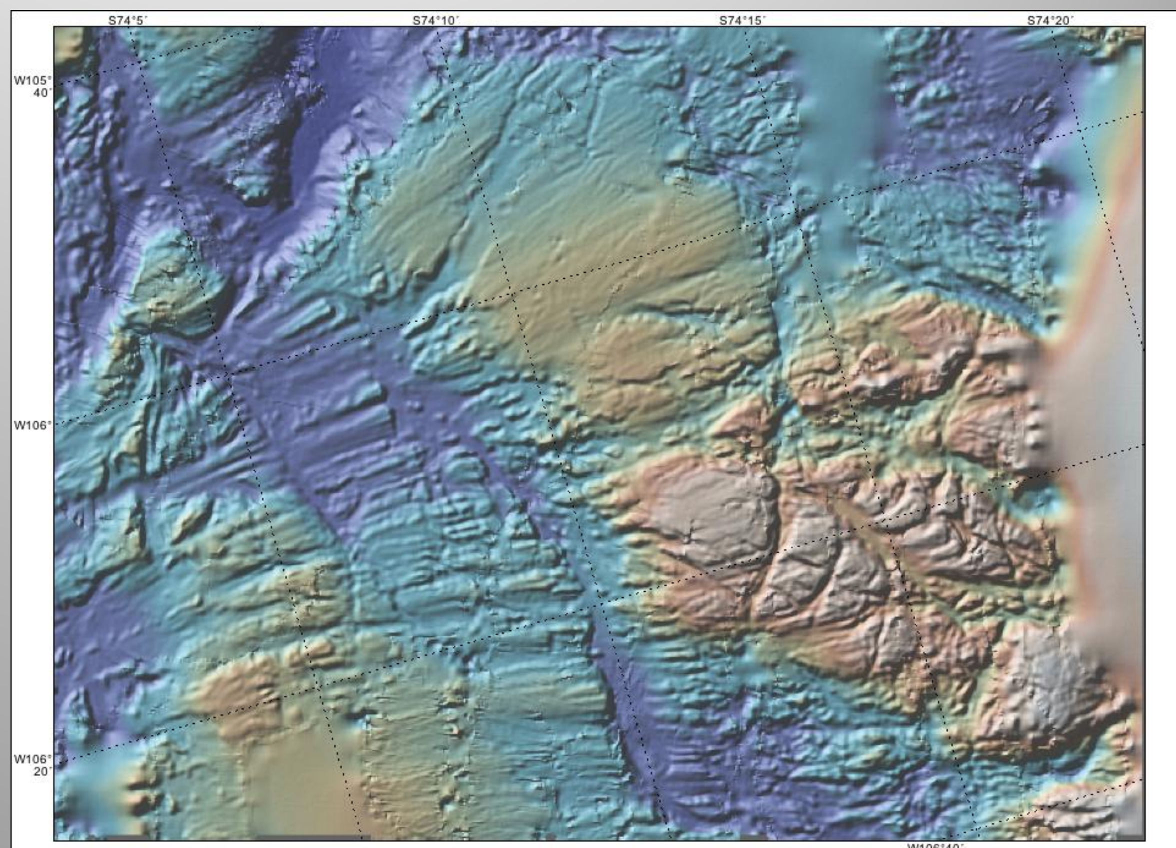
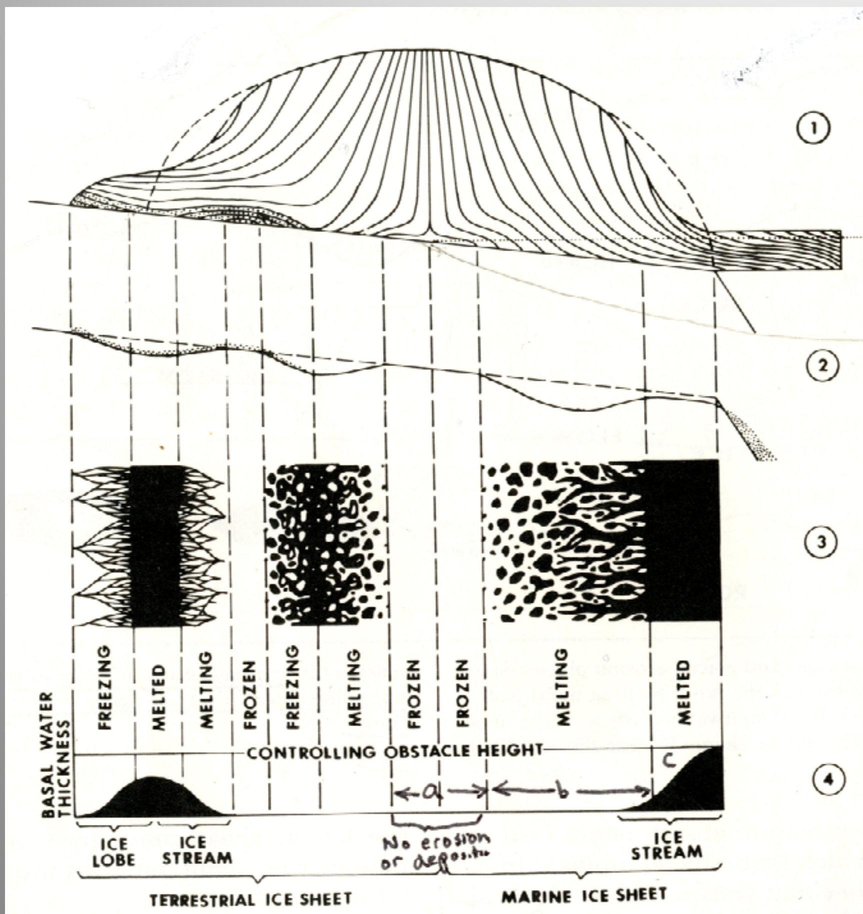
Geological Evidence for Subglacial floods: example from Pine Island Bay, West Antarctica

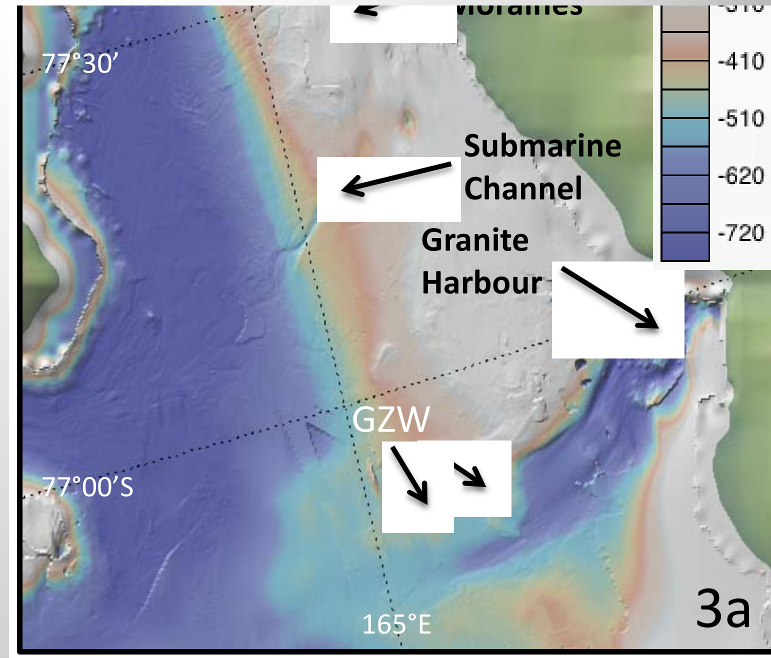
Alexandra E. Kirshner , Carolyn M. Branecky , John B. Anderson , Rice University, Houston, TX
Witold Szczuciński , Adam Mickiewicz University, Poznan, Poland
Dustin Schroeder and Don Blankenship , University of Texas Institute of Geophysics, Austin, TX
Martin Jakobsson, Stockholm University, Stockholm, Sweden

