The Cenozoic tectonic evolution of the Scotia Sea area

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VU VRIJE UNIVERSITEIT AMSTERDAM

GEOMAR

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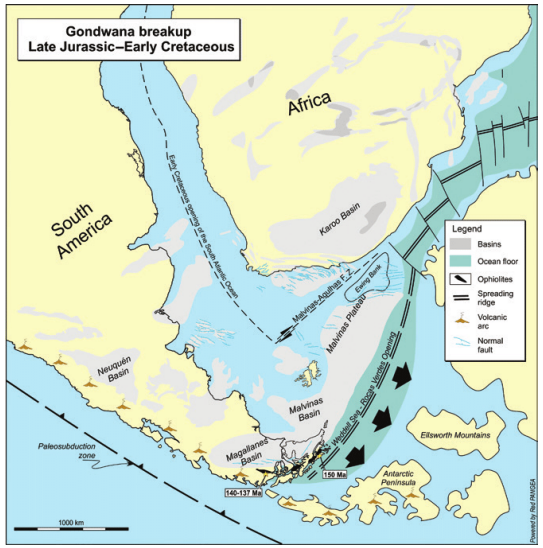
Short summary: what did we study?

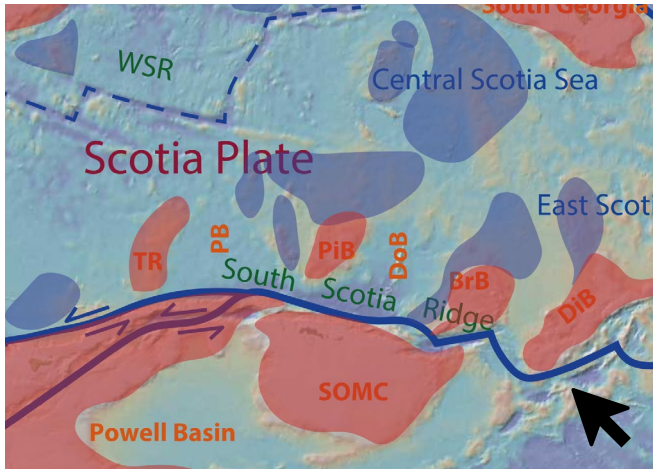
The evolution and development of the Scotia area starting with the break up of Southern Gondwana land

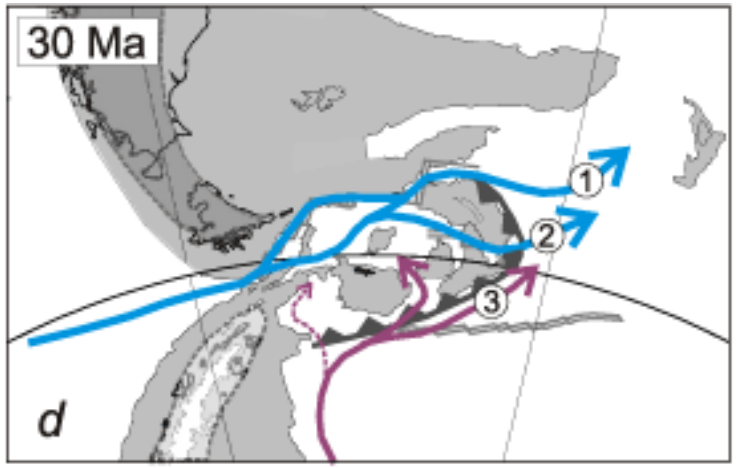
The extend of the Proto-Weddell Sea

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



Ramos et al., 2019





Livermore et al., 2007

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.

