Eocene cooling linked to early flow across the Tasmanian Gateway

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The warmest global temperatures of the past 85 million years occurred during a prolonged greenhouse episode known as the Early Eocene Climatic Optimum (52–50 Ma). The Early Eocene Climatic Optimum terminated with a long-term cooling trend that culminated in continental-scale glaciation of Antarctica from 34 Ma onward. Whereas early studies attributed the Eocene transition from greenhouse to icehouse climates to the tectonic opening of Southern Ocean gateways, more recent investigations invoked a dominant role of declining atmospheric greenhouse gas concentrations (e.g., CO_2). However, the scarcity of field data has prevented empirical evaluation of these hypotheses. We present marine microfossil and organic geochemical records spanning the early-to-middle Eocene transition from the Wilkes Land Margin, East Antarctica. Dinoflagellate biogeography and sea surface temperature paleothermometry reveal that the earliest throughflow of a westbound Antarctic Counter Current began ~49–50 Ma through a southern opening of the Tasmanian Gateway. This early opening occurs in conjunction with the simultaneous onset of regional surface water and continental cooling (2–4 °C), evidenced by biomarker- and pollen-based paleothermometry. We interpret that the westbound flowing current flow across the Tasmanian Gateway resulted in cooling of Antarctic surface waters and coasts, which was conveyed to global intermediate waters through invigorated deep convection in southern high latitudes. Although atmospheric CO_2 forcing alone would provide a more uniform middle Eocene cooling, the opening of the Tasmanian Gateway better explains Southern Ocean surface water and global deep ocean cooling in the apparent absence of (sub-) equatorial cooling.

climate cooling | dinoflagellate cysts | organic palaeothermometry | paleoceanography

Plant microfossils reveal the presence of paratropical rainforest biomes on the Antarctic continent during the early Eocene (1). Organic biomarker paleotemperature reconstructions also reveal extremely warm Southern Ocean sea surface temperatures (SSTs) at that time (2–4). Both lines of evidence indicate remarkably warm climate conditions for the highest southern latitudes during peak Cenozoic greenhouse conditions. Early hypotheses explaining the Eocene warmth at high latitudes invoked a pivotal role of ocean surface currents that, subject to a continental configuration fundamentally different from today, facilitated an increased heat transport to the Antarctic coastline (5, 6). Closed Southern Ocean gateways (i.e., Drake Passage and the Tasmanian Gateway) obstructed the formation of an isolating circumpolar surface current: the Antarctic Circumpolar Current (ACC) and associated coastal currents. In the absence of the isolating ACC, warm, low latitude-derived currents were thought to have bathed the Antarctic continent (5). Southern Ocean SSTs were characterized by a marked, gradual cooling starting in the latest early Eocene (~49.5 Ma) (2–4), which culminated in the onset of large-scale glaciation of Antarctica at 34 Ma (7, 8). The timing of the opening of Southern Ocean gateways seemed roughly time equivalent with major climatic transitions in the southern high latitudes (9).

Opposition to the gateway hypothesis emerged in the 1990s, when sophisticated computer simulations [general circulation models (GCMs)] indicated that the Eocene surface current configuration in the Southern Ocean featured circulating gyres (10, 11). Despite the closed gateways, gyral Southern Ocean circulation prevented low latitude-derived currents from reaching and warming the coasts of Antarctica (10, 11). Additional evidence against the gateway hypothesis was obtained from drill cores in the Tasmanian Gateway region (Fig. S1), which showed that the accelerated deepening and widening of the Tasmanian Gateway occurred 2 million y before the onset of major Antarctic glaciation (12)—therefore, contradicting a direct mechanistic link between gateway opening, thermal isolation, and Antarctic glaciation. The circum-Antarctic biogeographical patterns of marine phytoplankton (13) lend additional support to the ocean current regime indicated by GCM experiments (Figs. S2 and S3) (11, 14). This biogeographical information is primarily based on organic-walled dinoflagellate cysts (dinocysts; fossil remains of dinoflagellates), which are highly sensitive indicators of surface ocean conditions (Table S1) (15). Before the opening of the Tasmanian Gateway, the Antarctic margin-derived Tasman Current influenced surface waters in the Pacific sector of the Tasmanian region, which is consistent with high abundances of Antarctic-endemic dinocysts (11). In contrast, surface waters in the Australo-Antarctic Gulf (AAG), west of Tasmania, were sourced by low latitude-derived Indian Ocean waters by the Proto-Leeuwin Current (PLC) (11). Indeed, dinocyst assemblages in the AAG were dominated by cosmopolitan and low-latitude taxa (13) (*SI Text* and Figs. S2 and S3). The early GCM experiments, strongly supported by the