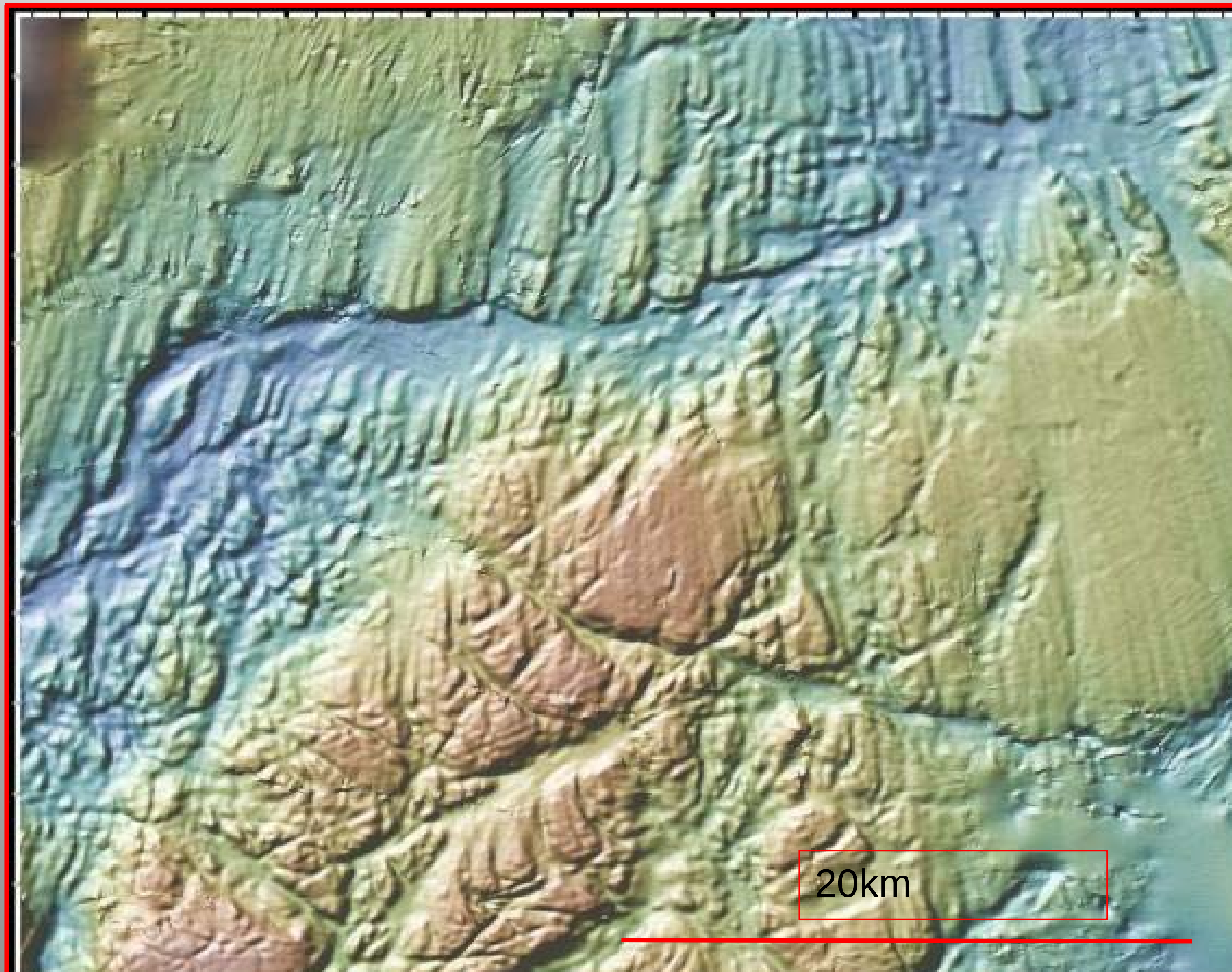


Geological Record of subglacial floods



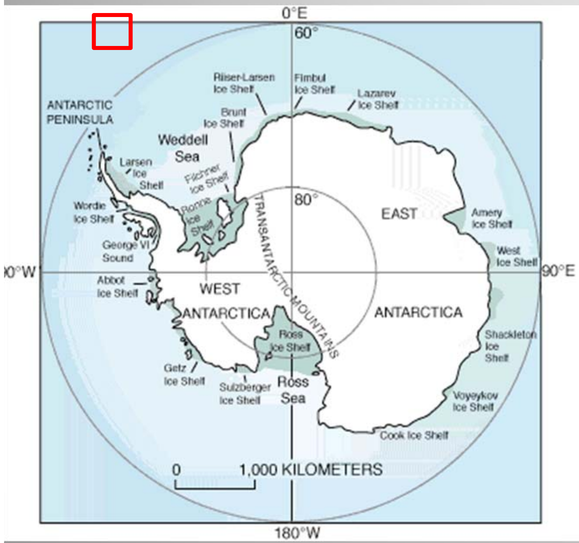
Hughes, 1991

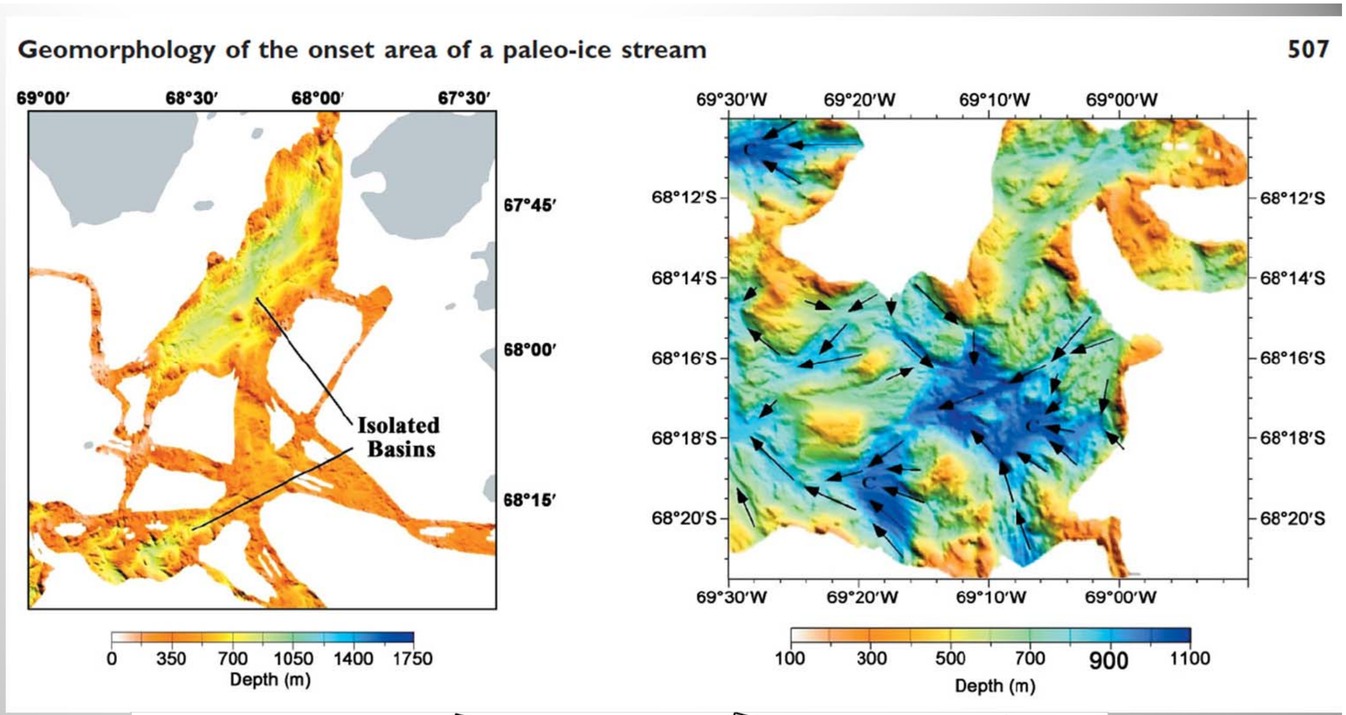


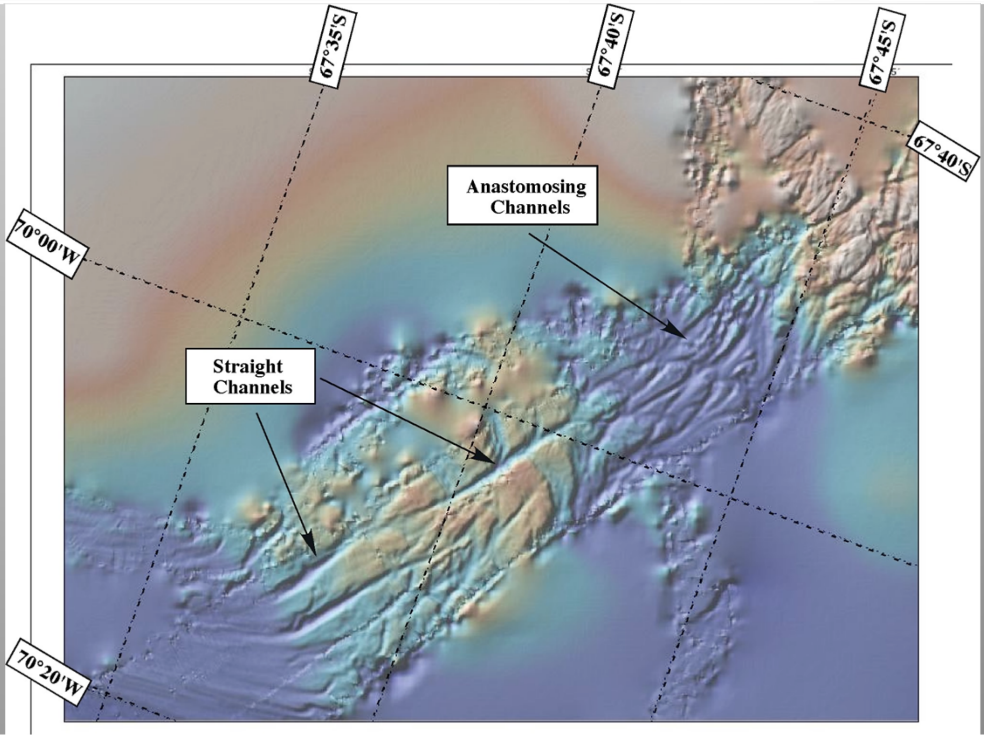


Lowe and Anderson, 2003, J. Glaciology

Marguerite Bay







(Anderson and Oakes, 2008, Geomorphology

Where these subglacial drainage systems active during the post-LGM retreat of the ice sheet?

What evidence is there that subglacial water contributed to ice stream instability in the past?

Stagnation of ice stream C, West Antarctica by water piracy

Sridhar Anandakrishnan and Richard B. Alley

RESEARCH ARTICLES

An Active Subglacial Water System in West Antarctica Mapped from Space

Helen Amanda Fricker,[1*] Ted Scambos,[2] Robert Bindschadler,[3] Laurie Padman[4]

Vol 440|20 April 2006|doi:10.1038/nature04660 nature

LETTERS

Rapid discharge connects Antarctic subglacial lakes

Duncan J. Wingham[1], Martin J. Siegert[2], Andrew Shepherd[3]† & Alan S. Muir[1]

GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L03501, doi:10.1029/2004GL021387, 2005

Evidence for subglacial water transport in the West Antarctic Ice Sheet through three-dimensional satellite radar interferometry