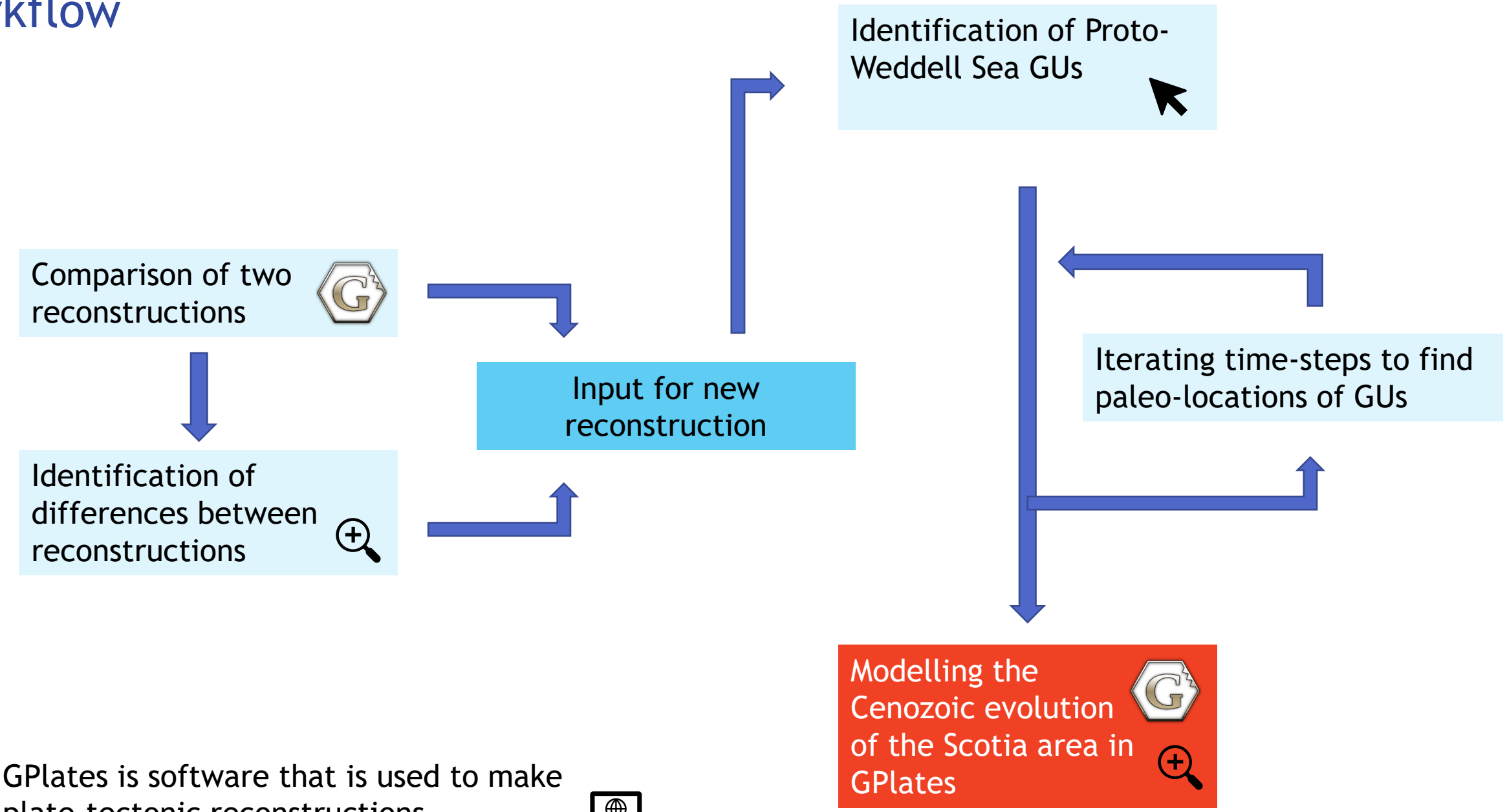
We defined the extend of the remnants of the Proto-Weddell sea by rotating the Geological Units (GUs) back and forth in time in GPlates and by analysing and comparing existing reconstructions of the Scotia area