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biogeographical patterns in microfossils (11, 16), suggested that poleward ocean heat transport was not much larger than today's transport with closed oceanic gateways and cannot be the sole explanation for the warmth on Antarctica (11, 16).

As an alternative explanation, it was proposed that elevated atmospheric greenhouse gas concentrations (e.g., CO_2) drove Eocene climates into hothouse conditions. Accordingly, a decline in the concentration of these greenhouse gases was considered the primary forcing agent for the cooling of the middle Eocene, ultimately leading to the development of the Oligocene and Neogene icehouse world (17). However, the apparent absence of cooling through the middle and late Eocene in subequatorial regions (2, 18, 19) is not compatible with the greenhouse gas hypothesis. In the absence of ice albedo feedbacks, which would amplify high-latitude cooling during the Eocene, climate cooling through CO_2 decline alone would have been globally more uniform (20, 21) than documented in the available climate proxy data (2). The observation that polar regions show pronounced cooling, whereas (sub-) equatorial temperatures remained stable suggests that alternative forcing factors must have been driving high-latitude climates in the Eocene without influencing the (sub-)equatorial surface waters.

Although the opening of Southern Ocean gateways fails to explain the onset of continental-scale Antarctic glaciation at 34 Ma, the oceanographic changes resulting from gateway opening most likely had a climatic impact on the Southern Ocean surface waters (12, 14). Moreover, these regional climatic effects had significance at a supraregional level, because the signature of the Southern Ocean climatic evolution (2) is effectively transported to the rest of the world through deep water formation (21, 22). Detailed geologic reconstructions have previously focused on the climatic consequences of the gateway deepening that occurred at 35.5 Ma (12), whereas earlier stages of the opening of the Tasmanian Gateway were largely ignored. One difficulty has been the lack of early-to-middle Eocene records that are spatially dispersed around the Tasmanian Gateway.

Integrated Ocean Drilling Program (IODP) Expedition 318 recovered Eocene sediments from the Wilkes Land margin, a hitherto unexplored sector of the Antarctic margin for the Eocene time interval (Fig. 1 and Fig. S1). We generated dinocyst assemblage and organic biomarker data from Site U1356 (Fig. S4), which was on the Antarctic margin within the AAG. Dinocyst assemblage analyses were also generated from Ocean Drilling Program (ODP) Leg 182, Site 1128 in the Australian Bight (23) (Fig. 1 and Fig. S1). Dinocyst assemblage and organic biomarker records from ODP Leg 189, Site 1171 on the South Tasman Rise (STR) and Site 1172 on the East Tasman Plateau (13) were revisited for the purpose of this study (sediments from Site 1171 lack biomarkers for SST reconstructions) (Fig. 1 and Fig. S1). Dinocyst assemblage data from the Otway Basin and RV *Sonne* and RV *Rig Seismic* gravity cores on the west coast of Tasmania as well as dredge sample surveys were obtained from the literature (24, 25) (Fig. 1 and Fig. S1). The combined dataset from these sites has sufficient spatial coverage to reconstruct changes in biogeographical patterns across the early-to-middle Eocene transition.