Laurence Gray,[1] Ian Joughin,[2,3] Slawek Tulaczyk,[4] Vandy Blue Spikes,[5] Robert Bindschadler,[6] and Ken Jezek[7]

Journal of Glaciology, Vol. 55, No. 190, 2009 303

Connected subglacial lake activity on lower Mercer and Whillans Ice Streams, West Antarctica, 2003–2008

Helen Amanda FRICKER,[1] Ted SCAMBOS[2]

GEOPHYSICAL RESEARCH LETTERS, VOL. 35, L17504, doi:10.1029/2008GL034937, 2008

Click Here for Full Article

High sensitivity of subglacial hydrological pathways in Antarctica to small ice-sheet changes

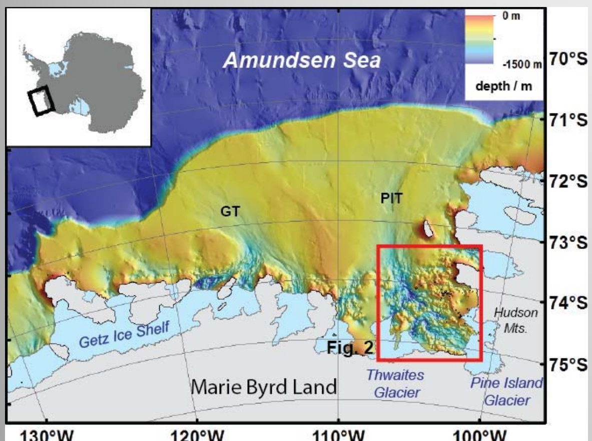
A. P. Wright,[1] M. J. Siegert,[1] A. M. Le Brocq,[2] and D. B. Gore[3]

LETTERS

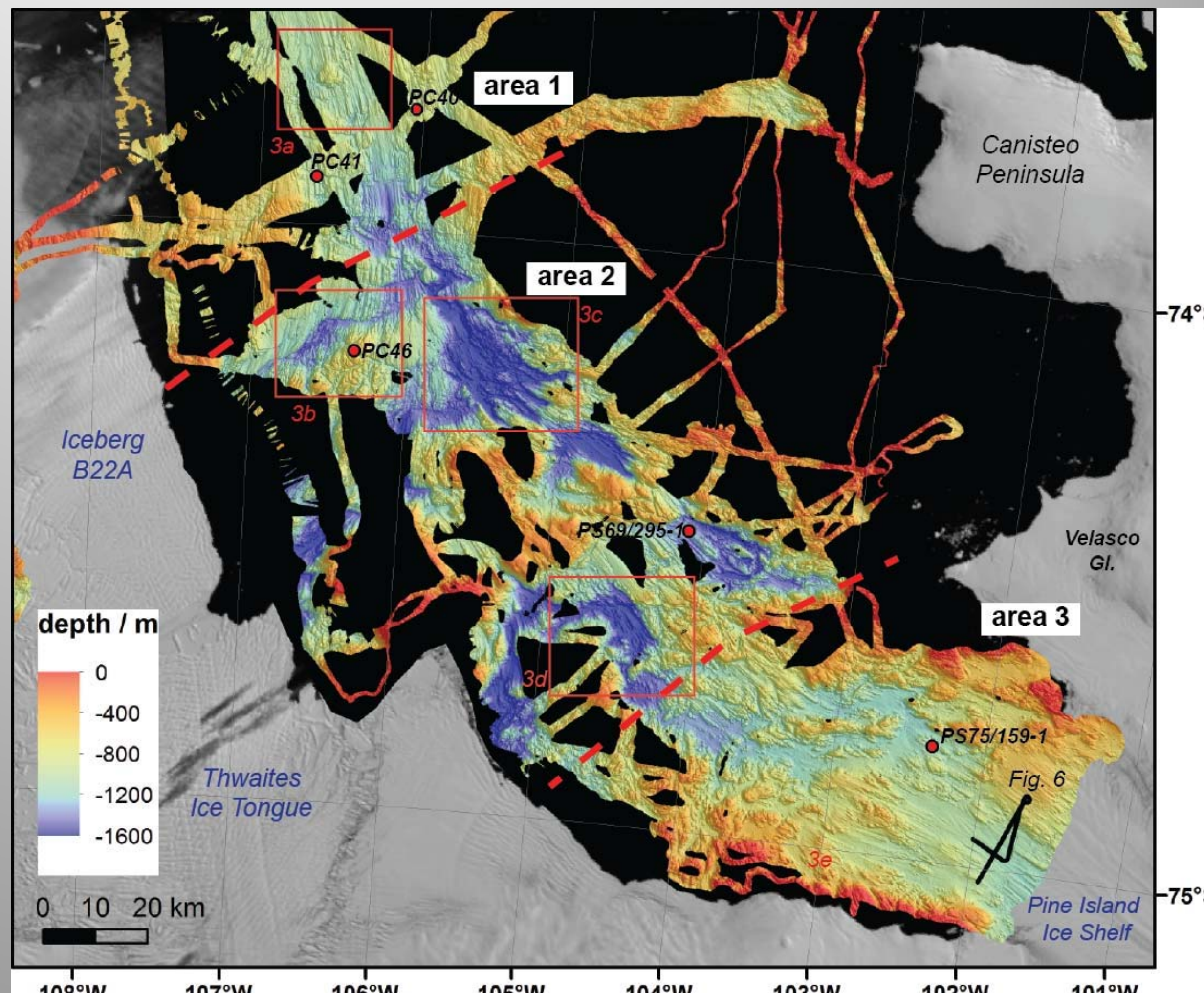
Increased flow speed on a large East Antarctic outlet glacier caused by subglacial floods

LEIGH A. STEARNS[1]*, BENJAMIN E. SMITH[2] AND GORDON S. HAMILTON[1]
[1]Climate Change Institute, University of Maine, 5790 Bryand Global Science Center, Orono, Maine 04469, USA
[2]Applied Physics Laboratory, University of Washington, 1013 NE 40th Street, Seattle, Washington 98105, USA
*e-mail: leigh.stearns@maine.edu.

