Reviews of Geophysics

Supporting Information for

Antarctic sedimentary basins and their influence on ice sheet dynamics

A.R.A. Aitken[1,2], L. Li[1], B. Kulessa[3,4], D. Schroeder[5,6], T.A. Jordan[7], J.M. Whittaker[8], S. Anandakrishnan[9], E.J. Dawson[5], D. A. Wiens[10], O. Eisen[11,12], M.J. Siegert[13,14]

1. School of Earth Sciences, The University of Western Australia, Perth, Western Australia, Australia
2. Australian Centre of Excellence for Antarctic Science, The University of Western Australia, Perth, Western Australia, Australia
3. School of Biosciences, Geography and Physics, Swansea University, Wales, UK
4. School of Geography, Planning and Spatial Sciences, The University of Tasmania, Hobart Tasmania, Australia
5. Department of Geophysics, Stanford University, Stanford, California, USA
6. Department of Electrical Engineering, Stanford University, Stanford, California, USA
7. British Antarctic Survey, Cambridgeshire, UK
8. Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia
9. College of Earth and Mineral Sciences, Pennsylvania State University, Pennsylvania, USA
10. Department of Earth & Planetary Sciences, Washington University, St. Louis, Missouri, USA
11. Glaciology, Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
12. Department of Geosciences, University of Bremen, Bremen, Germany
13. Grantham Institute and Department of Earth Science and Engineering, Imperial College London, London, UK
14. Tremough House, University of Exeter, Penryn, Cornwall, UK

Contents of this file

Figures S1 to S5

Additional Supporting Information (Files uploaded separately)

Movie S1: Tectonic reconstruction showing the context of basin formation since 410 Ma (Müller et al., 2019; Young et al., 2019). East Antarctica is held fixed in this reconstruction which also does not include rift block motions or internal plate deformation. Sedimentary *basins are shown from their base-of-basin age to their top-of-basin age, with basin age indicating the time elapsed since the former. Continent-ocean boundaries (COB), oceanic crust age and isochrons and mid-ocean ridges (MOR) are also shown. Reconstruction was made using GPlates reconstruction software*

Introduction

Supplementary figures included here show additional representations of the data shown in the main text including in Fig S1 an equivalent of Figure 1, zoomed into the data-rich McMurdo Sound region, and unannotated versions of Figures 3, 13, 14 and 16. All data and visualization are equivalent.

The tectonic reconstruction shows the context of Antarctica's basin s during the dispersal of plates from a Pangean configuration, beginning 410 Ma. The reconstruction was implemented in GPlates reconstruction software using the combined rotations of Müller, Cao, and Young (Cao et al., 2022; Müller et al., 2019; Young et al., 2019) with the Torsvik et al. (2019) correction applied for the Pacific. The rotations do not contain all block motions discussed in the text nor any explicit model of internal plate deformations.

As well as Antarctic basins (this study), we include in the reconstruction mid-ocean ridges from Müller et al. (2016), continent ocean boundaries from Müller et al. (2019) and the oceanic age grid and ocean crust isochrons from Seton et al. (2020). All these files are available by default in later versions of GPlates (version 2.3 was used here). The reconstruction uses East Antarctica as the fixed plate and shows relative motions to that plate. The animation is generated from a series of snapshots at 1 Ma intervals.

