from the Jutulrora Complex are <~0.8Gpa at ~500Ma with a path consistent with crustal loading. The Rootshorga and Fuglefjellet Complex are inferred to comprise a mega-nappe, emplaced during the Kuunga Orogeny ~500Ma ago, over the footwall Jutulrora Complex. Geophysical data are consistent with this interpretation.

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New geochemical data from central Dronning Maud Land: Implications for Gondwana reconstruction.

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The western Mühlig-Hoffman Mountains and the area around Gelsvikfjella in central Dronning Maud Land, East Antarctica can provide important information to the understanding of the assembly of the Gondwana Supercontinent. Rocks in this area comprise a polyphase deformed and metamorphosed assembly of Mesoproterozoic ortho-gneisses with minor supracrustal components and mafic bodies which were reworked during the late Neo-Proterozoic East-African Orogen and subsequent Kuunga Orogen and intruded by large volumes of post tectonic A-type granites of Cambrian age. In addition, the area has been intruded by multiple phases of syn- to post-tectonic felsic veins which remained poorly studied until now. This study aims to provide a comprehensive geochemical survey of all rock types in the area but in particular the felsic veins through the analysis (major, trace, REE and Nd-Sr isotopes) of 68 samples. The majority of basement rocks plots in the monzogranite – granodiorite field with the mafic rocks classifying as syeno-monzo-grabbro and gabbro. All the felsic veins (27 samples) plot as granite, however, results indicate that these rocks are subdivided into two geochemically distinct groups. This distinction is supported by structural data, cross-cutting relationships and differences in isotopic signatures suggesting two possible different sources not related to host country rocks and pointing to older and deeper sources. The new geochemical data sheds light on the petrogenisis of the late felsic veins which could play an important role in the understanding of the final stages of collision in Central Dronning Maud Land where current theories are inconsistent and conflicting.

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Age, affinity and architecture of basement to the Bruce Rise, Wilkes Land, East Antarctica

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The Bruce Rise is a prominent bathymetric feature offshore the Bunger Hills in Wilkes Land, East Antarctica. In East Gondwana, the Bruce Rise is reconstructed near the Naturaliste Plateau (offshore SW Australia) and microcontinents now submerged in the eastern Indian Ocean (Batavia and Gulden Draak knolls). We investigate the age and affinity of two Bruce Rise granitic rocks dredged from a steep eastern escarpment onboard the R/V Hakurei-Maru.

The zircon U-Pb-Hf data are complex and dominated by xenocrystic cargo with ages of c. 1590 Ma, 1500 Ma and 1270 Ma. Xenocrystic cores show textural evidence of melt-mediated coupled dissolution-precipitation to form rim domains with apparent ages that skew towards c. 1190-1150 Ma. We suggest that c. 1150 Ma is the likely crystallisation age of both samples.

The zircon U-Pb-Hf signatures from the Bruce Rise granites, and from c. 1230 to 1180 Ma granites and orthogneisses from the conjugate Naturaliste Plateau, suggest that late Mesoproterozoic magmatism occurred at a transition in the Australo-Antarctic tectonic architecture between a reworked Archean cratonic margin and Proterozoic juvenile crust.

Basement to the Bruce Rise and Naturaliste Plateau was extended and exhumed during the rifting of India from East Gondwana (prior to c. 120 Ma). Onshore NW-trending basement faults in Antarctica are subparallel to offshore bounding fracture zones, suggesting an array of favourably oriented basement structures played a role in the early evolution of this extended margin. Minor further thinning likely occurred leading up to the onset of seafloor spreading (from c. 90 to 84 Ma).

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Antarctica in Gondwana and earlier Supercontinents: Evidence from the Rauer Islands, Prydz Bay

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The Rauer Islands is critical to interpretations of the assembly of east Gondwana and links between eastern India and Antarctica. The Rauers preserve a punctuated geological record spanning from 3.5 Ga to 0.5 Ga, including high-grade tectonothermal events that broadly correspond in timing to global supercontinent episodes and recently have been proposed to correlate with events recorded in the Rengali Province of India.

The Archaean of the Rauers features 3.5 Ga, 3.3 Ga and 2.8 Ga TTG gneisses, and 3.3 Ga and 2.8 Ga layered mafic-ultramafic metaigneous complexes. Mesoproterozoic granitic to dioritic intrusives were emplaced at 1 Ga into a Fe-Al pelites and metabasites, the Filla Supracrustals, derived from older Proterozoic sources and deposited prior to 1.06 Ga. A 1.03-0.96 Ga granulite facies tectonothermal event preserved in the Filla Supracrustals is not recorded in the Archaean orthogneisses with which they are now interleaved. 0.58 Ga Ultrahigh-temperature (UHT) metamorphism is uniquely preserved in the Mather Supracrustals. The 0.53-0.51 Ga Prydz Tectonic Event is the only high-grade tectonism shared by all rock units. Hence, this transpressional event resulted in the assembly of the polycyclic crustal units, so that like the Rengali the Rauers is an amalgam of units sandwiched between an Archaean craton to the north and a late Mesoproterozoic to Neoproterozoic collisional belt to the south. However, the constitution of the Archaean, the timing of the Mesoproterozoic tectonism, and the unique presence of 0.58 Ga UHT metamorphism point to the Rauers being distinct from, rather than an extension of, the Rengali.