The lowermost 110 m of sedimentary strata recovered in Hole U1356A (Fig. S5) consist of a relatively complete, well-dated early-to-middle Eocene shelf sequence (26). The sequence is barren of carbonate and biogenic opal but contains remarkably abundant and well-preserved dinocysts (Fig. 2), biomarker assemblages (Fig. 3), and pyritized siliceous microfossils (*SI Text*) that allow for the reconstruction of environmental conditions along the Wilkes Land shelf. To assess the oceanographic history of the Tasman region during the early-to-middle Eocene, we integrated the dinocyst results from Site U1356 with the results from other sites around the Tasmanian Gateway to evaluate biogeographic patterns. Along with organic biomarker paleothermometry, we used these records to reconstruct the surface water and terrestrial temperature evolution on both sides of the Tasmanian Gateway. We then compared these results with the global intermediate water temperature trends as derived from the compilation of benthic foraminiferal oxygen isotopes (17) to evaluate the global significance of Tasmanian Gateway opening. Additional information regarding lithological descriptions and age models for sites used for this study as well as a full methodology of the proxies applied is in *SI Text*.

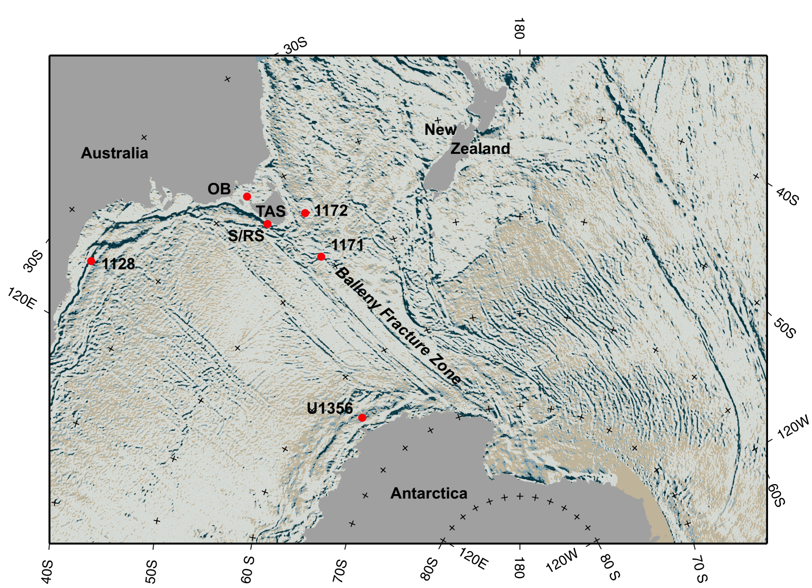

Fig. 1. Present day ocean bathymetry of the Australian sector of the Southern Ocean. The bathymetry of the ocean floor between Australia and Antarctica is characterized by major spreading ridges (magnetic anomalies are in Fig. S1). The Balleny Fracture Zone marks the direction of motion of the Australian plate away from Antarctica through the Cenozoic. Red dots mark the present day position of the sites used in this study. OB, Otway Basin; S/RS, RV *Sonne* and RV *Rig Seismic* samples; TAS, Tasmania. Modified from ref. 44.

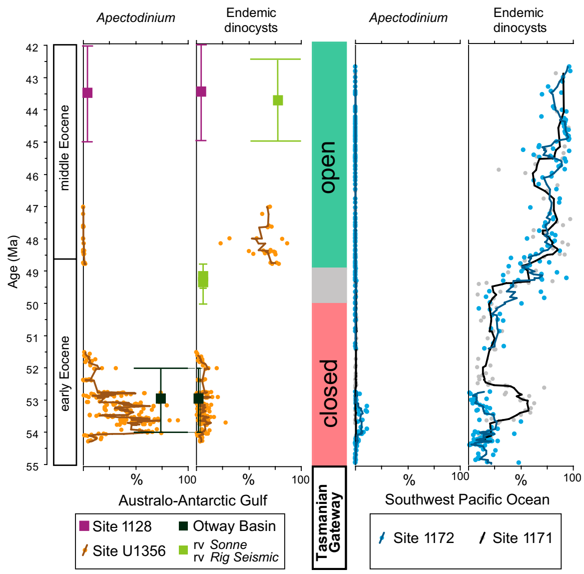

Fig. 2. Differences in surface water plankton (dinocyst) assemblages on both sides of the Tasmanian Gateway across the early-to-middle Eocene transition. Relative abundances of *Apectodinium* spp. and endemic Antarctic dinocysts from the six investigated localities are plotted separately for both sides of the Tasmanian Gateway. Error bars reflect stratigraphic uncertainty (*SI Text*). The lines through the dinocyst records from IODP Site U1356 and ODP Sites 1172 and 1171 are five-point running means. Data from Otway Basin are from ref. 23. Data from RV *Rig Seismic* and RV *Sonne* cruises are from ref. 24.