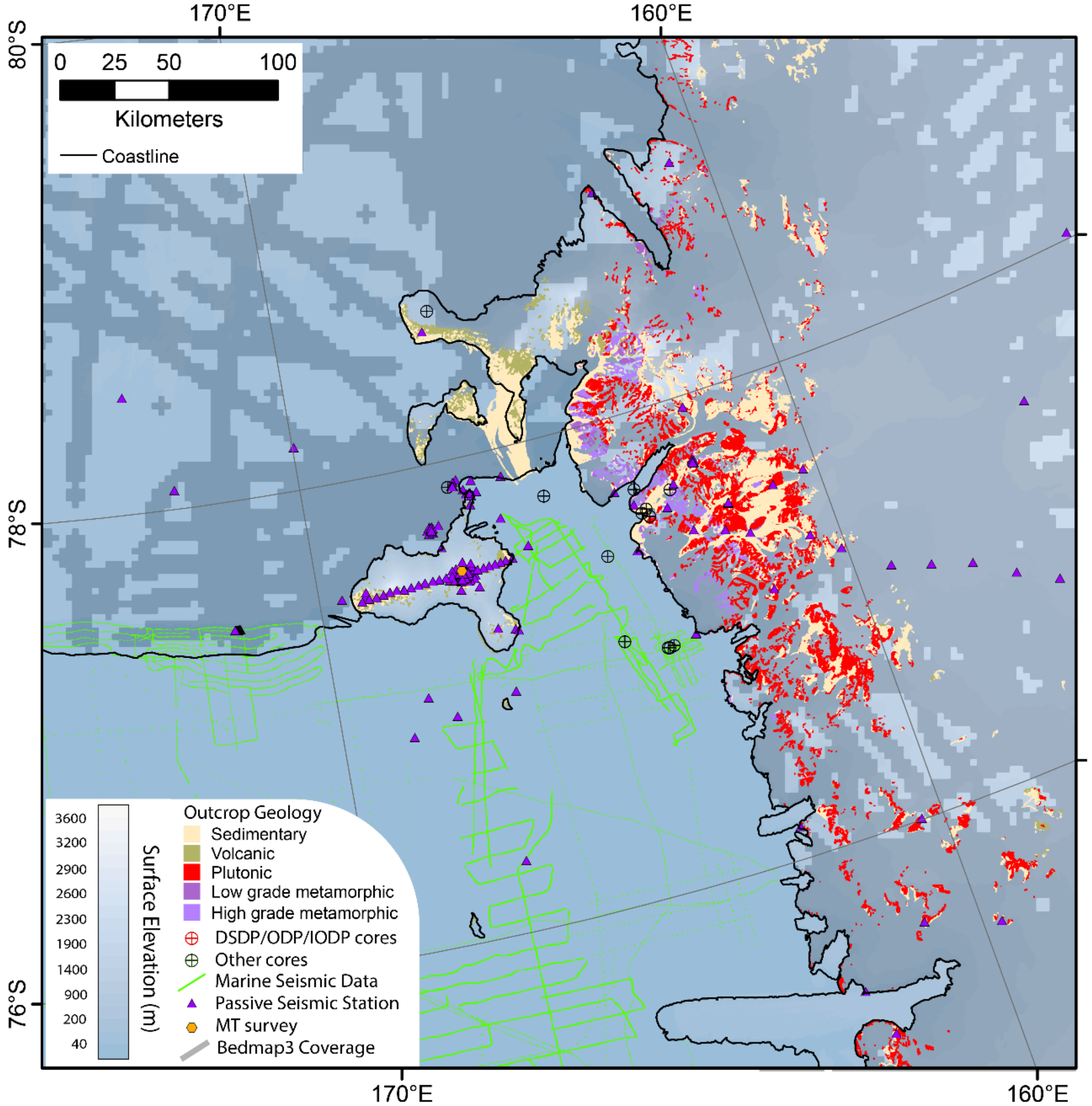

Figure S1. *Representative data coverage in the vicinity of McMurdo Sound and Ross Island, indicating outcropping geology, drill core sites, onshore passive seismic and MT stations, and marine seismic reflection lines offshore. Bedmap3 data coverage is shown only for onshore ice-covered areas.*