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Structure of East Antarctica revealed by Connecting Geology & Geophysics: the Dronning Maud Land perspective

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Dronning Maud Land in East Antarctica is a key area for unravelling the protracted assembly of East Antarctica and Gondwana in late Neoproterozoic/early Paleozoic times. Integrating geophysics with geology, and specifically geochronology, reveals the complex tectonic history of East Antarctica that appears to consist of at least seven cratons and cratonic fragments that amalgamated along a network of Grenville-age and Pan-African orogenic belts. Extensive juvenile crustal additions and remnants of the Neoproterozoic Mozambique Ocean are exposed in central to eastern Dronning Maud Land, which can be traced underneath the ice for a considerable distance by geophysical means. Glacial moraine studies confirm the extent of the large extent of juvenile Neoproterozoic crustal additions. This region has the size of present day Antarctic Peninsular and resembles the Arabian-Nubian-Shield farther north along the East African-Antarctic Orogen; it is underlain by thick continental crust. In this contribution, we also provide spatial estimates of pre-Neoproterozoic crustal blocks of African, Indo-Antarctic, Australian and Laurentian heritage and investigate the path of Pan-African mobile belts and their suture zones across East Antarctica from a Dronning Maud Land perspective.

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Geochemistry of basalt pebbles from short sediment drill cores beneath the Ekström Ice Shelf, East Antarctica: Evidence of the Explora Wedge?

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There is evidence that the Explora Wedge basalts, a counterpart to the Jurassic Karoo volcanism in southern Africa, outcrop at the sea floor beneath the Ekström Ice Shelf, Dronning Maud Land, Antarctica. In preparation for a geoscientific deep drilling campaign to further investigate the Explora Wedge and the overlying Meso-/Cenozoic sediments, pre-site surveys were conducted comprising seismic reflection surveying and surface sediment coring through hot-water drilled access holes. Recovered surface sediment cores contained pebbles of 0.5¬-10cm in size, which potentially provide information about the Explora Wedge and the upstream pre-glacial material eroded from the continent.

The large-sized pebbles consist of basalt/dolerite, serpentinite, siltstone, granite and gneiss. Thin-section microscopy of the smaller pebbles revealed mainly basaltic material and minor sedimentary fragments. Geochemically, the basaltic pebbles can be divided into four groups on their (Low/High) Ti and Zr contents: LTHZ1, LTHZ2, HTZ, LTZ. The latter two resemble the high and low Ti-Zr Karoo basalts from central Lembobo (S-Africa; Sweeney et al. 1994). However, while HTZ overlaps with the Southern-Karoo group of Luttinen (2018), the LTZ has higher Nb content. Groups LTHZ1 and LTHZ2 differ from Karoo basalts by their very high Zr and low Ti contents. LTHZ1 resembles the Group 4 basic dykes from Ahlmannryggen (Dronning Maud Land; Riley et al. 2005). LTHZ2 stands out through its extremely high Zr and Nb values and could not yet be correlated.

Luttinen (2018) Nature Sci Rep 8, 1-11
Sweeney et al. (1994) J Petrol 35, 95-125
Riley et al. (2005) J Petrol 46, 1489-1524

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Geochemical and geochronological features of the formation of the earliest crust in East Antarctica

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The nature of the Earth's earliest crust is a subject of ongoing investigation. Gneisses of the Tula Mountains in the Napier Complex of Enderby Land and from the Aker Peaks of Kemp Land reveal some similarities in crustal development through geochemistry and geochronology. These rocks in both areas were metamorphosed at ca. 2.5 Ga during ultra-high temperature (UHT) metamorphism, with an additional ca. 2.8 Ga and ca. 3.6 Ga events identified locally. These events affect magmatic protoliths which were formed before 3.6 Ga, as revealed by new 207Pb/206Pb ages >3.6 Ga (Eoarchean). Orthogneisses from Tula Mountains were geochemically subdivided into Y-HREE-Nb-Ta depleted and undepleted groups, with geochemical diversity demonstrated in Eoarchean protoliths. This indicates that during the Archean, various sources and processes were involved, including re-melting and recycling of various crustal components. The identification of Eoarchean crust in both, Enderby and Kemp Land, at localities around 300 km apart, may be an indication that such crust is widespread around the complex. Like other Archean cratons, the Napier Complex is likely to represent a composite of continental crust formed at different times during the Archean assembled as late as 2.5 Ga.