Eocene Dinocyst Assemblages Around the Tasmanian Gateway

Early Eocene (54–52 Ma) age sediments from Site U1356 contain extremely high percentages (50–80%) of the dinocyst *Apectodinium* (Fig. 2). The persistent dominance of this (sub-)tropical (27) dinocyst genus along the Wilkes Land margin (at 65°S paleolatitude) is remarkable but consistent with the observation that many other sites in the northern AAG yield dominant *Apectodinium* in the same time interval (28). Endemic Antarctic dinocysts occur only sporadically and in low abundance (<5% on average) (Fig. 2) at all study sites within the AAG. In contrast, coeval sediments from the southwest Pacific Ocean typically contain few *Apectodinium*. Instead, these sites yield, on average, 15% typical Antarctic-endemic taxa together with cosmopolitan species (Fig. 2 and statistical evaluation in *SI Text*). This distinct biogeographic pattern illustrates the strong association between dinocyst assemblages and the water masses on either side of the Tasmanian Gateway. It also reflects the influence of the low latitude-derived PLC on the AAG vs. the Antarctica-derived Tasman Current in the southwest Pacific Ocean (*SI Text*). More importantly, the distinct difference in dinocyst assemblages between the AAG and southwest Pacific sites suggests that the Tasmanian Gateway served as an effective barrier to surface water exchange before 50 Ma (Fig. 4*A*).

During the latest early-to-middle Eocene (hereafter referred to as mid-Eocene; 49–46 Ma), abundant Antarctic endemic dinocysts appear along the Wilkes Land Margin of the AAG (Fig. 2). Many endemic taxa that are not reported from the AAG in late Paleocene–early Eocene sediments (25, 29–31) first occur at Site U1356 between 52 and 49 Ma (the uncertainty of which is caused by a hiatus in the Site U1356 record) (*SI Text*). It is highly unlikely that these taxa were brought into the AAG by the PLC; the northern side of the AAG, which is influenced by the PLC (11, 14), was dominated by low to midlatitude and cosmopolitan dinocysts in the early Paleogene (65–33 Ma) (Fig. 2), and records from that region are devoid of endemic Antarctic dinocysts (13). However, endemic Antarctic taxa reach relatively high abundances (15%) in the southwest Pacific Ocean (i.e., east of the Tasmanian Gateway region) during the early Eocene, where they dominate from ~50 Ma onward (Fig. 2). We infer that these biogeographic patterns are best explained by an opening in the southern part of the Tasmanian Gateway, which allowed migration of endemic dinocysts into the AAG. Hence, we attribute the appearance of dominant endemic Antarctic dinocysts on the Wilkes Land Margin between 52 and 50 Ma to the onset of westward throughflow of the Antarctic Counter Current from the southwest Pacific Ocean into the southern AAG (Fig. 4*B*).

A grab-sample survey along the East Antarctic margin (from Wilkes Land to Prydz Bay) also shows that mid-Eocene samples contain many endemic Antarctic taxa (32), which extends the reach of the Antarctic Counter Current to large parts of the East Antarctic margin. In sediment cores retrieved off southwest Tasmania [Otway Basin (25) and RV *Rig Seismic* and RV *Sonne* cores (24)] (Fig. 1), endemic dinocysts occur in low abundance (>5%) during the late early Eocene (~50–49 Ma) (Fig. 2) but dominate mid-Eocene assemblages (~45–42.5 Ma onward) (Fig. 2). The dominance of endemic species in these cores supports our interpretation that surface water throughflow occurred from the southwest Pacific Ocean into the AAG in the middle Eocene. The virtual absence of southwest Pacific dinocysts in the early Eocene section of the same cores indicates that, before 49–50 Ma, the Tasmanian Gateway was still closed. This constrains the timing of the onset of surface water throughflow to between 50 and 49 Ma. The age uncertainty of 1 million y is caused by the stratigraphic uncertainty of the lowermost samples in the RV *Sonne* and RV *Rig Seismic* cores (*SI Text*).