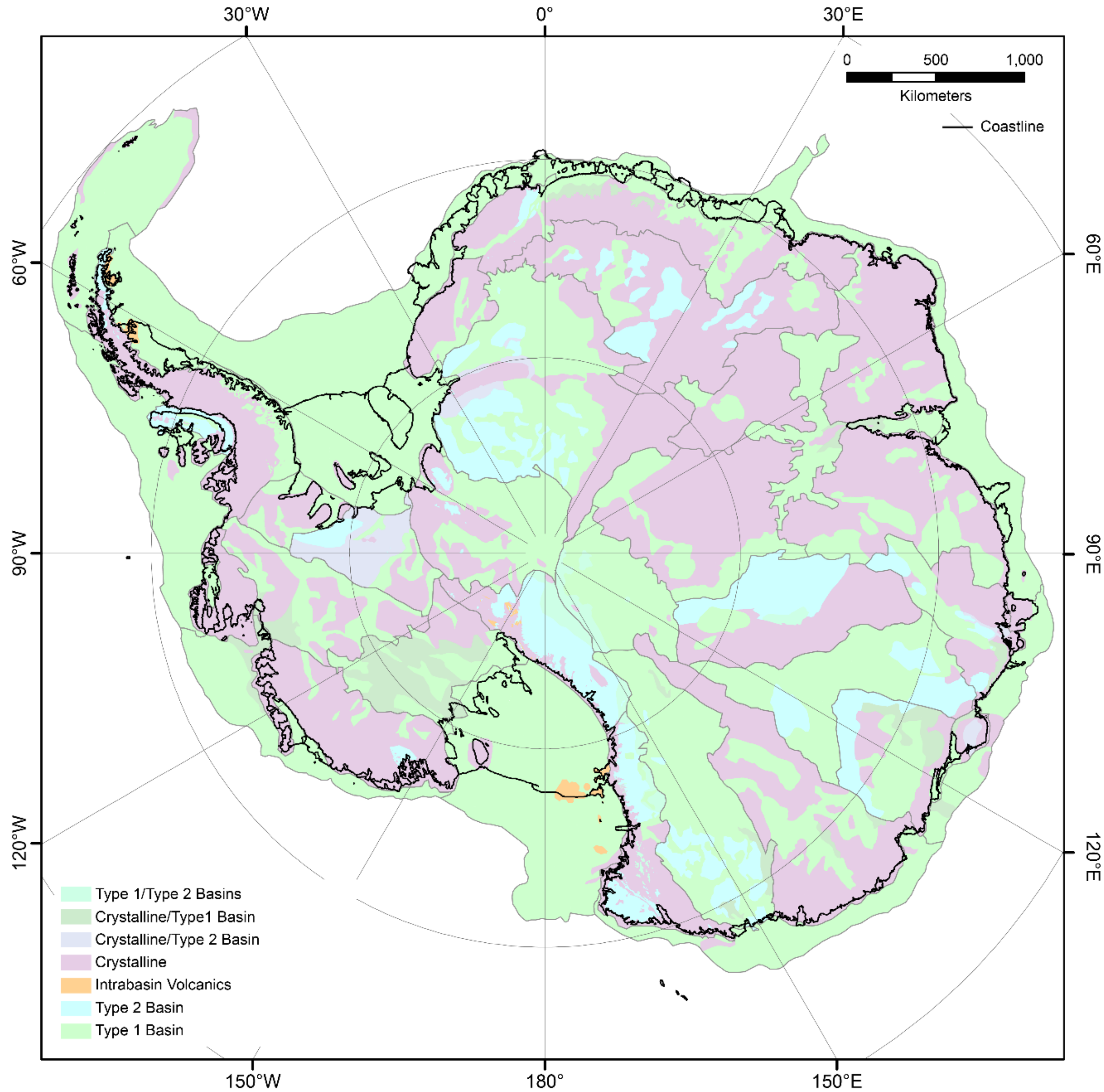

Figure S2*: Classification of geological bed type in Antarctica showing the main classes of Type 1 and Type 2 basins, intra-basin volcanics, and crystalline basement, as well as regions of mixed class without annotations. Major sedimentary basin regions are outlined in grey. The coastline shows both the ice sheet grounding line and the ice shelf edge.*