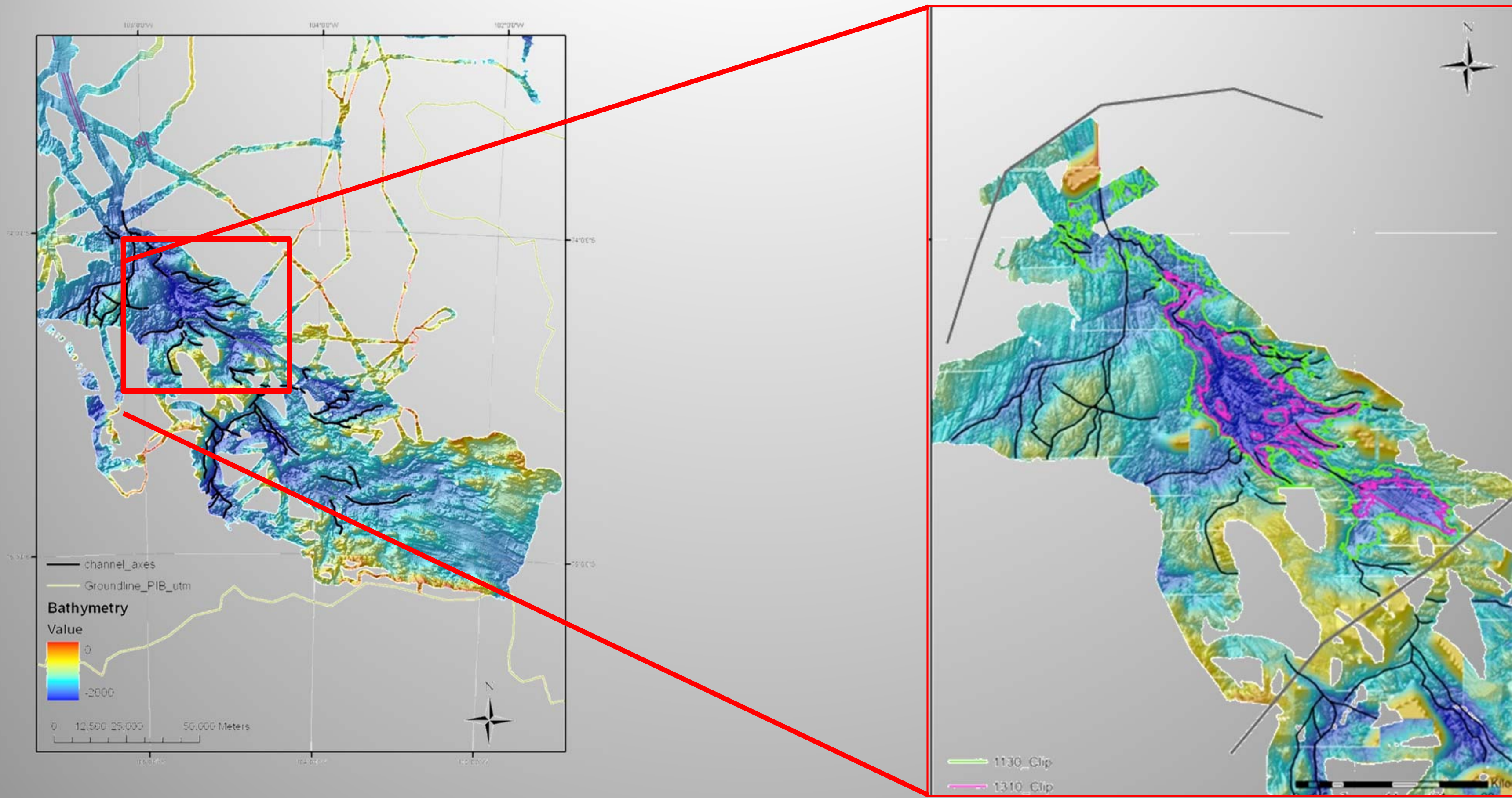
Pine Island Bay



Nitsche et al., 2012
Cryosphere



Subglacial Water Storage Potential



Interior basin of Pine Island Bay → isolated basins and connected basins.