Along with endemic dinocysts, the mid-Eocene section at Site U1356 contains low-latitude taxa that do not occur in age-equivalent strata in the southwest Pacific (*SI Text*). This combination of endemic and low-latitude constituents in the dinocyst assemblages testifies to a continued influence of the PLC on the Wilkes Land margin during the mid-Eocene, with the PLC mixing with southwest Pacific waters that entered the AAG through the Tasmanian Gateway. The absence of low-latitude taxa from the southwest Pacific Ocean also implies that the northern continental blocks in the Tasmanian Gateway and/or the westward throughflow of the Antarctic Counter Current effectively blocked the eastward flow of PLC surface waters to the Pacific side of the Tasmanian Gateway during the middle Eocene (Fig. 4).

Tectonic Reconstructions of the Eocene Tasmanian Gateway

The sediment records from the continental blocks that constitute the southern part of the Tasmanian sill indicate that an abrupt increase in subsidence occurred at the end of the early Eocene (~51 Ma) (33, 34). This increase correlates to a seismic reflector that can be traced throughout the STR. The overlying Eocene strata cover large areas of the STR, vary in thickness, and are mostly absent on the main structurally high areas. The seismic reflector has been interpreted to represent the transition from a southwest–northeast trending movement to north–south rifting of the STR dated as late Paleocene to early Eocene (34, 35). Subsequently, at ~48 Ma, oceanic spreading rates markedly increased in the AAG (36). The most plausible explanation for the recorded tectonic evolution is that accelerated rifting during the early-to-middle Eocene transition (~52–48 Ma) caused a gradual drowning of continental blocks in the southern part of the Tasmanian Gateway (*SI Text* and Fig. S6). This drowning scenario would explain the increased sedimentation rates in subbasins on the top of the STR, which in such shallow marine settings, are largely controlled by the subsidence of the continental crust (37). Furthermore, the deepening periphery of these blocks would facilitate the establishment of a southern connection of surface waters between the STR and the rifted margin of Antarctica. The southern region of the Tasmanian Gateway (>60°S) would have been under the influence of an atmospheric circulation dominated by easterlies