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

Workflow



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

Comparing different reconstructions

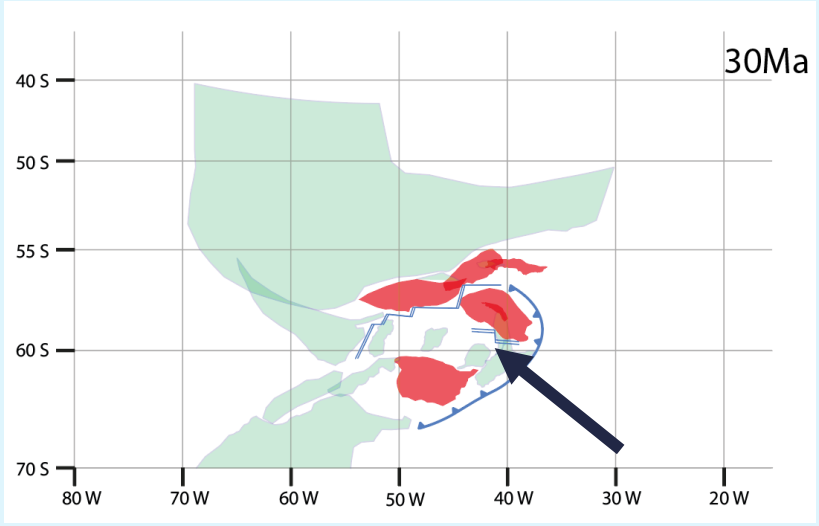
Back to workflow

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 are reconstructed and compared in GPlates, to visualize the major differences and similarities between the two studies.

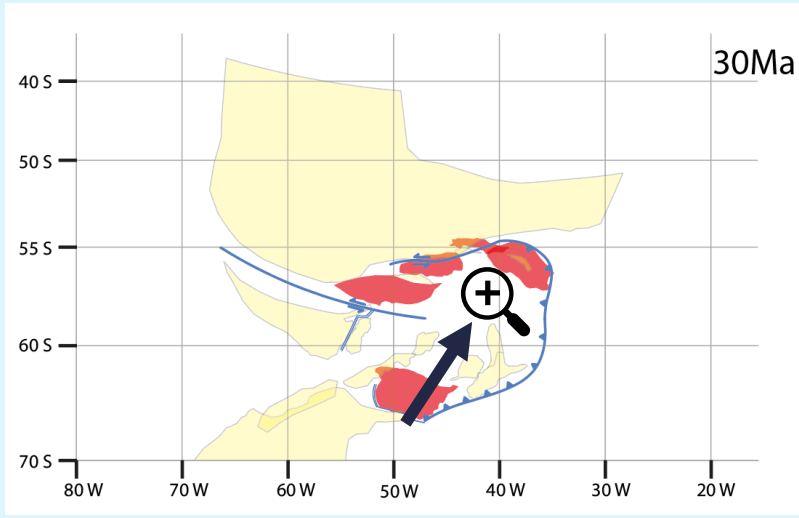
Major difference between the reconstructions:

- 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

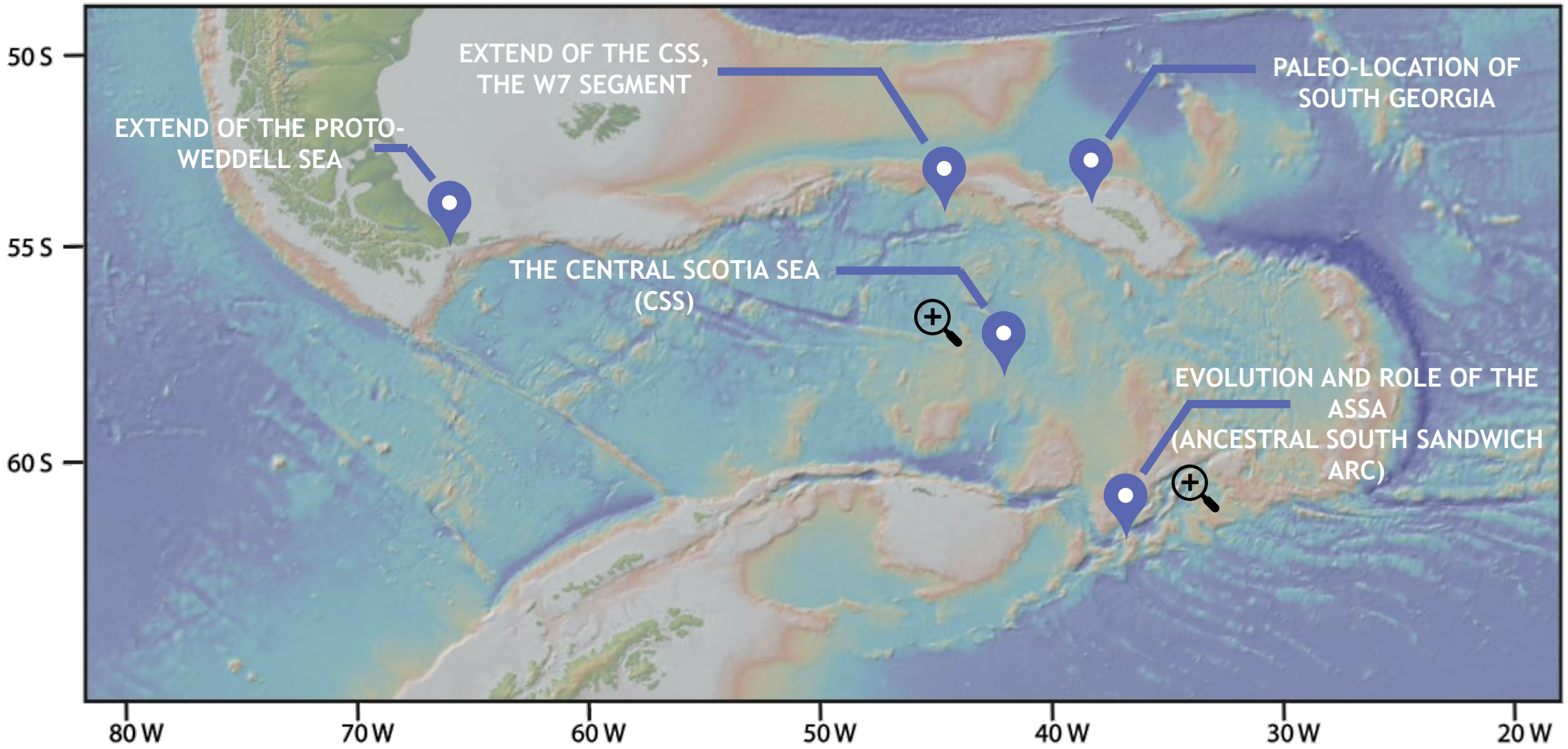
50 Ma



Tectonic reconstructions for paleobathymetry in Drake Passage. Eagles and Jokat, 2014

- 0 Ma
- 20 Ma
- 40 Ma
- 60 Ma
- 80 Ma
- 100 Ma
- 120 Ma
- 140 Ma
- 160 Ma
- 180 Ma
- 200 Ma

Area's of interest – resulting from the comparison



0 Ma
– 20 Ma
– 40 Ma
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– 100 Ma
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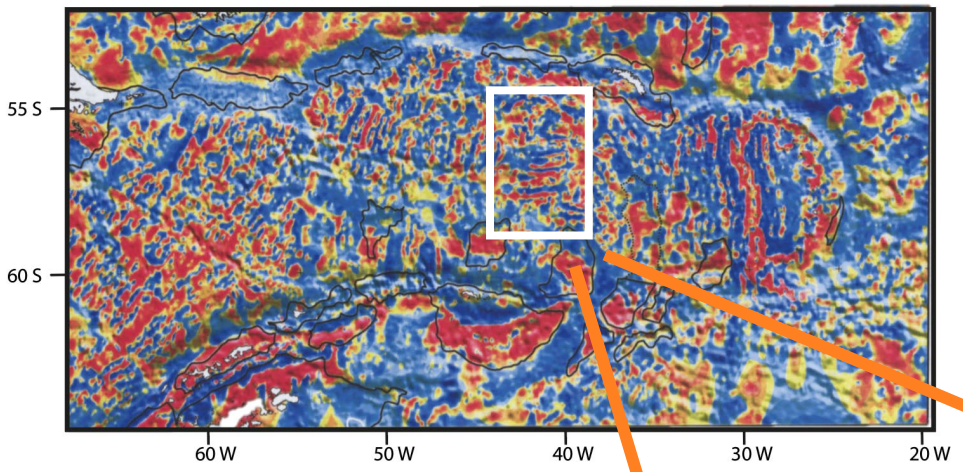
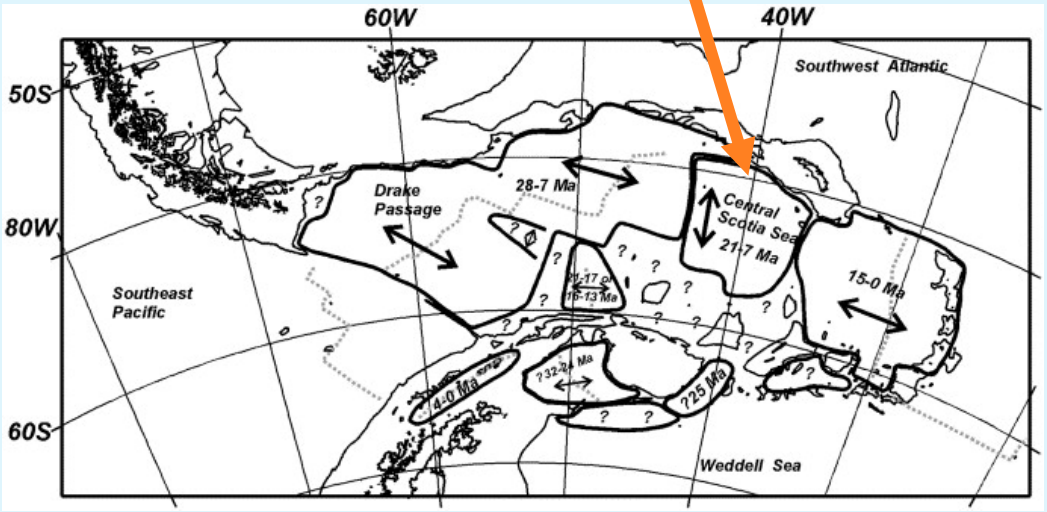
Map source: GeoMapApp, Ryan et al., 2009