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Tectonic Map of Antarctica, 2-nd edition

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A 2-nd edition of tectonic map of the Antarctic at 1:10M scale was compiled in VNIIOkeangeologia under the auspices of the Commission for the Geological map of the World. It is significantly upgraded in comparison with the 1-st edition published in 2012. The map shows the tectonic composition of the Antarctic with major crustal types (oceanic, transitional and continental) and their specific structural assemblages and features in geodynamic context. Structural assemblages on the Antarctic continent are underlain by unstrecthed and strethed continentasl crust and grouped in 4 major units: 1) Proterozoic and Phanerozoic accretional fold belts (including subduction and/or collision-related orogenic complexes and for-arc and intra-arc basin complexes); 2) platform covers; 3) intraplate fold systems (variably deformed supracrustal complexes and molasses); 4) intracontinental and marginal rift basins. The separate block of the legend includes archean continental protocrust lacking clear plate tectonics markers. Units in each block are distinquished by colors. Geodynamic environments of igneous rocks and structural features, such as subduction-related and/or intraplate magmatism, faults, thrusts, rifts, etc. are shown by different signs/hatchings which are explained in the Legend. Oceanic crust is mapped depending on its age defined by magnetic lineations. The main map is accompanied by a generalized view of Antarctic tectonic provinces which show the presumed distribution of ancient (Archean) domains, orogenic belts, platform covers and other tectonic features under the ice as well as rates of sea-floor spreading and areas with thickened oceanic crust in the Antarctic seas. The work was supported by the RNF project 16-17-10139.

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Glauconitization episodes before the onset of Antarctic glaciation

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The environmental changes leading up to the first continent-wide glaciation of Antarctica during the Eocene-Oligocene Transition (EOT) is still not fully understood. Declining atmospheric CO2 concentrations and associated feedbacks have been invoked as underlying mechanisms, but the role of the coeval opening/deepening of Southern Ocean gateways, and subsequent changes in paleoceanography remain poorly understood. Evidence suggests both a temperate late Eocene and cooling before the EOT, both broadly coetaneous with a wide, supra-regional diagenetic event that resulted in green-clay (glaucony) formation in the marine realm around Antarctica. Glaucony is a sensitive marker of sedimentation rates, sea-level and sediment physico-chemical conditions, and thus a powerful tool for marine sedimentological and climatic interpretation. In spite of all, the nature, depositional setting, paleoenvironmental implications and chronology of the late Eocene glaucony reported in diverse shallow-marine settings are loosely constrained. Here, we evaluate the palaeogeographic implications and temporal variations of Antarctic glaucony-bearing sediments deposited before major ice sheet advance during the EOT. In this sense, the morphological, mineralogical and geochemical features of late Eocene glauconitized fecal pellets in both ODP Site 696 and Seymour Island sections denote an autochthonous origin of the evolved glaucony grains, indicating a period of low sedimentation rate associated with rising sea levels related to plate reorganization and opening/deepening of Drake Passage.

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Volatile and rock chemistry integration helps deconvolve sources of volcanism in Southern Victorialand

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Formed following the breakup of Gondwana, the West Antarctic Rift System is associated with several magmatic provinces along the rift margins, including the Erebus Volcanic Province (EVP). Multiple sources of the highly alkaline, rare-earth element enriched lavas of the EVP have been hypothesized, including mantle plume(s), melting of a fossilized plume head, and mixing of recycled oceanic crust with one or more enriched mantle sources from the deep mantle. However, the ability to determine a unique source of volcanism in this region has proven to be particularly difficult using traditional methods. Though major element chemistry, trace element chemistry, and radiogenic isotopes (e.g., Sr, Nd, and Pb) are commonly used to delineate magma sources, these elements are readily recycled between the crust and the mantle, and their concentrations and isotopic compositions can change with the degree of partial melting. In contrast, noble gases are chemically inert, have well-characterized and externally defined endmembers, and are not recycled between the crust and mantle, making them reliable tracers of subsurface fluids. Here, we present noble gas isotope ratios (e.g., $^{3}He/^{4}He$, $CO_2/^{3}He$, $^{40}Ar/^{36}Ar$, $^{40}Ar^{*}/^{4}He$) along with trace element chemistry for a suite of lavas in the EVP. Preliminary results suggest small contributions from a low partial melt MORB mixing with a more radiogenic endmember such as a HIMU (high $^{238}U/^{204}Pb$) plume. By coupling noble gas geochemistry with traditional geochemical analyses, we can better constrain the magmatic source and deconvolve mantle-lithosphere interactions in the EVP.

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Fingerprinting Proterozoic Bedrock in Interior Wilkes Land, East Antarctica

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Wilkes Land in East Antarctica remains one of the last geological exploration frontiers on Earth. Hidden beneath kilometres of ice, its bedrock preserves a poorly-understood tectonic history that mirrors that of southern Australia and holds critical insights into past supercontinent cycles. Here, we use new and recently published Australian and Antarctic geological and geophysical data to present a novel interpretation of the age and character of crystalline basement and sedimentary cover of interior Wilkes Land. We combine new zircon U–Pb and Hf isotopic data from remote Antarctic outcrops with aeromagnetic data observations from the conjugate Australian-Antarctic margins to identify two new Antarctic Mesoproterozoic basement provinces corresponding to the continuation of the Coompana and Madura provinces of southern Australia into Wilkes Land. Using both detrital zircon U–Pb–Hf and authigenic monazite U–Th–Pb isotopic data from glacial erratic sandstone samples, we identify the presence of Neoproterozoic sedimentary rocks covering Mesoproterozoic basement. Together, these new geological insights into the ice-covered bedrock of Wilkes Land substantially improve correlations of Antarctic and Australian geological elements and provide key constraints on the tectonic architecture of this sector of the East Antarctic Shield and its role in supercontinent reconstructions.