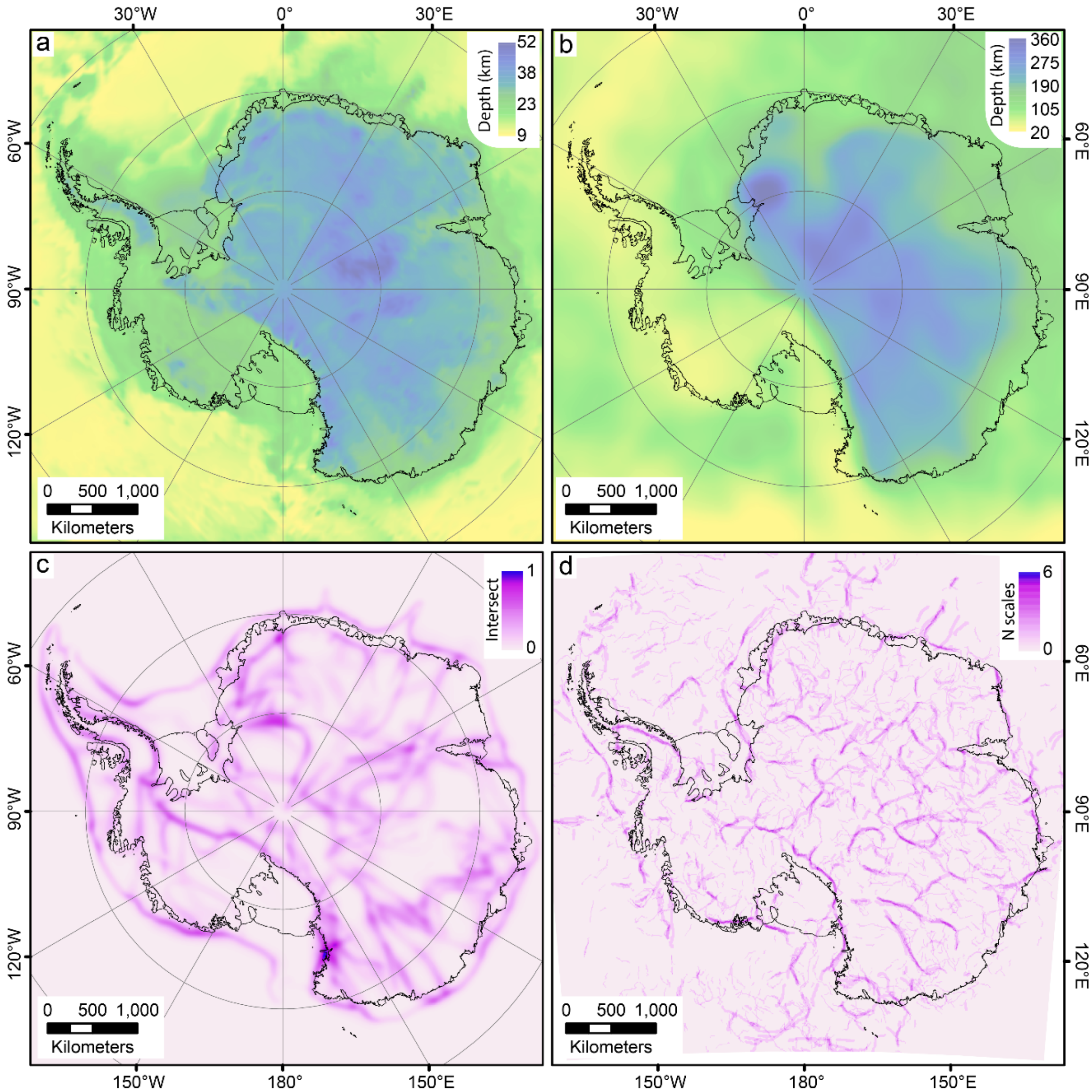

Figure S3: *Structure of the Antarctic lithosphere showing a) Moho depth (Pappa et al., 2019), b) lithosphere-asthenosphere boundary depth (Hazzard et al., 2023), c) multidata lineament analysis (Stål et al., 2019) and d) multiscale gravity edge analysis.*