Major difference: The origin of the Central Scotia Sea

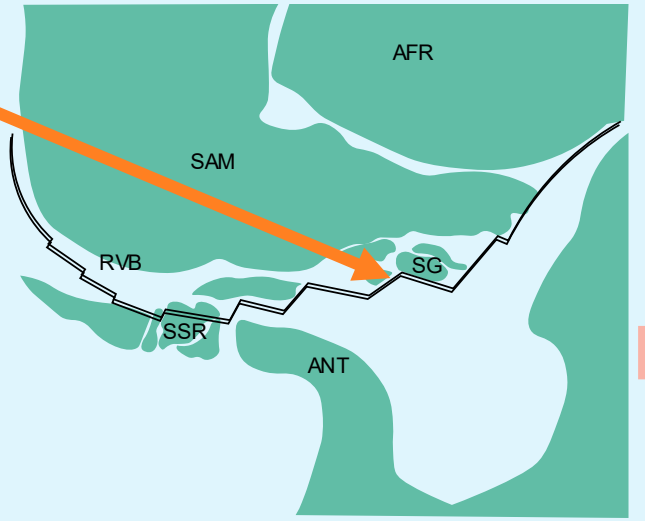


Do you know how the Central Scotia Sea formed?

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



1. Scotia Sea regional tectonic evolution: implications for mantle flow and palaeocirculation Barker, 2001



2. South Georgia and Gondwana's Pacific Margin: Lost in translation? Eagles, 2010b

Do you want to learn more about these anomalies? See Barker, 2001 or Eagles, 2010a

1 – 0 Ma
– 20 Ma
– 40 Ma
– 60 Ma
– 80 Ma
– 100 Ma
– 120 Ma
– 140 Ma
2
– 160 Ma
– 180 Ma
– 200 Ma

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.

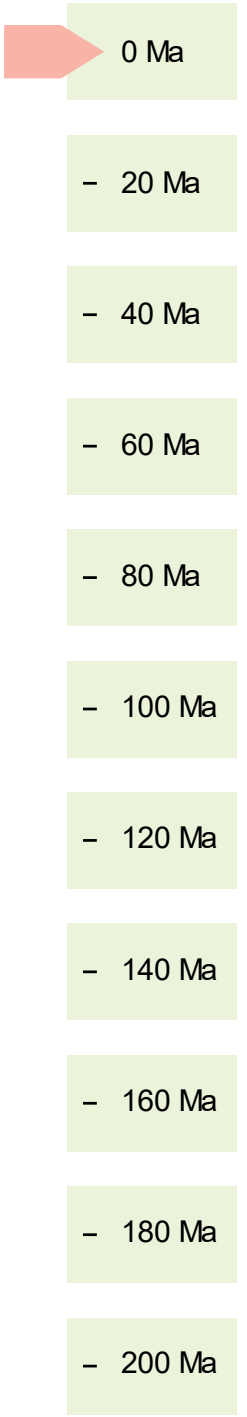
We discovered that:

- 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.