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Pangea Rifting Shaped the East Antarctic Landscape

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East Antarctica exhibits strongly contrasting topographic relief between the Precambrian basement domains of Indo-Antarctica and Australo-Antarctica. Plate-scale geodynamic processes and long-term fluvial/glacial erosion are broadly responsible for such variable hypsometry but their relative contribution to the Phanerozoic landscape evolution remains poorly constrained. Low-temperature thermochronology studies of exposed Precambrian basement have revealed discrete episodes of heating/cooling during the Paleozoic–Mesozoic; however, the significance of these thermal events and their relationship with the vastly different topographic responses in each domain is unclear. Furthermore, reported Paleozoic–Mesozoic cooling ages imply low long-term erosion rates which are at odds with the record of sedimentation offshore. To better elucidate the Phanerozoic landscape evolution of East Antarctica, we present the first low-temperature thermochronology data from Precambrian–Early Cambrian basement in the Bunger Hills region, located close to the transition between the Indo-Antarctic and Australo-Antarctic domains. Our results confirm the overall Paleozoic–Mesozoic cooling trend of East Antarctic basement and, combined with existing thermochronological, tectonic and stratigraphic evidence, reveal widespread thermal disturbance of Precambrian crust associated with Pangea-wide Late Paleozoic–Triassic intracontinental extension. Therefore, we infer that the topographic framework of both Indo-Antarctica and Australo-Antarctica was largely established during this Late Paleozoic–Triassic extensional phase through differential uplift of sections of Precambrian basement and the formation of large intracontinental sedimentary basins. Subsequently, prolonged erosion has acted to reinforce this landscape through the preservation of basement highlands and the focusing of large-scale erosion in low-lying sedimentary basins.

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Petrological and Geophysical Characterization of Exhumed Subcontinental Mantle along the Australian-Antarctic Ocean-Continent Transition Zone

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The final lithospheric breakup of the Australian-Antarctic rift system remains controversial due to sparse geological constraints on the nature of the basement along ocean-continent transition zones. One particular location where the early rift to drift transition can be studied is along the East Antarctic margin, and more precisely at Seamount B, offshore Terre Adélie. Dredges from this large seamount reveal the ubiquitous presence of mantle rocks (peridotites and pyroxenites) and a complete lack of either crustal fragments or volcanic and plutonic rocks (basalts, gabbros), the latter being characteristic of steady-state ocean crust. We present new petrological characterization of these dredged mantle rocks and combine them with new interpretations of multichannel seismic reflection transects on either side of Seamount B. By combining both datasets, we show that a 50–100 km wide domain of cold and fertile subcontinental mantle was exhumed along this non-volcanic Antarctic margin. These mantle rocks show strikingly similar features as exhumed mantle rocks along other (ultra)-slow passive margins worldwide. In addition, they preserve characteristics similar to mantle xenoliths found in syn- to post-rift volcanism at the eastern end of the Australian margin (Victoria and Tasmania), indicating the sampling of a common fertile subcontinental mantle during rifting between Australia and Antarctica. We will further discuss the implications of Seamount B on our understanding of the rift-to drift transition and magnetic anomaly patterns along the Australian-Antarctic margin.

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3D modelling from multichannel seismic, ODP sediments and potential fields analysis of the South Orkney Microcontinent (southern Scotia Arc, Antarctica)

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The South Orkney Microcontinent (SOM) is a key element in the reconstruction of the opening and deepening of the Powell Basin, and hence the Drake Passage. The SOM is the largest continental block, with an area of more than 70.000 km2, and is located in the central sector of the South Scotia Ridge and the northern Weddell Sea. Geological and geophysical modelling enables to characterise the nature of the margins and the complex structure of the SOM that respond to different tectonic phases since the Mesozoic.

Geological records in the area include the Hole 696B from the Ocean Drilling Program (ODP) located in the south-eastern margin of the SOM. This hole span from Middle Eocene to the Quaternary in its 650 m of sedimentary record. We combine the results from sonic data obtained on shipboard at 696B with multi-channel seismic profiles that cross the hole and nearby to make an age-depth conversion. Seismic data come from the Seismic Data Library (SDLS) and Spanish cruises (i.e. SCAN97; DRAKE2018). In addition, the modelling of gravimetric satellite data and compiled magnetic data from WDMAM allows to establish the basement geometry. This study presents new insights into the 3D geometry of structural highs and sedimentary basins and the tectonic evolution of the SOM.

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What does the southern margin of the Rayner Complex tell us about the amalgamation of East Antarctica?

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The Rayner Complex in East Antarctica extends >2000 km and separates a number of regions of Archean crust, making it critically important for understanding the geological development of East Antarctica. Together with its counterpart, the Eastern Ghats Province in India, it records extremely hot, long-lived metamorphism. It is generally thought that this metamorphic system developed in a back-arc that was shortened during the during the formation of the Rodinia supercontinent. However, the position of the Rayner–Eastern Ghats terrane remains a major uncertainty in Rodinia reconstructions.