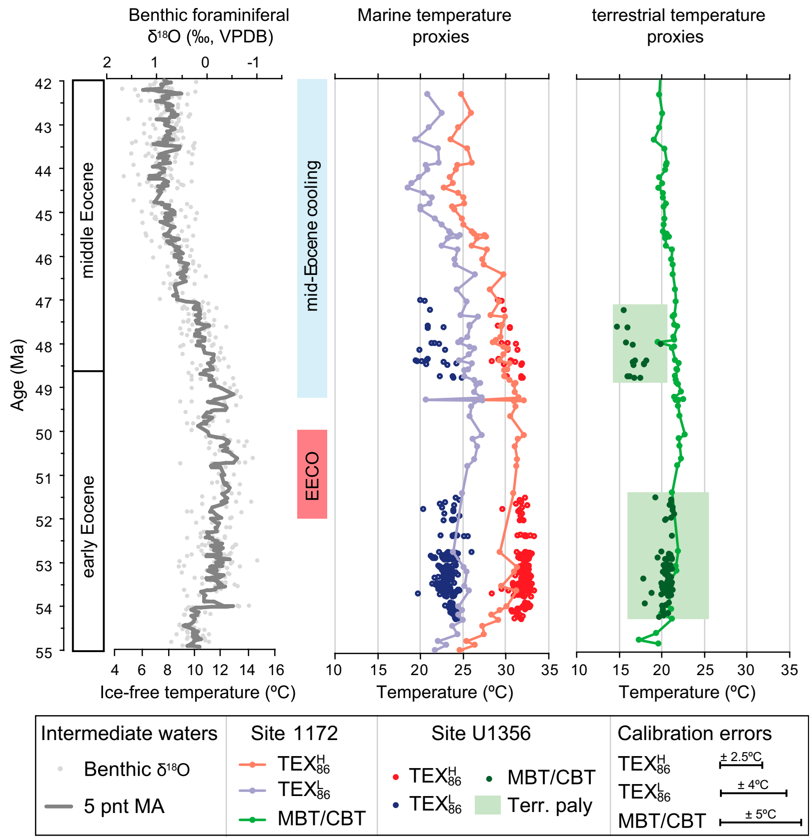

Fig. 3. Middle Eocene cooling of global intermediate waters compared with the evolution of SSTs and continental temperatures on both sides of the Tasmanian Gateway. (*Left*) Benthic foraminiferal stable oxygen isotope stack (data from ref. 16 with amendments) (4). The dark gray line represents a five-point moving average through the data (45). (*Center*) TEX_{86}-based reconstructions [two calibrations: TEX^H_{86} (red) and TEX^L_{86} (blue)] (*SI Text*) from each side of the Tasmanian Gateway [IODP Site U1356 (dots) and ODP Site 1172 (2) (lines)]. (*Right*) MBT/CBT-based continental air temperatures of the hinterland from two sites on each side of the Tasmanian Gateway [Site U1356 (dots) (1) and Site 1172 (lines)] (calibrated based on data from ref. 42). Also plotted are mean summer temperatures from the terrestrial palynomorph assemblages. Analytical errors for the TEX_{86} (±0.3 °C) and MBT/CBT (±1.0 °C) are too small to be indicated; the calibration errors are indicated in the legend.

(11) favoring a westward throughflow, which is consistent with our dinocyst-inferred surface water circulation patterns.

Temperature Evolution

Recent GCM experiments comparing a closed vs. open Tasmanian Gateway suggest a regional Southern Ocean surface water cooling of ∼3 °C as the gateway opened (14). These experiments were set up to investigate the deepening of the Tasmanian Gateway at 35.5 Ma and are not directly applicable to the scenario of early southern opening of the gateway around 49–50 Ma. The model results, which assume a shallow but open Drake Passage (9), imply that any circum-Antarctic circulation would have effectively reduced the SST of the Southern Ocean because of the longer residence time of surface waters at high latitudes. To test this implication, we have applied organic biomarker proxies on sediments from Site U1356 to estimate sea surface (TEX_{86}) (38–40) and continental air temperature (pollen assemblages and the organic Methylation Index of Branched Tetraethers over the Cyclisation Ratio of Branched Tetraethers (MBT/CBT) biomarker proxy) (41, 42). We also generated MBT/CBT data for ODP Site 1172 in the southwest Pacific Ocean (Fig. 1) and compare the paleotemperature records with the previously published TEX_{86} SST record at that site (2) (Fig. 3). The TEX_{86} data from Site U1356 indicate near-tropical conditions in the early Eocene, with SSTs reaching 31 °C (calibration error ± 2.5 °C) and 24 °C (calibration error ± 4.0 °C) using the TEX^H_{86} and TEX^L_{86} calibrations, respectively (39, 40) (Fig. 3). Mean summer air temperatures of the Antarctic coastal regions were 20–23 °C (calibration error ± 5.0 °C), which were reconstructed independently from both terrestrial palynomorphs and the MBT/CBT proxy (42) (Fig. 3). More important to the study presented here is the cooling across the early-to-middle Eocene transition: SSTs along the Wilkes Land margin cooled by 2–4 °C, whereas air temperatures cooled by ∼4 °C (Fig. 3 and statistical evaluations in *SI Text*). Although the magnitude of cooling falls within the calibration errors (for absolute temperature) of the proxies, proxy intercomparison studies have shown that TEX_{86} variability within the calibration error does match temperature changes invoked from other temperature proxies (40) also in the Eocene Southern Ocean (6). Moreover, the same magnitude of continental cooling as seen in the MBT/CBT proxy is inferred from parallel pollen–spore assemblage analyses analyzed from the same sediments (1) (Fig. 3). In the southwest Pacific Ocean, gradual cooling after the Early Eocene Climatic Optimum (EECO) started at ∼4.5 Ma. This onset of cooling is also seen in multiproxy temperature reconstructions from Eocene sections in New Zealand (3, 4), which extend the temperature signal to larger parts of the Southern Ocean. The combined micropaleontological and organic geochemical results show that the termination of the EECO and the onset of cooling coincided with the early opening of the Tasmanian Gateway (49–50 Ma).