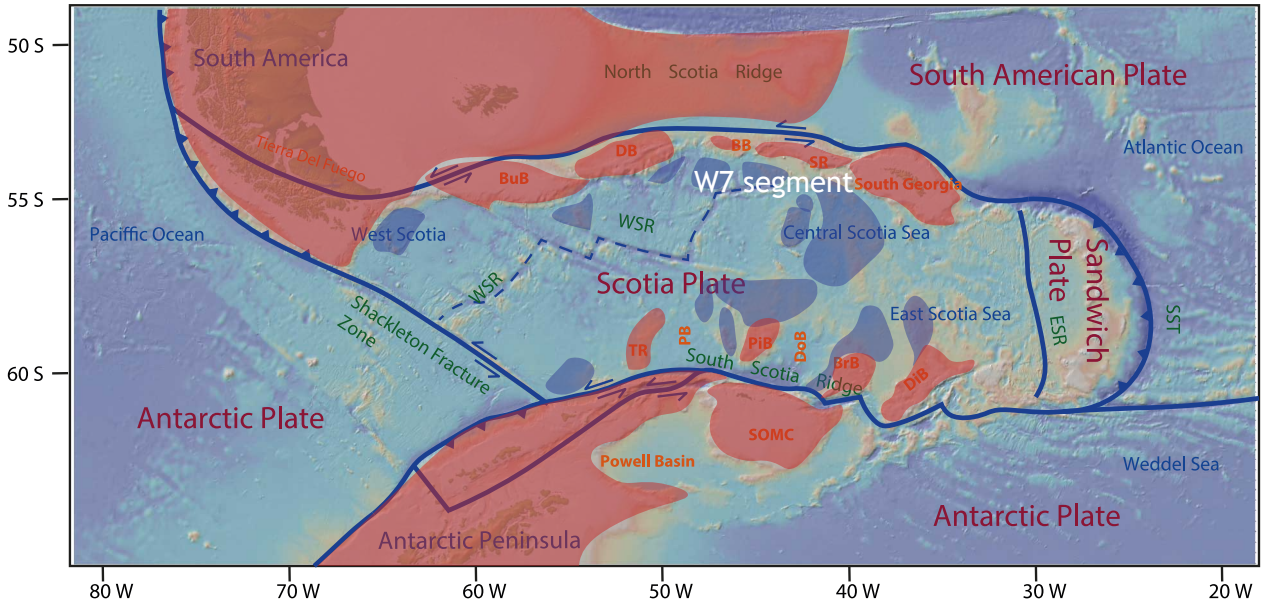
Which area's did we define as remainders of the Proto-Weddell Sea?

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

Learn more about the Proto-Weddell Sea!



Geological Units originating from the Proto-Weddell Sea (blue)



Red: GUs that have originated from Gondwana

Blue: GUs that have been part of the Proto-Weddell Sea

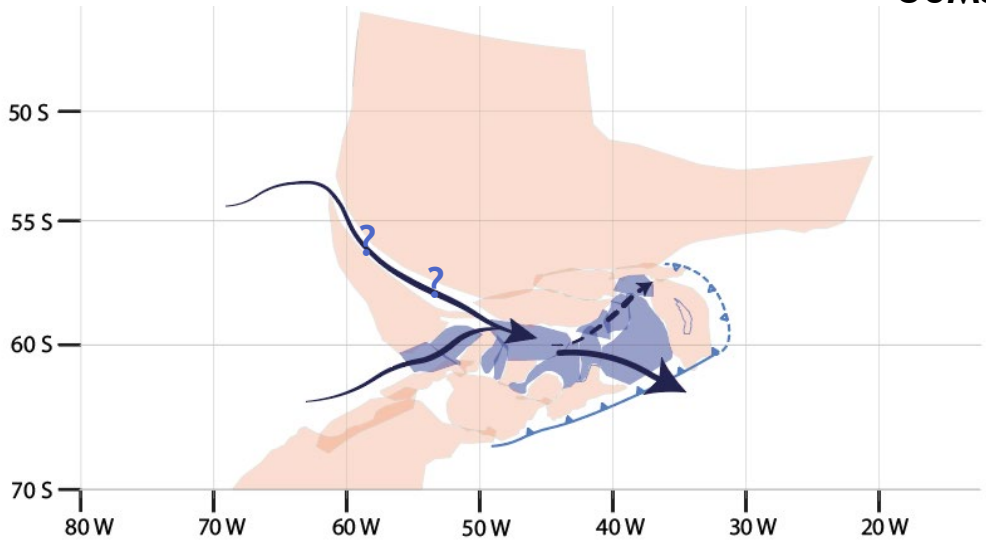
Go to 30 Ma

Go to conclusions

On the right the configuration of the GUs at 50Ma. The remnants of the Proto-Weddell Sea fit together inside the land bridge between South America and Antarctica