Recent work in the Fisher Terrane, a volcanic arc in the southern Rayner Complex, suggests that there is additional complexity that cannot be accounted for by simply shortening an extended back-arc system. Detrital zircon data suggests the volcaniclastic rocks in the Fisher Terrane were deposited prior to Rodinia-aged metamorphism, and the Fisher Terrane was located on the same plate as the rest of the Rayner Complex. However, the Fisher Terrane records no evidence for Rodinia-aged metamorphism, despite being surrounded by high temperature Rodinia-aged metamorphic rocks. Instead, it records a single phase of high thermal gradient metamorphism at c. 510 Ma.

The fact that the Fisher Terrane does not record the same metamorphic history as the Rayner Complex until after the amalgamation of Gondwana highlights that this part of East Antarctica is still poorly understood. Future work that integrates geophysics with new data on protolith age and isotopic character is required to understand how the Fisher Complex fits into Rodinia reconstructions.

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A Multiproxy provenance approach to uncovering the assembly of East Gondwana in Antarctica

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East Antarctica is a collage of Precambrian terranes that assembled along a series of Neoproterozoic—Cambrian orogens during the construction of Gondwana. The least understood of these Gondwana-forming orogens is the Kuunga orogen, which records the closure of a major ocean basin between crust of Indian (Indo-Antarctica) and Australian (Australo-Antarctica) affinity. However, the location of the key boundary separating Indo-Antarctica and Australo-Antarctica within the Kuunga orogen remains controversial because extensive ice cover in East Antarctica precludes traditional characterisation of terranes.

We integrate Pb-isotope analysis of detrital feldspar grains with U-Pb dating of detrital monazite and zircon grains from offshore sediments to infer the location of the onshore boundary between Indo-Antarctica and Australo-Antarctica. New and compiled data from onshore basement exposures highlight the distinct age and Pb-isotope signatures of Indo-Antarctica and Australo-Antarctica. Holocene sediments offshore from Mirny Station (Queen Mary Land) have detrital feldspar Pb-isotope signatures and detrital monazite and zircon ages that reflect contributions from both Indo-Antarctica and Australo-Antarctica.

The presence of both Indo-Antarctic and Australo-Antarctic crust beneath ice cover near Mirny Station implies proximity to a fundamental terrane boundary within the Kuunga orogen, which could coincide with a geophysical lineament at ~94°E (Mirny fault). The geophysical expression of this boundary extends into the subglacial interior of East Antarctica where it may have connected with one or more previously inferred Gondwana-forming sutures. This revised geometry of the Kuunga orogen provides a new framework for interpreting future geophysical surveys and understanding the timing and evolution of the assembly of East Gondwana.

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Paleomagnetism of Jurassic Dykes from dronning Maud Land, Antarctica

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Similarities between the geology of Dronning Maud Land, Antarctica, relative to southern Africa have been well established. These include comparisons made between the Archaean Craton basement rocks, the Mesoproterozoic cratonic cover sequences and related magmatism and Paleozoic sedimentary sequences and Karoo/Ferrar magmatism. This study describes and interprets paleomagnetic and 40Ar/39Ar data from Jurassic dolerite dykes in western Dronning Maud Land (DML). Orientated block samples from dolerite dykes were analysed with spinner magnetometer and MAP 215-50 Noble Gas Mass Spectrometer at the University of Johannesburg to determine paleomagnetic poles and whole-rock 40Ar/39Ar ages. The robust geochronological results suggest ages between ~188-176 Ma. Eight dykes provided a consistent paleomagnetic pole of Plat = -52.1 & Plong = 181.0, A95 = 13, N = 8. This pole infers significant displacement of Antarctica from southern Africa at the time of emplacement of the 188-176Ma dykes studied here.

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Characterization and significance of Neoproterozoic events in East Antarctica

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East Antarctic shield (EAS) preserves relicts of ~4 billion years old history. The conventional structure of EAS proposed and repeatedly updated in the last two decades, exhibits distinct Archean to Mesoproterozoic units with debatable Neoproterozoic terrains. In the last decade, sporadic reports of Neoproterozoic magmatism and metamorphism have emerged not only in East Antarctica but also in its conjugate terrains of India and Australia.

Our recent investigations of exposed coastal outcrops of Princess Elizabeth Land (PEL) as well as proximal marine sediments off-coast of Wilkes Land (WL) and PEL indicates presence of extensive Neoproterozoic terrain in EAS. Examination of granulites from PEL indicates metamorphic assemblage developed at ~500 Ma with relicts of an ~800 Ma orogeny, as estimated from chemical geochronology of texturally constrained monazite. Heavy mineral and sedimentological data from IODP and ODP drill sites suggest polymetamorphosed terrain. Chemical geochronology of texturally constrained monazites analyzed in rock fragments also provides evidence of 700-800 Ma and ~500 Ma fabric producing event. The 700-800 Ma orogeny represents a hitherto less recognized orogenic activity preserved in EAS. This work represents the first comprehensive report of a definite Neoproterozoic orogeny in the easternmost segment of WL and PEL. Its implications for the supercontinent assembly are also discussed.