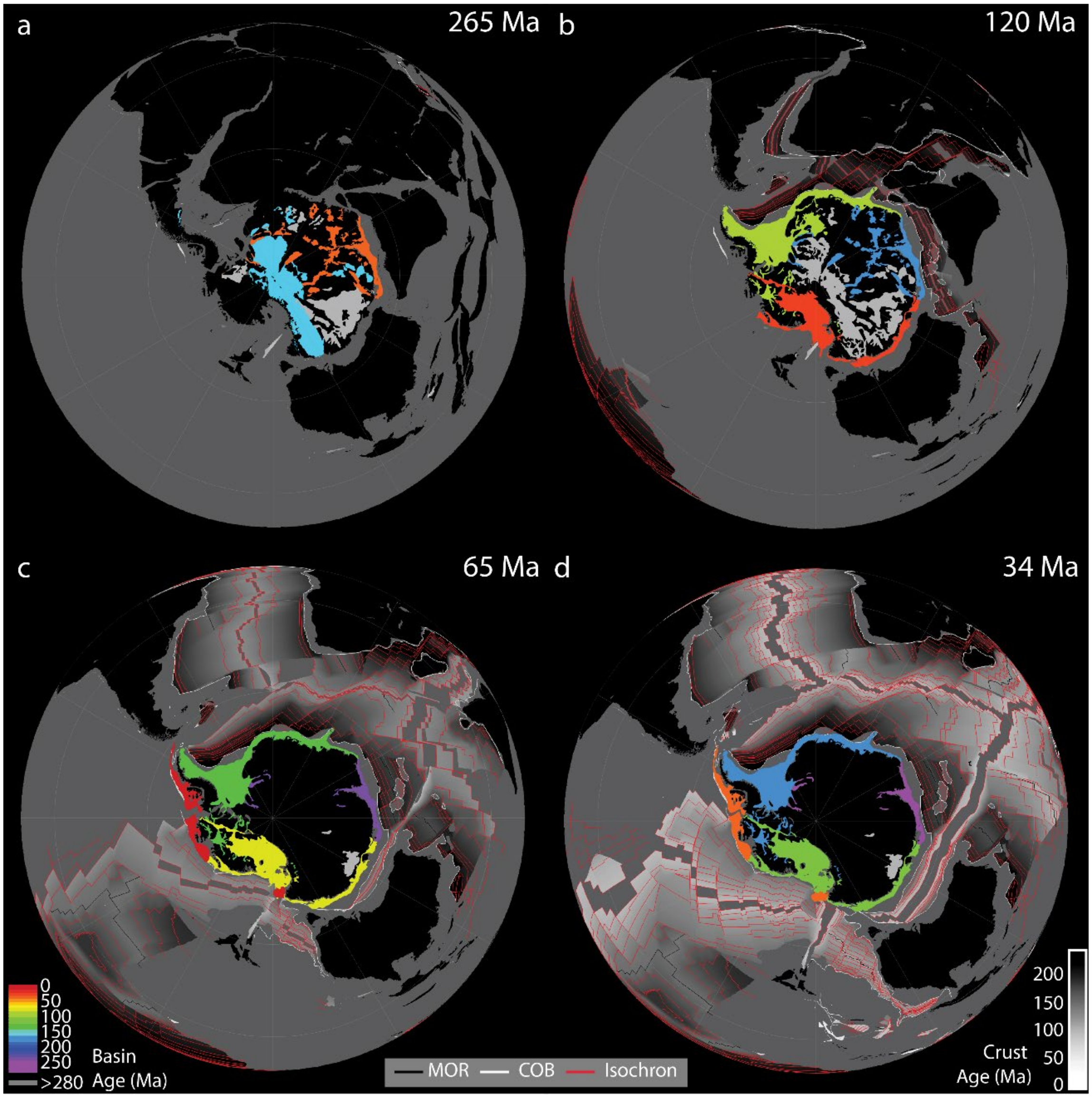

Figure S4*: Unannotated tectonic reconstruction snapshots a) 265 Ma, b) 120 Ma, c) 65 Ma and d) 34 Ma showing the context of basin formation since Pangea (Müller et al., 2019; Young et al., 2019).*

