Insight into Drake Passage opening from sediment provenance and thermochronology

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Whereas the Antarctic Circumpolar Current's effect upon the modern thermal structure of the Southern Ocean is evident, its exact influence on paleoclimate is less well resolved. Accurate determination of the kinematic history of the ocean gateways that enable circumpolar circulation is a fundamental but challenging requirement for assessing the role of the Southern Ocean in geohistorical climate change.

Herein we present geochemical data from southernmost South America, the Antarctic Peninsula and the Scotia Sea that provide new insight into the timing and pattern of the opening of Drake Passage. Trace element & Nd-isotope geochemistry, EDS-assisted heavy mineral analysis and U-Pb geochronology of detritus deposited in the Magallanes & Larsen basins and the Scotia Sea provide a record of the sediment sources contributing to each of the basins during the Paleogene. Temperature-time pathways generated from (U-Th-Sm)/He and fission-track thermochronology of apatite and zircon collected from adjacent highlands in the southernmost Andes and the Antarctic Peninsula contribute an independent record of sediment-source evolution and record the history of tectonic exhumation along the margins of Drake Passage.

Together, our data indicate a dramatic reorganization of the Fuegian Andes in the middle Eocene (c. 40 Ma) during a period of tectonic quiescence in the northern Antarctic Peninsula, and broadly coincident with the penetration of Pacific water-mass into the Atlantic sector of the Southern Ocean. Moreover, our data indicate that the Magallanes and Larsen basins received sediment from fundamentally different sources since at least the late Paleocene. Nascent examination of older strata and of marine sediment cores from the Scotia Sea should allow us to evaluate the possibility that Drake Passage began opening prior to the Eocene.

Linkage of terrestrial and marine records during OAE2 (94Ma)

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Detailed correlation of hemipelagic to paralic records of the Cenomanian-Turonian (C-T) Ocean Anoxic Event 2 (OAE2), provides an excellent opportunity to examine coeval marine and terrestrial responses to a major biogeochemical perturbation. This ~600ky event, characterized by widespread development of organic-carbon rich marine facies, a >2‰ positive shift in stable carbon isotopes of carbonate, as well as marine and terrestrial organic carbon, and increased marine extinction rates, represents one of the most significant shifts among interdependent biogeochemical cycles known from the geologic record. Although recent work has suggested that the event was triggered by enhanced volcanism, the exact causal sequence remains unknown. In this study, shoreline deposits of the Dakota Fm. in SW Utah were correlated to the orbitally tuned C-T boundary stratotype in Pueblo, CO, combined with a detailed study of plant fossil material, including stomatal index and carbon isotopes. Both the initial +2‰ & +4‰ shifts in C_{org} are resolved, demonstrating that land plants record these carbon cycle excursions with high fidelity. Using the stomatal index record across the onset of OAE2 as a proxy for $p\mathrm{CO_2}$, we show that decreases in $p\mathrm{CO_2}$ closely track the global $\delta^{13}C_{org}$ record, suggesting that the atmospheric, terrestrial and marine carbon reservoirs were tightly coupled during the Late Cenomanian. Our data support the hypothesis that elevated primary productivity led to enhanced burial of marine organic carbon, resulting in a CO_2 decrease of ~26% at the onset of OAE2. Stomatal index data were converted to CO_2 values using two modern analogue species; the calculated values are consistent with other published estimates from this time interval. The $p\mathrm{CO_2}$ decreases within OAE2 were overlain on a longer term CO_2 rise that began up to 500ky before the onset of the C-isotope perturbation. Background CO_2 levels of ~370 $^{+100}/_{-70}$ ppm increased by 20 percent prior to anoxia, reaching a peak of ~500 $^{+400}/_{-180}$ ppm in the early portion of OAE2. This increase provides support for the hypothesis of a massive magmatic episode initiating OAE2. Volcanic release of sulphur, and its addition as sulphate to a sulphate-depleted ocean, may have allowed for the recycling of phosphate to fuel primary production, while higher $p\mathrm{CO_2}$ levels raised global temperatures, increased chemical weathering and nutrient flux from land, and helped drive increased phosphate delivery to the ocean.