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.**

50Ma



- 0 Ma
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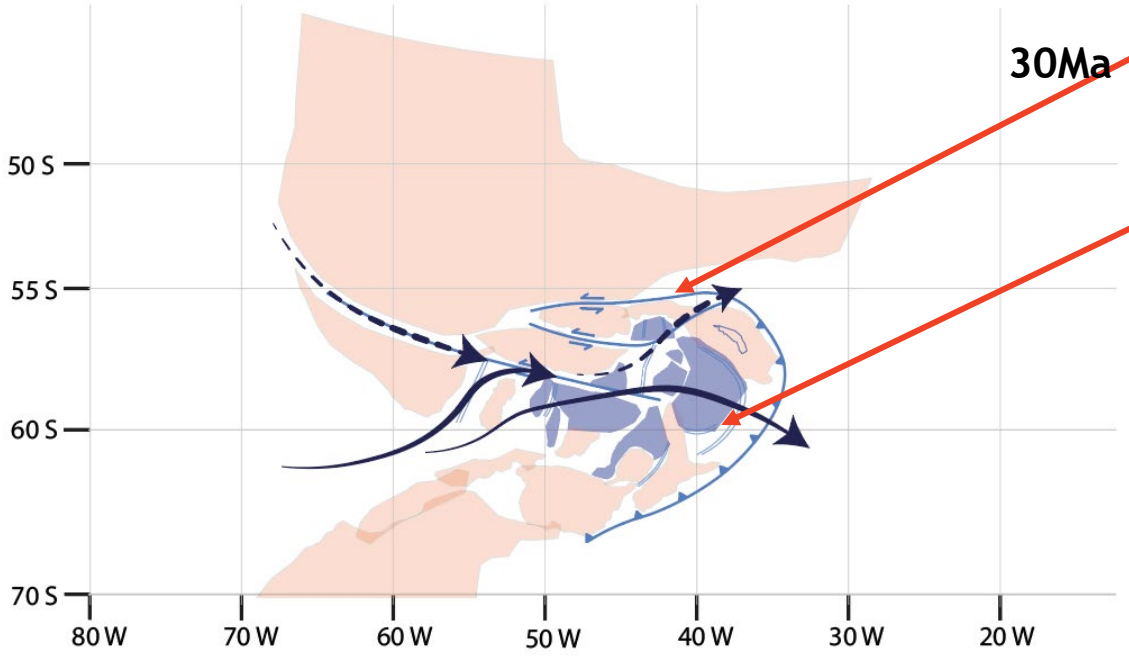
Our new paleogeographic reconstruction



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)

Back to workflow

Back to map

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

– 0 Ma
– 20 Ma
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Conclusions

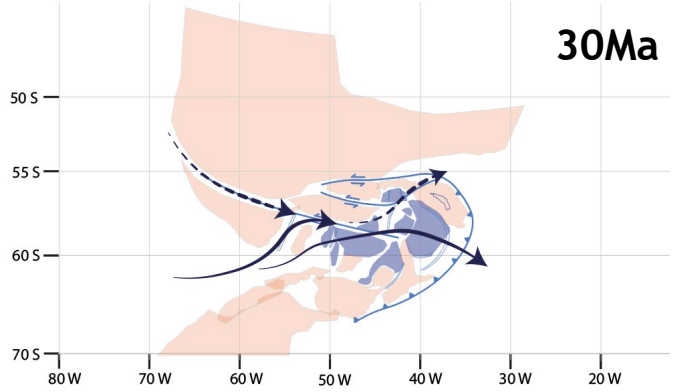
The CSS is a trapped piece of Cretaceous oceanic crust. But smaller and more scattered than previously assumed

