The Cenozoic tectonic evolution of the Scotia Sea area

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Short summary: what did we study?

The evolution and development of the Scotia area starting with the break up of Southern Gondwana land

The extend of the Proto-Weddell Sea

Defining the role of the Drake Passage gate way opening in the onset of the Antarctic glaciations

We suggest that the break-up of Southern Gondwanaland resulted in the formation of the Proto-Weddell sea. Remnants of this are still present in the Scotia Plate.

We defined the extend of the remnants of the Proto-Weddell sea by rotating the Geological Units (GUs) back and forth in time in GPlates and by analysing and comparing existing reconstructions of the Scotia area.

We present a new reconstruction with different and new GUs. This results in differences in paleo-locations throughout the Cenozoic, influencing ocean circulation.

Find out how we did this!  Shortcut to conclusions
Comparison of two reconstructions

Identification of differences between reconstructions

Input for new reconstruction

Modelling the Cenozoic evolution of the Scotia area in GPlates

Iterating time-steps to find paleo-locations of GUs

Identification of Proto-Weddell Sea GUs

GPlates is software that is used to make plate-tectonic reconstructions. It is freely available on www.GPlates.org
Comparing different reconstructions

Why? To visualize and understand the differences in tectonic evolution of the Scotia area

- We compared two different studies with opposing hypotheses about the origin of the Central Scotia Sea and the absence (Livermore et al., 2007) and the origin of the CSS (Eagles and Jokat, 2014).
- The shape of the Ancestral South Sandwich Arc (ASSA) and paleo-locations of other Geological Units (GUs)

Major difference between the reconstructions:

- The paleo-location of South Georgia and the absence (Livermore et al., 2007) and the origin of the CSS (Eagles and Jokat, 2014).
- The shape of the Ancestral South Sandwich Arc (ASSA) and paleo-locations of other Geological Units (GUs)

Drake Passage and Cenozoic climate: An open and shut case? Livermore et al., 2007

Tectonic reconstructions for paleobathymetry in Drake Passage. Eagles and Jokat, 2014
Area’s of interest - resulting from the comparison

- Extend of the Proto-Weddell Sea
- Extend of the CSS, the W7 Segment
- The Central Scotia Sea (CSS)
- Paleo-location of South Georgia
- Evolution and role of the ASSA (ancestral South Sandwich Arc)

Map source: GeoMapApp, Ryan et al., 2009
Major difference: The origin of the Central Scotia Sea

Do you know how the Central Scotia Sea formed?

Option 1) Cenozoic: Back arc extension in different directions in response to subduction along the curved South Sandwich Trench.

Option 2) Cretaceous: Sea floor spreading along the Weddell Sea spreading system

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Do you want to learn more about these anomalies? See Barker, 2001 or Eagles, 2010a
What did we do to explain the origin of the CSS?

- We combined both hypotheses about the origin of the CSS.
- We defined GUs of that we assigned to the Proto-Weddell sea based on bathymetry, magnetic anomalies.

We discovered that:

- Remnants of a Proto-Weddell Sea are scattered over the Scotia Plate.
- This explains the variety in ages that have been observed in the Scotia Area.

Which area’s did we define as remainders of the Proto-Weddell Sea?

What did cause the distribution of the Proto-Weddell Sea?

Learn more about the Proto-Weddell Sea!
Due to the presence of the Proto-Weddell Sea remnants, we argue that a shallow-water ocean gateway already might have existed at the start of the Cenozoic.
Several transform faults to accommodate E-W displacement of GUs.

Extension in all directions (N-S and E-W) due to back-arc extension related to the ASSA.

We also argue that a deep-water ocean gateway did exist at 30Ma. (Dark blue arrows)

The Ancestral South Sandwich Arc (ASSA) was a volcanic arc at the eastern margin of the Scotia area from the Early-Oligocene till the Late Miocene as a result of subduction of the South Atlantic ocean floor. This resulted in back-arc extension in the Proto-Weddell Sea.

With our reconstruction we show that the back-arc extension does explain several younger ages, that have been observed in the Scotia Area.

Do you want to learn more about the ASSA? See Pearce et al., 2014
Conclusions

The CSS is a trapped piece of Cretaceous oceanic crust. But smaller and more scattered than previously assumed.

This oceanic crust was formed during the first phase of extension along the Weddell Sea spreading system.

This first phase has formed the Proto-Weddell Sea. The second phase consists of extension in various directions.

Remnants of this Proto-Weddell Sea are scattered over the Scotia plate, mainly around the Central Scotia Sea.

A deep water gateway was functional around 30Ma, a shallow water passage might have been possible around and before 50Ma.

In the future...

We expect more Cretaceous oceanic crust to be found in the Scotia area.

Defining these Cretaceous pieces could help predicting the sub-marine geology of the Scotia area.

Do you want to learn more about the geology of the Scotia Area?
Major differences between the reconstructions at 50Ma:

- No CSS is present at all in Livermore et al., 2007 and overlap between the GUs, while Eagles and Jokat (2014) depict the CSS south of South Georgia which results in gaps between the GUs (in blue).
- The subduction zone depicted by Livermore et al. (2007) is much smaller that illustrated by Eagles and Jokat (2014).
In more detail: A Proto-Weddell Sea?

We defined several area’s on the Scotia plate which have not been part of Gondwana and do not have an origin of sea floor spreading in the Cenozoic.

We argue that these area’s have formed during the first phase of extension of the Weddell Sea along the Weddell Sea rift system. This phase is depicted by Eagles (2010) in this image. We do not propose a precise timing for this event, but suggest a Cretaceous for the oceanic crust that has been created in this phase.

A major reason to assume the Cretaceous origin of these pieces of oceanic crust is the study by Riley et al, 2019. They studied the W7 segment (which is nowadays north of the West Scotia Ridge) and suggest the same origin for this piece of crust as the ‘old’ CSS.

Do you want to learn more about the W7 segment? See Riley et al., 2019