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Crust and Uppermost Mantle Structure of the Davis-Casey Region, and its Tectonic Setting within East Antarctica.

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The region between Davis and Casey stations is one of the least visited regions of East Antarctica. A deployment of GPS and seismic stations at 9 locations in this region began in the 2016/17 summer season and is ongoing, pending upgrade of key sites. The geodetic observations and seismic records will be used in a medium-term monitoring initiative to inform the interaction between the solid-Earth and cryosphere in a region with high uncertainty in (for example) the satellite observations and ice sheet modelling that constrain the contribution of the overlying ice sheet to sea level rise.

In this contribution, we present the first results from the seismology component of the deployment, which enable the seismic structure of the crust and uppermost mantle to be inferred. We use recordings of earthquakes that occurred at teleseismic distances, mostly from the Tonga-Kermadec subduction zone, Papua New Guinea and Indonesia. Using the receiver function method, we infer the significant wavespeed discontinuities within the crust, the depth of the seismic Moho, and the nature of this transition in seismic wavespeed to the mantle beneath.

We interpret these results in the light of the geology and geochronology along this margin of East Antarctica and possible interpretations of the tectonic setting of the lithospheric domains in this region. We make use of airborne geophysics compilations, and a recently published study of lithospheric boundaries constrained by multivariate data, to estimate the extent to which the seismic structure determined at the individual station locations may be extrapolated inland.

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Origin of the Conrad Rise: Key to understanding the tectonic development of the southwestern Indian Ocean during Late Cretaceous

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Conrad Rise is one of the largest edifices in the southwestern Indian Ocean. A previous investigation by Borisova et al. (1996) has shown that lavas from this structure share geochemical similarities with those from the Kerguelen archipelago and Afanasy-Nikitin Rise, raising the possibility that their mantle sources host a common continental derived component. Whether or not, these structures are produced by a common hotspot activity remains a matter of debate. Within this framework, we performed six cruises at the Conrad Rise by R/V Hakuho-Maru and collected rock samples by dredging and geophysical data.

Based on our new tectonic reconstruction by geomagnetic isochron determination, at a regional scale, the Conrad and Del Cano Rises and the southern Madagascar Plateau might have formed a single plateau during Late Cretaceous now separated into three distinct entities.

Igneous rocks were recovered from Ob, Lena, and two small seamounts on the Conrad Rise by dredging during KH-10-7, KH-19-1, and KH-20-1 cruises. They occur as massive lava, porous lava, and volcanic breccia. They are mainly alkali rocks, and lesser amounts of sub-alkali rocks were recovered. Their trace element contents are similar to those from Marion and Crozet Islands and Kerguelen Plateau. However, they have distinct Sr-Nd-Pb-Hf isotope compositions with samples from Marion Islands and Kerguelen Plateau, even in their present proximity.

This suggests that detailed and precised petrological, geochemical, geochronological, and geophysical investigations and analyses are needed for revealing the tectonic development between Gondwana break-up and seafloor spreading in the Indian Ocean during Late Cretaceous.

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High-resolution global bathymetry grids for key Cretaceous and Early Cenozoic climate stages

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Ocean currents are strongly controlled by seafloor topography. Recent studies have shown that small-scale features with slopes steeper than 0.05° significantly affect subsurface eddy velocities and the vertical structure of ocean circulation patterns. Such slope gradients represent the majority of the present-day oceanic basins. Modeling past oceanographic conditions for key climate stages requires similarly detailed paleo seafloor topography grids, in order to capture ocean currents accurately, especially for ocean models with sufficient resolution (<0.1°) to resolve eddies. However, existing paleobathymetry reconstructions use either a forward modeling approach, resulting in global grids lacking detailed seafloor roughness, or a backward modeling technique based on sediment backstripping, capturing realistic slope gradients, but for a spatially restricted area. Both approaches produce insufficient boundary conditions for high-resolution global paleo models. Here, we compute high-resolution global paleobathymetry grids, with detailed focus on the Southern Ocean, for key Cretaceous and early Cenozoic climate stages. We backstrip sediments from the modern global bathymetry, allowing the preservation of present-day seafloor slope gradients. Sediment isopach data are compiled from existing seismo-stratigraphic interpretations along the Southern Ocean margins, and expanded globally using total sediment thickness information and constant sedimentation rates. We also consider the effect of mantle flow on long-wavelength topography. The resulting grids contain realistic seafloor slope gradients and continental slopes across the continent-ocean transition zones that are similar to present-day observations. Using these detailed paleobathymetry grids for high-resolution global paleo models will help to accurately reconstruct oceanographic conditions of key climate stages and their interaction with the evolving seafloor.