Deep Basins storage capacity of ~70 km ^{3} stagnant water

Basin Connectivity

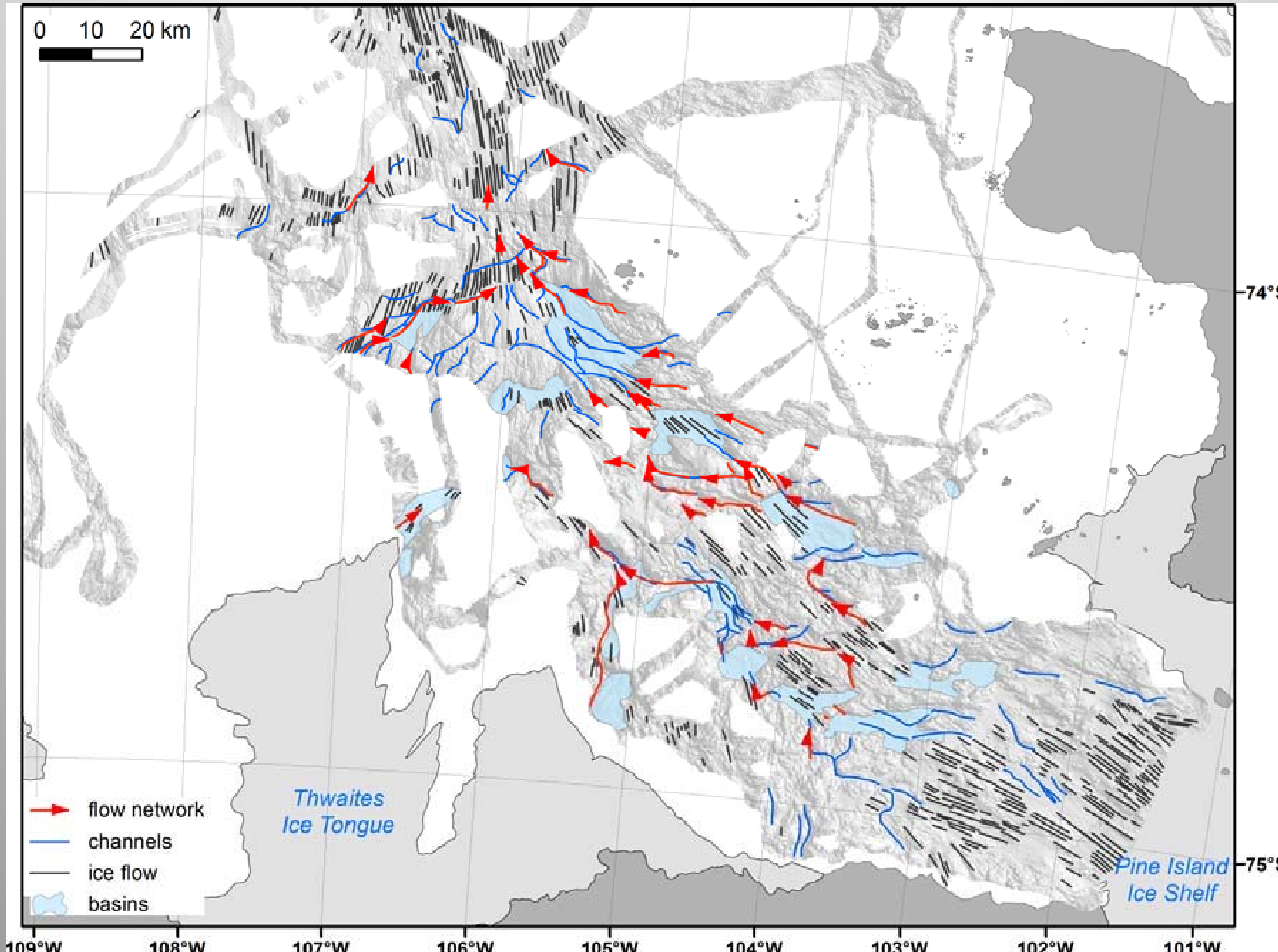
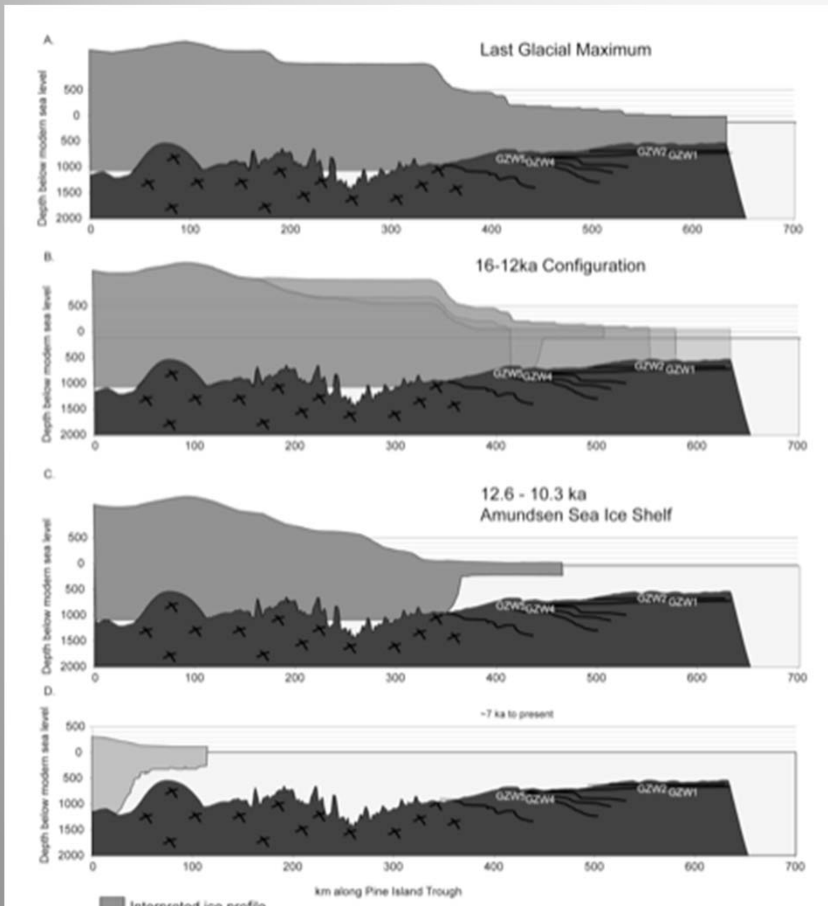


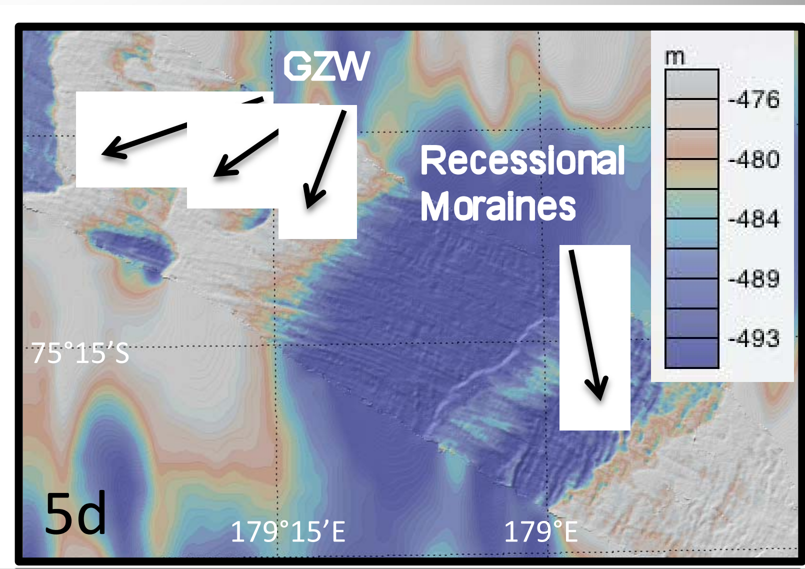
Fig. 7: Digitized lineations indicating ice flow (black), minor (blue) and major meltwater channels (red with arrows). The extent of swath bathymetry data is shown as gray shaded area. Light and dark gray shaded areas represent ice shelves and land, respectively, from the Antarctic Digital Database v6 (http://www.add.scar.org).

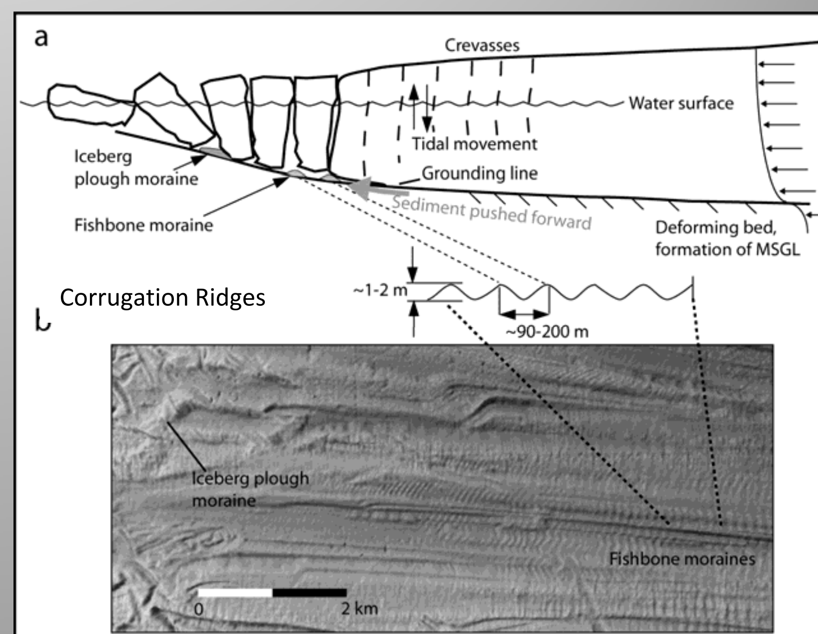
Nitsche et al., 2012

Punctuated retreat of ice sheet from the continental shelf in both areas is indicated by wedges and other features