Climatic Significance of Tasmanian Gateway Opening

The GCM experiments that simulate the effects of Tasmanian Gateway opening suggest that the onset of circum-Antarctic

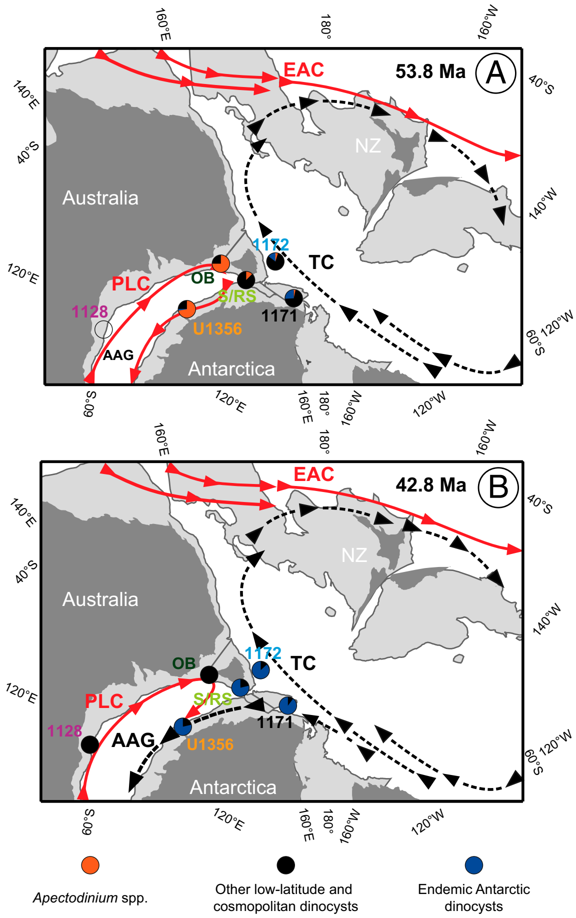

Fig. 4. Tectonic evolution of the Tasmanian Gateway. Eocene continental configurations of the Australian sector of the Southern Ocean for the (*A*) early Eocene (subchron C24n; 53.8 Ma) and (*B*) middle Eocene (chron C20; 42.8 Ma). Maps show the positions of the study sites: ODP Site 1128 (23); IODP Site U1356 (this study); Dilwyn Formation, Otway Basin (OB), Victoria (25); *RV Sonne* and *RV Rig Seismic* gravity core sites (S/RS) (24); ODP Site 1172 (13); and ODP Site 1171 (13). Dark gray areas reflect present day shorelines, and light gray areas are submerged continental blocks above 3,000 m water depth. The maps are overlain by surface currents as interpreted from modeling experiments (11, 14). The Tasmanian Gateway was open to shallow circulation from ∼50 Ma onward, which allowed for westward leakage of the Antarctic Counter Current. EAC, East Australian Current; NZ, New Zealand; TC, Tasman Current. Modified from ref. 44.