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Updated tectonic framework of West Antarctica and legacy of formation upon the complex convergent margin of the Gondwana supercontinent

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Results of 21st century airborne and ground-based geophysical, radar, and geology campaigns advance our understanding of the physical properties of Antarctic lithosphere, and contribute new perspectives to the long held view that independent microcontinental blocks (terranes) underpin West Antarctica (WANT). Extensive new petrogenetic, age, and thermochronology datasets help to address questions of provenance, paleotopography, and tectonic connections among WANT, East Antarctica, Zealandia and South America. This paper integrates information from the Weddell Sea sector, including its onshore mountain highlands, Marie Byrd Land (MBL) and Ross Embayment, and the Antarctic Peninsula (AP) provinces. New and legacy datasets determine the subglacial extent and lithospheric characteristics of these provinces, and reveal common elements among sectors of the complex Gondwana margin. The body of evidence points to a shared rather than disparate geotectonic evolution within the paleo-Pacific margin system. For example, all three provinces record discontinuous magmatism in the Paleozoic, giving way to Permian through Cretaceous magmatic flare-up events linked to subduction dynamics. Strong isotopic evidence shows that Jurassic supra-subduction zone decompression melting factored in to inboard Ferrar mafic magmatism and drove coeval voluminous crustal melting and silicic magmatism in the AP. The main phase of continental margin arc magmatism was synchronous in AP and MBL, achieving substantial continental growth and stabilization across WANT, up to an inboard limit newly identified along the mid-line of Ross Embayment. This tectonic boundary is marked by a dramatic contrast in magnetic characteristics and spatially coincides with the southward continuation of the Central High beneath Ross Ice Shelf.

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The Wilkes Land sector including the Aurora Basin, and its most probable subglacial geology

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With no direct observations, the subglacial geology of the Antarctic interior is unknown. However, with a growing awareness of the complex interaction between the ice sheet and the solid Earth, there is a need for well-posed estimates of properties such as crustal heat production, extent and thickness of sedimentary basins, and timing and extent of exhumation. Constraining the likely nature of the bedrock is also the key to a better understanding of the tectonic history of East Antarctica, e.g. the extent of cratonic blocks and orientation of Proterozoic orogens.

We present a probabilistic approach to describe the range of possible interpretations of the Antarctic interior with a focus on The Wilkes Land sector, including the Aurora Basin. Along the coast, we utilize geological observations and tectonic reconstructions of Gondwana. In the interior, the constraints depend more heavily on geophysical data. We use the geological and geophysical data to construct 'membership functions' that quantify the likelihood of a given property of the subglacial geology. Properties include tectonic affiliation, crustal type and crustal stabilisation age. The membership functions are defined from a range of classification and regression methods, assembled in a novel workflow using the agrid package and provided Python code. The outcome is treated as a likelihood distribution and combined with expected prior values, for each property mapped.

Our resulting outputs and interpretations, including most likely broadscale bedrock geology, are made available as maps in widely usable formats for use in the wider geoscience and interdisciplinary Antarctic research communities.

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Scratching the surface: a marine sediment provenance record from the continental slope of central Wilkes Land, East Antarctica

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The subglacial geology in Wilkes Land, East Antarctica is masked by thick ice and remains largely unexplored. Yet the underlying crustal architecture records evidence of repeated supercontinent cycles and provides the geological template for the evolution of the Antarctic Ice Sheet. Sediment eroded from under the ice is ultimately deposited in the ocean, such that marine sediment can be used to characterize proximal subglacial geology. We use detrital grain morphology, trace element geochemistry and detrital U-Pb geochronology from a kasten core to construct the first marine sediment provenance record for the continental slope of central Wilkes Land, and provide new Pb-Pb isotopic signatures from proximal coastal outcrops for comparison. A principally igneous source is revealed with dominant age populations between c. 1200-1100 Ma and c. 1600-1300 Ma, characteristic of the proximal Banzare, Nuyina and Wilkes Provinces. The detrital geochronology suggests no change in sediment provenance over the last 23.5 ka, despite major ice sheet retreat during this time. A minor c. 700-500 Ma detrital age population unknown from the central Wilkes region was likely transported westward via icebergs to the core site. These findings broadly correspond with earlier interpretations of the subglacial geology and with erosion rates at the base of the ice sheet predicted from two ice sheet models, demonstrating the value of sediment provenance studies for uncovering proximal subglacial geology and reconstructing past ice sheet configurations.

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Opening of the Tasman Gateway - revisiting the final separation between Australia and Antarctica

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Plate tectonic motions separating Australia and Antarctica during the Cenozoic opened the Tasman Gateway around the time of the Eocene-Oligocene transition. The opening of the Tasman Gateway likely played an important role in the onset of the Antarctic Circumpolar current. While there has been ongoing discussion around the evolution of the depth of the Tasman Gateway, the timing of the tectonic opening of the Tasman Gateway has been thought to be well constrained.