Kirshner et al., 2012, QSR



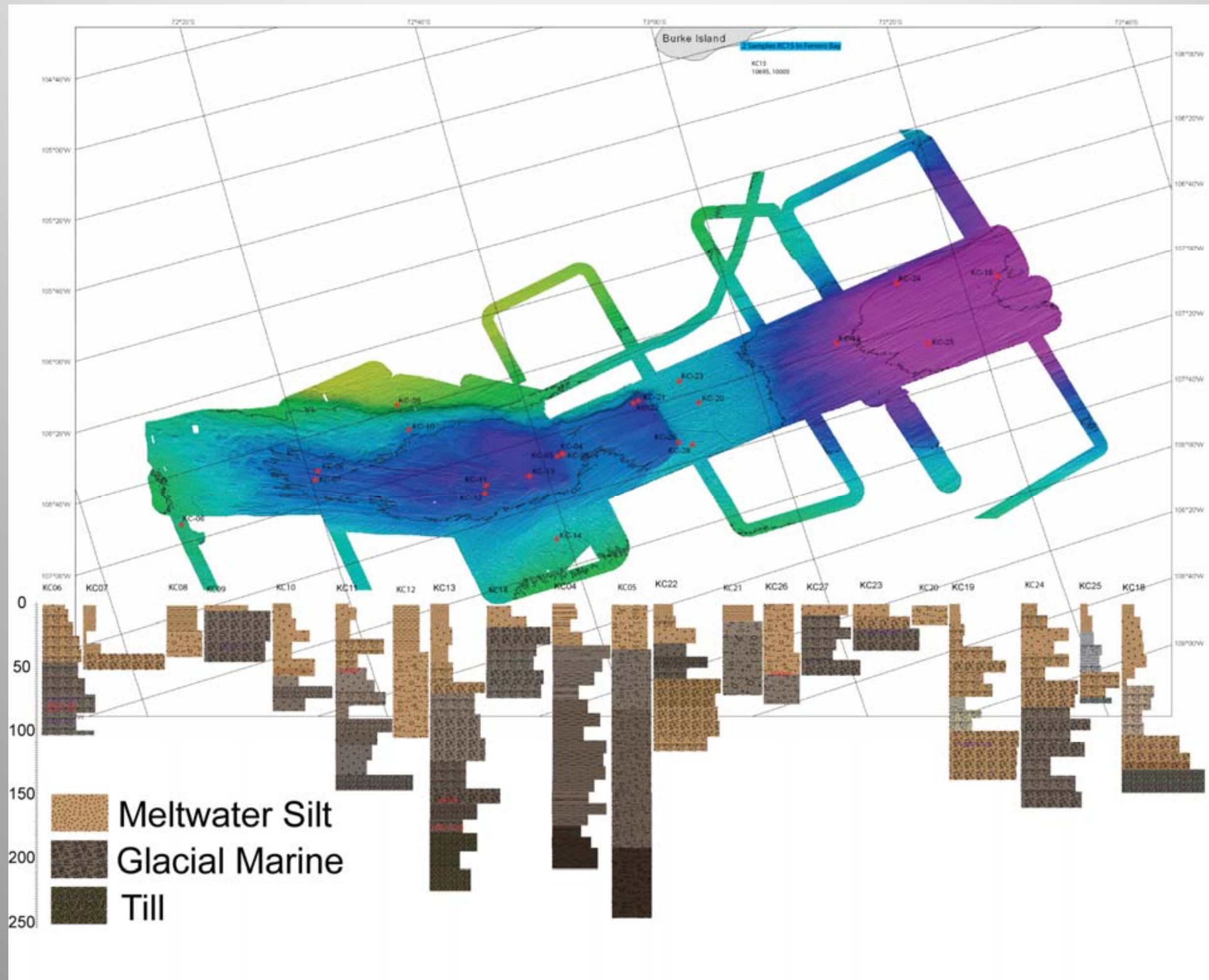


Jakobsson et al, 2010, Geology

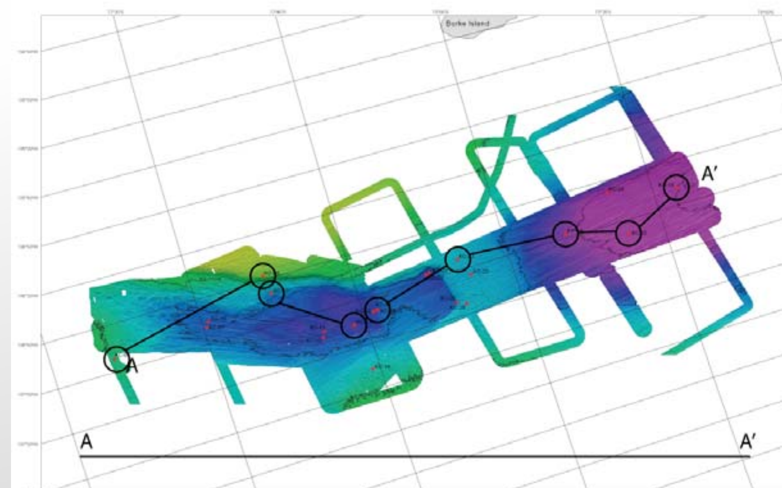
Movement of water may be due to changing ice profile or shallowing of the grounding line, reaching a critical level in the hydraulic potential.

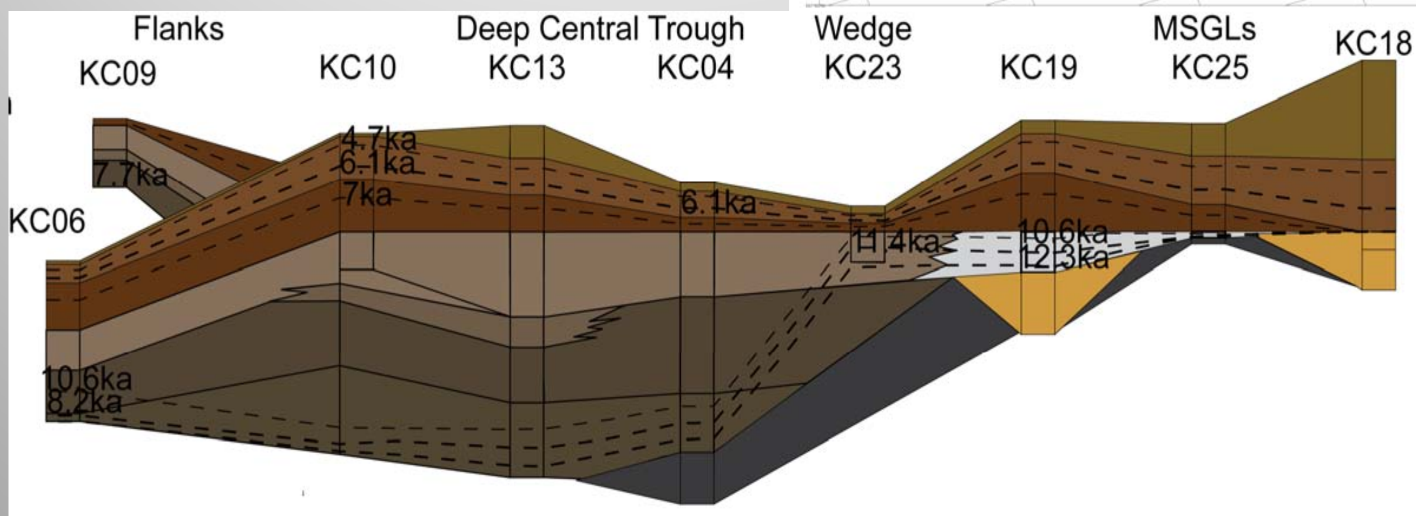
Where these subglacial drainage systems active during the post-LGM retreat of the ice sheet?

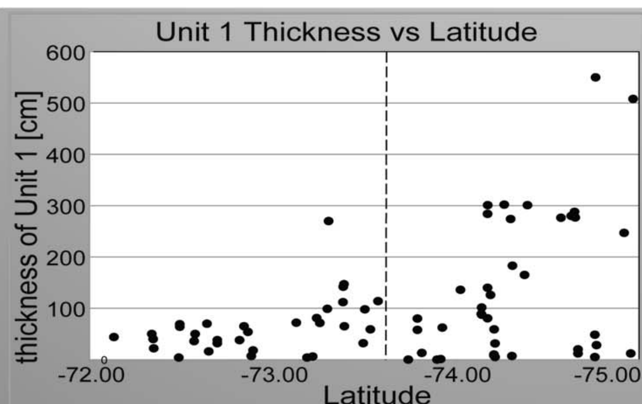
Meltwater? derived sediments
Timing?