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…

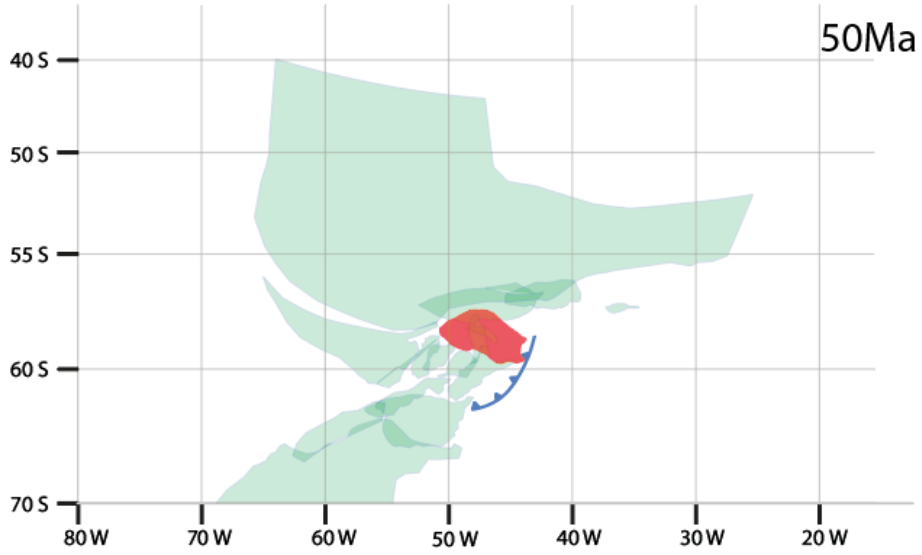
We expect more Cretaceous oceanic crust to be found in the Scotia area

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).



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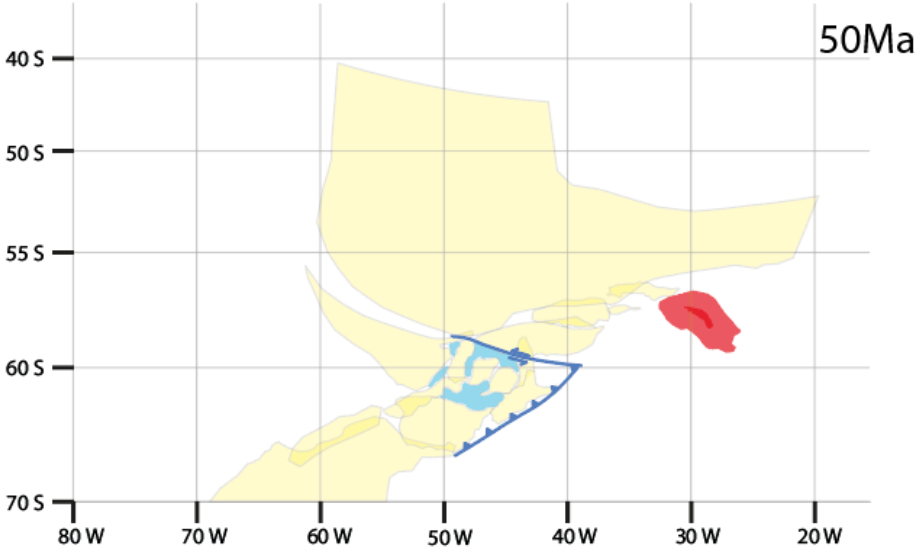

Tectonic reconstructions for paleobathymetry in Drake Passage. Eagles and Jokat, 2014

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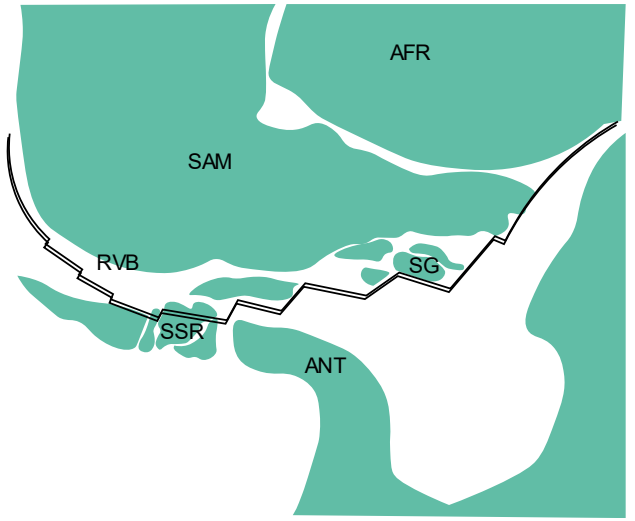
In more detail: A Proto-Weddell Sea?

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.



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Back to workflow

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