In early 2019, we mapped a bathymetric feature that we interpret as an extinct spreading ridge between the East and South Tasman Rise. This finding was unexpected as most models predict that the seafloor between the East and South Tasman Rise formed early in the drift phase of Zealandia's separation from Australia (from around 83 Ma to 70 Ma), although a slightly younger formation around 60 Ma and an extinct spreading ridge were proposed for this basin, but never tectonically modelled. Further, we mapped deep (~2,500 mbsl) flat-topped seamounts proximal to the extinct spreading centre. Age, and geochemical, constraints from these seamounts, combining with plate tectonic and geodynamic understanding of seafloor and seamount formation, enables us to better constrain the timing of seafloor spreading between the East and South Tasman rises. Here, we use the new data and interpretations from the seafloor and seamounts to constrain a revised reconstruction model for the South Tasman Rise during the final stages of Australia's rifting from Antarctica, with implications for the timing and evolution of the Tasman Gateway.

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Revisiting the final separation between Australia and Antarctica – a role for the Balleny Mantle Plume?

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Plate tectonic motions between Australia and Antarctica opened Tasman Gateway around the time of the Eocene-Oligocene transition. The role of mantle plume volcanism in this separation and gateway opening is under investigation. A seamount chain extending from the Lord Howe Rise to east of Tasmania and the South Tasma Rise to the Balleny Islands in Antarctica is considered to relate to volcanism from the Balleny plume from 80 Ma to 2 Ma. This seamount chain includes the Cascade Seamount on the East Tasman Plateau which has been dated with Argon geochronology techniques to 36-37 Ma and coincides temporally with the opening of the Tasman Gateway. To the north and south of the Cascade Seamount are flat topped and conical seamounts that have not yet been dated, but could constrain the role of plume volcanism and dynamic topography in modulating the timing and rates of gateway evolution in this region.

In 2019, we mapped and sampled seamounts extending from the Lord Howe Rise to east of the South Tasman Rise. Age constraints from these seamounts combined with a HIMU geochemical signature representative of the Balleny Plume (high 143Nd/144Nd, low 87Sr/86Sr and distinctive Pb isotopic ratios) will be used to validate a role for the Balleny Plume for volcanism in this region. These geochronological and geochemical data will be incorporated into plate tectonic and geodynamic models to understand the evolution of the seafloor and seamount formation during the time of gateway opening.

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Implications of East Antarctic lithospheric structure for the history and tectonics of the Antarctic Craton

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We use a newly developed Antarctic seismic model to explore lithospheric structure and its implication for the geological history of East Antarctica. Lloyd et al [2019] use adjoint seismic tomography to invert frequency-dependent traveltimes from three component earthquake waveforms for seismic structure down to 800 km beneath Antarctica and adjacent oceans. We use this model to estimate the thickness and thermal structure of East Antarctic continental lithosphere. Lithospheric thickness is highly variable, ranging from around 100 km to greater than 220 km. The thickest lithosphere, found in Southern Victoria Land west of the Transantarctic Mountains, probably represents the continuation of the Australian Gawler Craton and the Antarctic Terre Adélie craton beneath the ice sheet. This large region, often termed the Mawson Craton, formed the Archean to Paleoproterozoic core of Gondwana. Although much of East Antarctica has lithospheric thickness of nearly 200 km, greater variability in lithospheric thickness and structure is found beneath the East Antarctic Highlands, stretching from western Dronning Maud Land to the Lambert Graben. The uppermost mantle beneath Fimbulheimen in Dronning Maude Land is characterized by an absence of fast lithosphere, consistent with early or mid-Phanerozoic tectonic activity and lithospheric delamination. Much thinner lithosphere is also imaged beneath Enderby and Kemp Land (including the Lambert Graben), suggesting the lithosphere was disrupted and thinned due to rifting activity connected with the breakup of Gondwana and the formation of Lambert Graben.

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Antarctic subglacial geology from detrital provenance in marine sediments; examples from the Wilkes Subglacial Basin and the Weddell Sea embayment

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Thermochronologic and geochronologic ages and isotope geochemistry of glacial sediment provide a way to investigate the geology of ice-covered areas of Antarctica, particularly the parts of the hinterland that are eroding fastest.

At IODP Site U1356, offshore of the Wilkes Subglacial Basin, ice-rafted detritus (IRD) was deposited in high concentrations during the mid-Miocene climate transition. At this time the ice sheet was eroding inland areas of the basin, in contrast to today, when detritus mainly comes from the marginal areas. The dominant $^{40}Ar/^{39}Ar$ thermochronological age of the ice-rafted hornblende grains is 1400-1550 Ma, implying an inland source area of this age extending along the eastern part of the Adélie Craton, which forms the western side of the Wilkes Subglacial Basin.

In the Weddell Sea, subglacial till and proximal glaciomarine sediment from Polarstern core sites along the edge of the Filchner and Ronne Ice Shelves were used to characterize the upstream geology by projecting provenance back along ice flow lines into the embayment. Detrital hornblende and biotite $^{40}Ar/^{39}Ar$ thermochronologic and zircon U-Pb geochronologic ages reflect Cretaceous and Jurassic tectonic activity and the Ross and Grenvillian orogenies, largely corresponding to the known ages of tectonic blocks in the embayment. εNd values of the fine-grained sediment fraction are quite unradiogenic across the central and eastern side of ice-shelf front (εNd -10 to -16), compared to the western side. We infer that the central sediments may be derived from Beacon-age sedimentary rocks, themselves derived from East Antarctica.

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