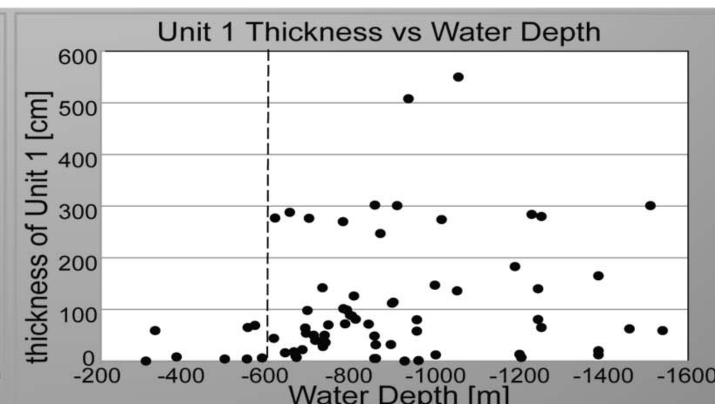


Widespread distribution pattern and accumulation at multiple water depths indicates dispersal by surface currents

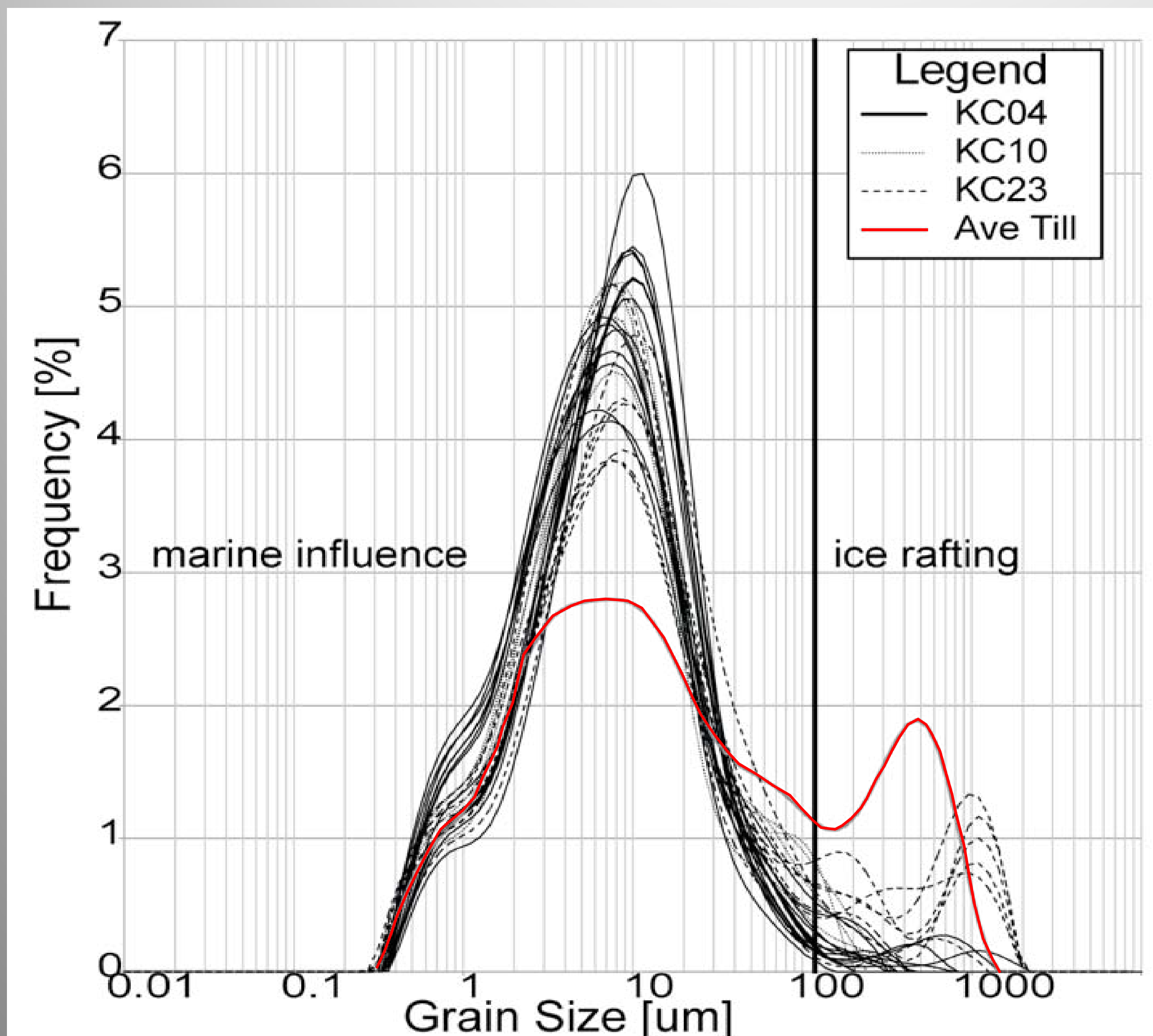


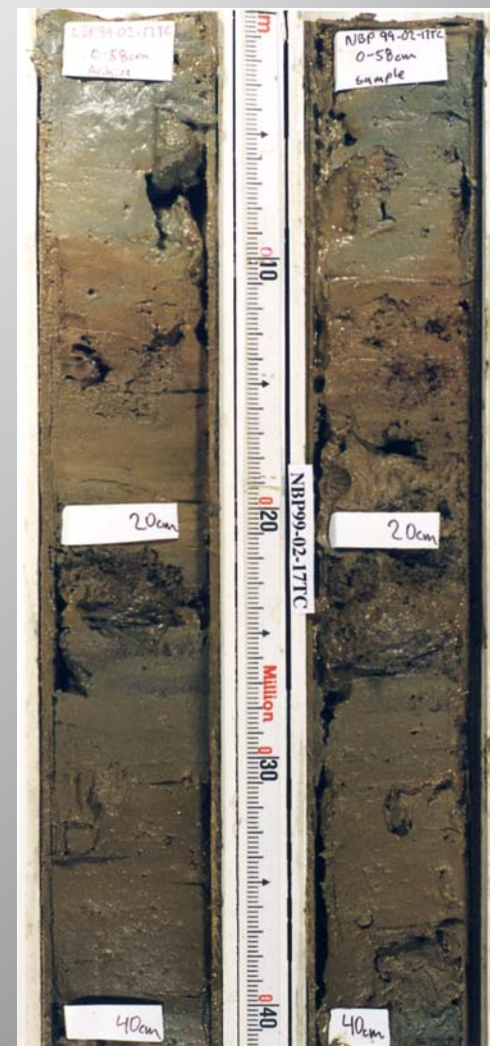


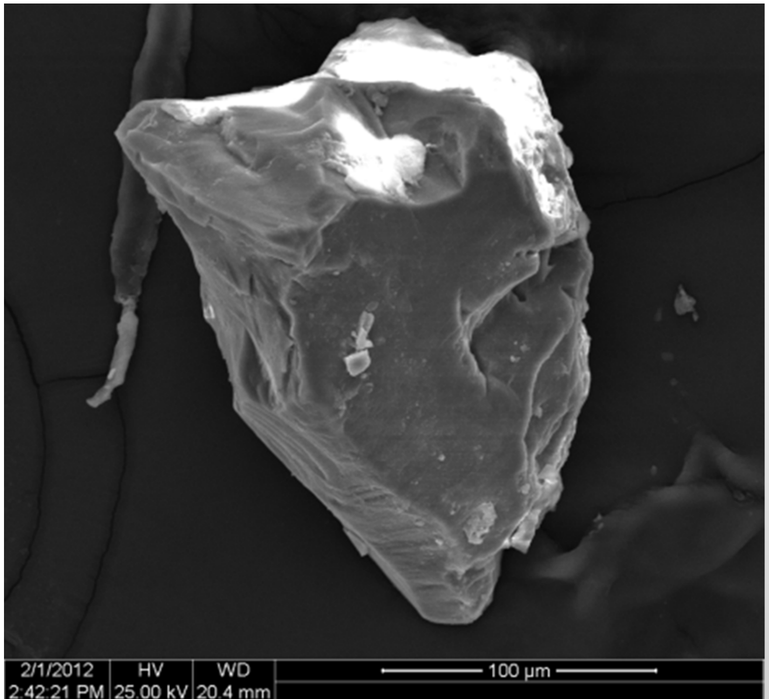




AutoSub mission beneath the modern Pine Island ice shelf support the presence of suspended sediment and transport of this sediment by ocean currents