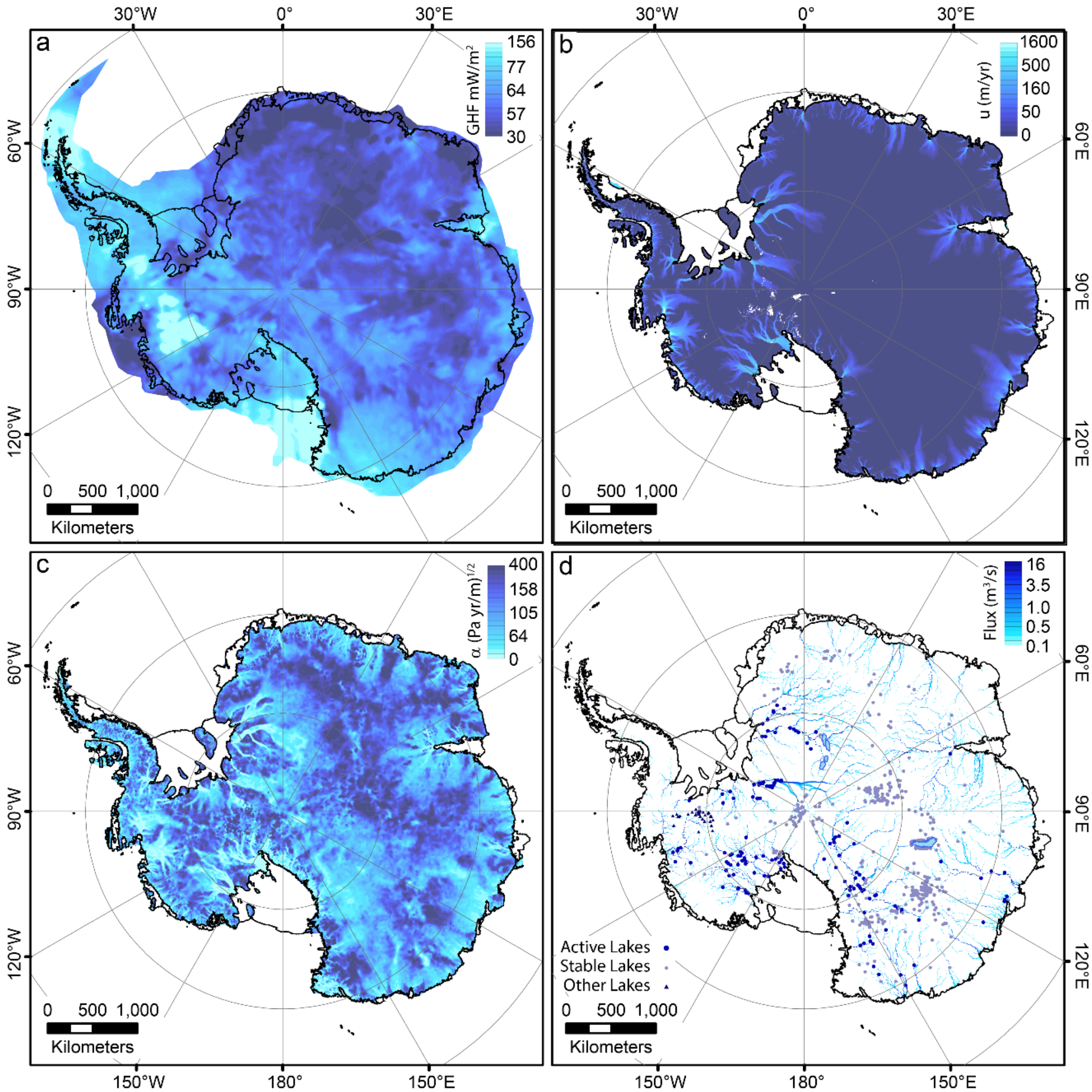

Figure S5*: Unannotated influences on ice sheet dynamics showing a) deep-seated geothermal heat flux (Lösing & Ebbing, 2021) b) surface ice sheet velocity from InSAR phase mapping (Mouginot et al., 2019) c) inferred basal friction coefficient derived by inverting for basal conditions using the Ice sheet and Sea level System Model (Dawson et al., 2022), and d) subglacial hydrology, including subglacial lakes (Livingstone et al., 2022), and a modern-day drainage network (Le Brocq et al., 2013).**Figure S5: Unannotated influences on ice sheet dynamics showing a) deep-seated geothermal heat flux (Lösing & Ebbing, 2021) b) surface ice sheet velocity from InSAR phase mapping (Mouginot et al., 2019) c) inferred basal friction coefficient derived by inverting for basal conditions using the Ice sheet and Sea level System Model (Dawson et al., 2022), and d) subglacial hydrology, including subglacial lakes (Livingstone et al., 2022), and a modern-day drainage network (Le Brocq et al., 2013).*

References

Cao, X., Zahirovic, S., Li, S., Suo, Y., Wang, P., Liu, J., & Müller, R. D. (2022). A deforming plate tectonic model of the South China Block since the Jurassic. Gondwana Research, 102, 3-16. https://doi.org/10.1016/j.gr.2020.11.010