surface circulation induces regional surface water cooling (11, 14). Moreover, because the Southern Ocean surface waters were the primary source region for intermediate waters in that time, the cooling is propagated globally through downward convection/water mass formation during the winter and then advection by currents at depth (2, 21). Three independent lines of marine proxy evidence directly support a primary source of intermediate water formation in the Southern Ocean. (*i*) Neodymium isotope measurements on fish teeth suggest that the Southern Ocean was the dominant region for intermediate water formation in the Eocene (22). (*ii*) Global intermediate waters witness a gradual cooling coincident with our inference of high-latitude surface water cooling and the onset of throughflow across the Tasmanian Gateway (Fig. 3). (*iii*) Pollen-based temperature reconstructions suggest mean wintertime temperatures on the Wilkes Land coastal margin of ∼10–15 °C (1). This season-specific winter temperature reconstruction agrees with the reconstructed temperatures of the intermediate water masses (Fig. 3). This consistency in temperature inferences lends additional support to the South Pacific intermediate water formation taking place primarily during wintertime. Other studies provide evidence for an additional North Atlantic source for deep water formation (43) initiating around the early-to-middle Eocene boundary. The depth of this water mass would suggest a position below the carbonate compensation depth, and that makes it uncertain whether this deep water mass is represented in the data compilation of benthic foraminiferal oxygen isotopes (Fig. 3). Moreover, the intermediate deep water carbon isotope gradients between oceanic basins lend additional support for increased formation of Southern Ocean intermediate waters (43) during the middle Eocene, providing additional evidence for a connection between the temperature trends in benthic foraminiferal oxygen isotopes and in Southern Ocean surface waters.

The absolute temperatures from benthic foraminiferal oxygen isotopes are much (10–18 °C) cooler compared with organic SST proxies in the high southern latitudes (Fig. 3). This offset is too large to be explained by an additional influence of continental ice on the isotopes. However, it can be readily reconciled considering that there is likely a summer bias of organic paleothermometer proxies when applied to Paleogene high latitudes (1, 2) (additional discussions in *SI Text*) and that deep water formation in the Southern Ocean took place primarily in winter (1, 2, 21). Both these inferences are well-supported by comparison with independent temperature data (1, 2).

Irrespective of constraints on absolute temperatures, the timing of the initiation of cooling in Southern Ocean surface and intermediate deep waters and Antarctic continental temperature records (Fig. 3) is remarkably consistent with the inferred onset of throughflow across the Tasmanian Gateway. However, it should be noted that the model experiments on Tasmanian Gateway opening simulate a different scenario, in which the Tasmanian Gateway deepens in the northern part of the gateway (14), causing an eastward throughflow of the PLC into the southwest Pacific Ocean (i.e., a proto-ACC) rather than the Antarctic Counter Current at higher latitudes; thus, it is the opposite of what we reconstruct for the early Eocene opening. We propose that any circum-Antarctic circulation arguably has an effect of cooling, because it reduces the influence of the lower-latitude currents on the high latitudes.

The stable (sub-) equatorial temperatures throughout the Eocene (2, 18, 19), in contrast to marked Southern Ocean cooling, are difficult to explain solely through atmospheric CO_2 forcing (17). In the presumed absence of major changes in ice albedo feedbacks in the Eocene, additional climatic forcings are required that only influence the high latitudes. In the scenario proposed here, opening of Southern Ocean Gateways and resulting throughflow resulted in cooling of Antarctic margins. This scenario would also explain why (sub-) equatorial temperatures remained stable: these regions are not widely influenced by the effects of the opening of high-latitude gateways. However, because intermediate deep water temperatures also cooled in the middle Eocene, it would be expected that equatorial regions that experienced upwelling from deep intermediate waters should have undergone some cooling in conjunction with high-latitude cooling. Thus, it is likely that equatorial temperature evolution was spatially heterogeneous in nature during the Eocene. Equatorial paleoclimate archives from the Eocene upwelling regions are required to test this hypothesis. Although the available data suggest that atmospheric CO_2 declined over the middle Eocene (17), an explanation of all available temperature records requires a climatic forcing in the Southern Ocean and the evolution of meridional temperature gradients. The early Eocene opening of the Tasmanian Gateway provides, at least conceptually, a plausible mechanism for cooling the southern high-latitude surface waters without affecting most of the global (sub-)equatorial surface waters.

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