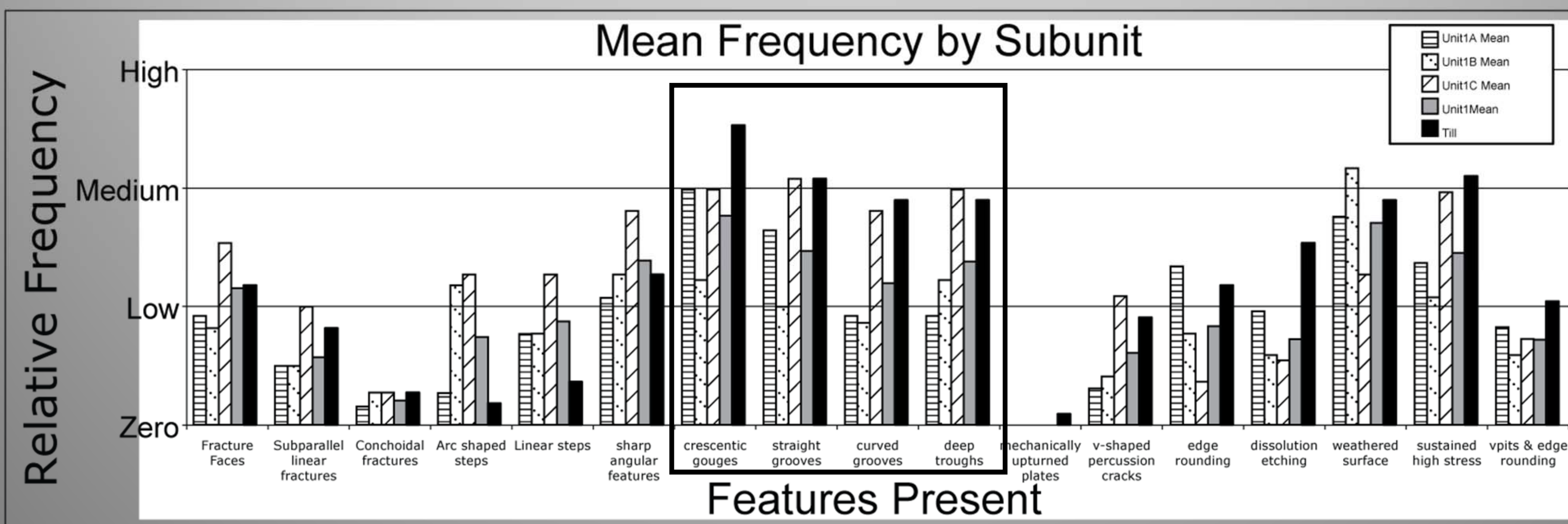


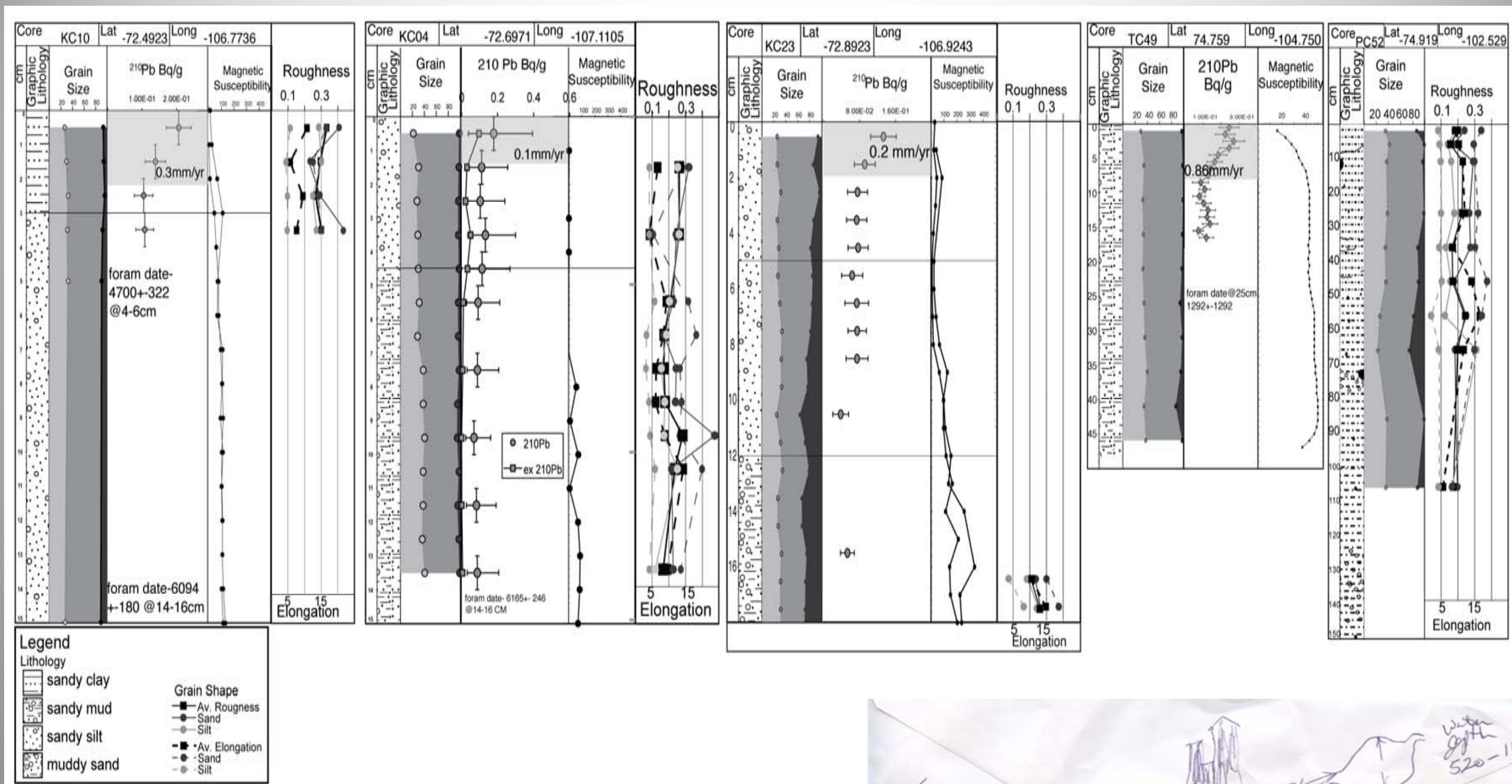


Distinguishing Transport Mechanism

Grain shape and texture of silt grains indicate glacial abrasion and transport with no significant alteration of grains

High Kaolinite concentration of clay fraction indicates non-glacial source





The sediment accumulation rates for subunit 1A are an order of magnitude faster than rates for subunit 1B. Current rates are on the order of 1 mm/yr, which implies high erosion rates

Rapid subglacial erosion beneath Pine Island Glacier, West Antarctica

A. M. Smith,1 C. R. Bentley,2 R. G. Bingham,3 and T. A. Jordan1

GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L12501, doi:10.1029/2012GL051651, 2012

We present measurements of ice thickness, gravimetry and surface elevation on Pine Island Glacier, West Antarctica, separated by a period of 49 years. At one station, on the main trunk of the glacier we measured a surface elevation lowering with no significant change in ice thickness. We interpret these as indicating subglacial erosion of 31.8 13.4 m at this location, at a mean rate over the measurement period of 0.6 0.3 m and suggest that a current erosion rate of 1 m a1 is possible.

Conclusion

- Well organized subglacial drainage networks occur in Pine Island Bay and in Marguerite Bay where extensive paleodrainage areas of paleo-ice streams have been mapped in detail.
- There is sufficient connectivity between channels and basins to enable organized drainage once a critical level in hydraulic potential has been met.
- Both areas experienced post-LGM histories with punctuated back-stepping grounding lines throughout their retreat from the continental shelf.
- Sediment cores from both areas sampled well sorted silts that are interpreted as having been derived from subglacial meltwater and dispersed by surface currents.
- The youngest "plumite" deposit is a modern deposit. Its relatively high accumulation rate is consistent with high erosion rates that have been observed beneath PIG (Smith et al., 2012).