Dawson, E. J., Schroeder, D. M., Chu, W., Mantelli, E., & Seroussi, H. (2022). Ice mass loss sensitivity to the Antarctic ice sheet basal thermal state. Nature Communications, 13(1), 4957. https://doi.org/10.1038/s41467-022-32632-2

Hazzard, J. A. N., Richards, F. D., Goes, S. D. B., & Roberts, G. G. (2023). Probabilistic Assessment of Antarctic Thermomechanical Structure: Impacts on Ice Sheet Stability. Journal of Geophysical Research: Solid Earth, 128(5), e2023JB026653. https://doi.org/10.1029/2023JB026653

Le Brocq, A. M., Ross, N., Griggs, J. A., Bingham, R. G., Corr, H. F. J., Ferraccioli, F., et al. (2013). Evidence from ice shelves for channelized meltwater flow beneath the Antarctic Ice Sheet. Nature Geosci, 6(11), 945-948. https://doi.org/10.1038/ngeo1977

Livingstone, S. J., Li, Y., Rutishauser, A., Sanderson, R. J., Winter, K., Mikucki, J. A., et al. (2022). Subglacial lakes and their changing role in a warming climate. Nature Reviews Earth & Environment, 3(2), 106-124. https://doi.org/10.1038/s43017-021-00246-9

Lösing, M., & Ebbing, J. (2021). Predicting Geothermal Heat Flow in Antarctica With a Machine Learning Approach. Journal of Geophysical Research: Solid Earth, 126(6), e2020JB021499. https://doi.org/10.1029/2020JB021499

Mouginot, J., Rignot, E., & Scheuchl, B. (2019). Continent-Wide, Interferometric SAR Phase, Mapping of Antarctic Ice Velocity. Geophysical Research Letters, 46(16), 9710-9718. https://doi.org/10.1029/2019gl083826

Müller, R. D., Seton, M., Zahirovic, S., Williams, S. E., Matthews, K. J., Wright, N. M., et al. (2016). Ocean Basin Evolution and Global-Scale Plate Reorganization Events Since Pangea Breakup. Annual Review of Earth and Planetary Sciences, 44(1), 107-138. 10.1146/annurev-earth-060115-012211

Müller, R. D., Zahirovic, S., Williams, S. E., Cannon, J., Seton, M., Bower, D. J., et al. (2019). A Global Plate Model Including Lithospheric Deformation Along Major Rifts and Orogens Since the Triassic. Tectonics, 38(6), 1884-1907. https://doi.org/10.1029/2018TC005462

Pappa, F., Ebbing, J., & Ferraccioli, F. (2019). Moho Depths of Antarctica: Comparison of Seismic, Gravity, and Isostatic Results. Geochemistry, Geophysics, Geosystems, 20(3), 1629-1645. https://doi.org/10.1029/2018GC008111

Seton, M., Müller, R. D., Zahirovic, S., Williams, S., Wright, N. M., Cannon, J., et al. (2020). A Global Data Set of Present-Day Oceanic Crustal Age and Seafloor Spreading Parameters. Geochemistry, Geophysics, Geosystems, 21(10), e2020GC009214. https://doi.org/10.1029/2020GC009214

Stål, T., Reading, A. M., Halpin, J. A., & Whittaker, J. M. (2019). A Multivariate Approach for Mapping Lithospheric Domain Boundaries in East Antarctica. Geophysical Research Letters, 46(17-18), 10404-10416. https://doi.org/10.1029/2019GL083453

Torsvik, T. H., Steinberger, B., Shephard, G. E., Doubrovine, P. V., Gaina, C., Domeier, M., et al. (2019). Pacific-Panthalassic Reconstructions: Overview, Errata and the Way Forward. Geochemistry, Geophysics, Geosystems, 20(7), 3659-3689. https://doi.org/10.1029/2019GC008402

Young, A., Flament, N., Maloney, K., Williams, S., Matthews, K., Zahirovic, S., & Müller, R. D. (2019). Global kinematics of tectonic plates and subduction zones since the late Paleozoic Era. Geoscience Frontiers, 10(3), 989-1013. https://doi.org/10.1016/j.gsf.2018.05.011