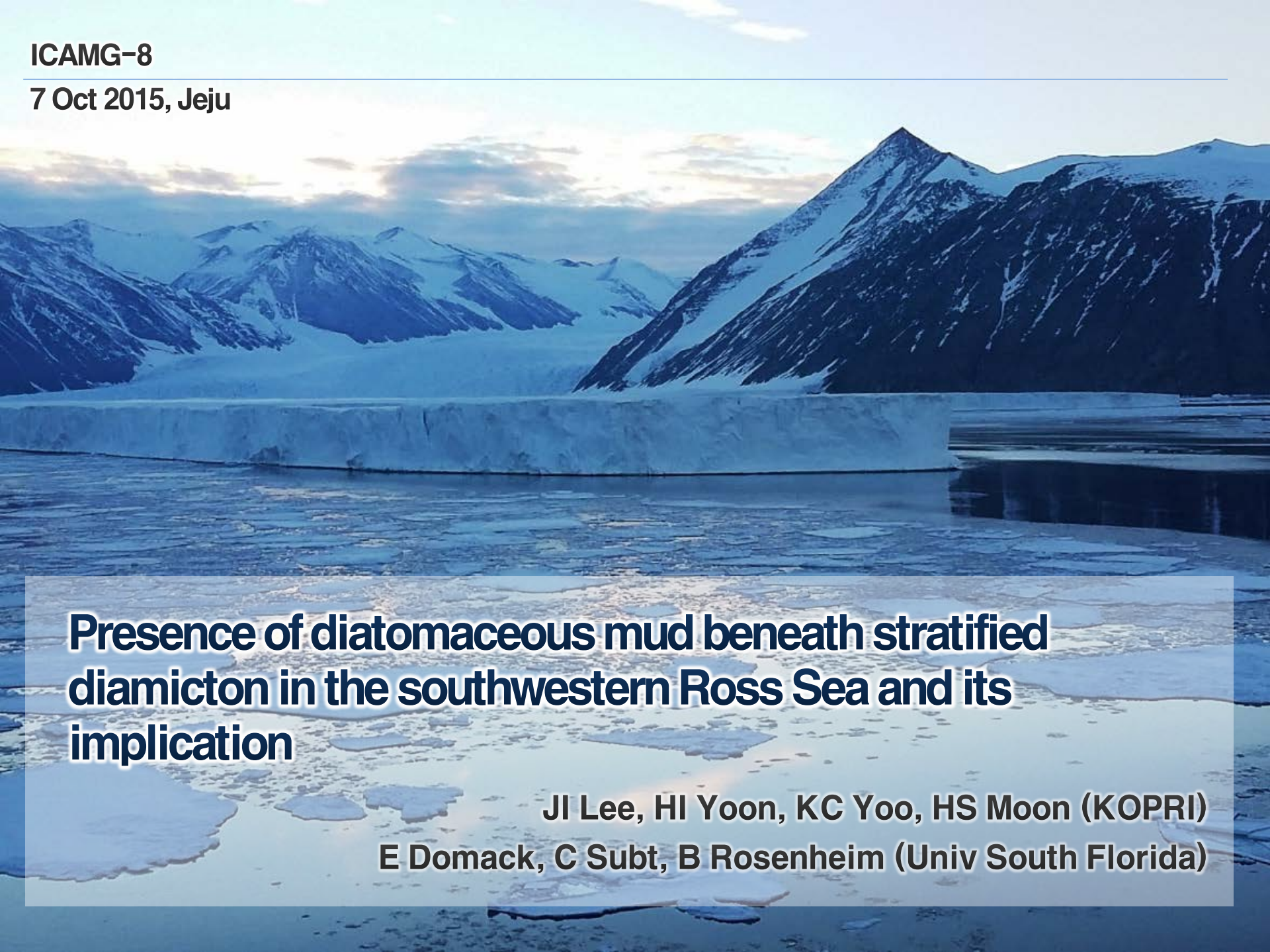
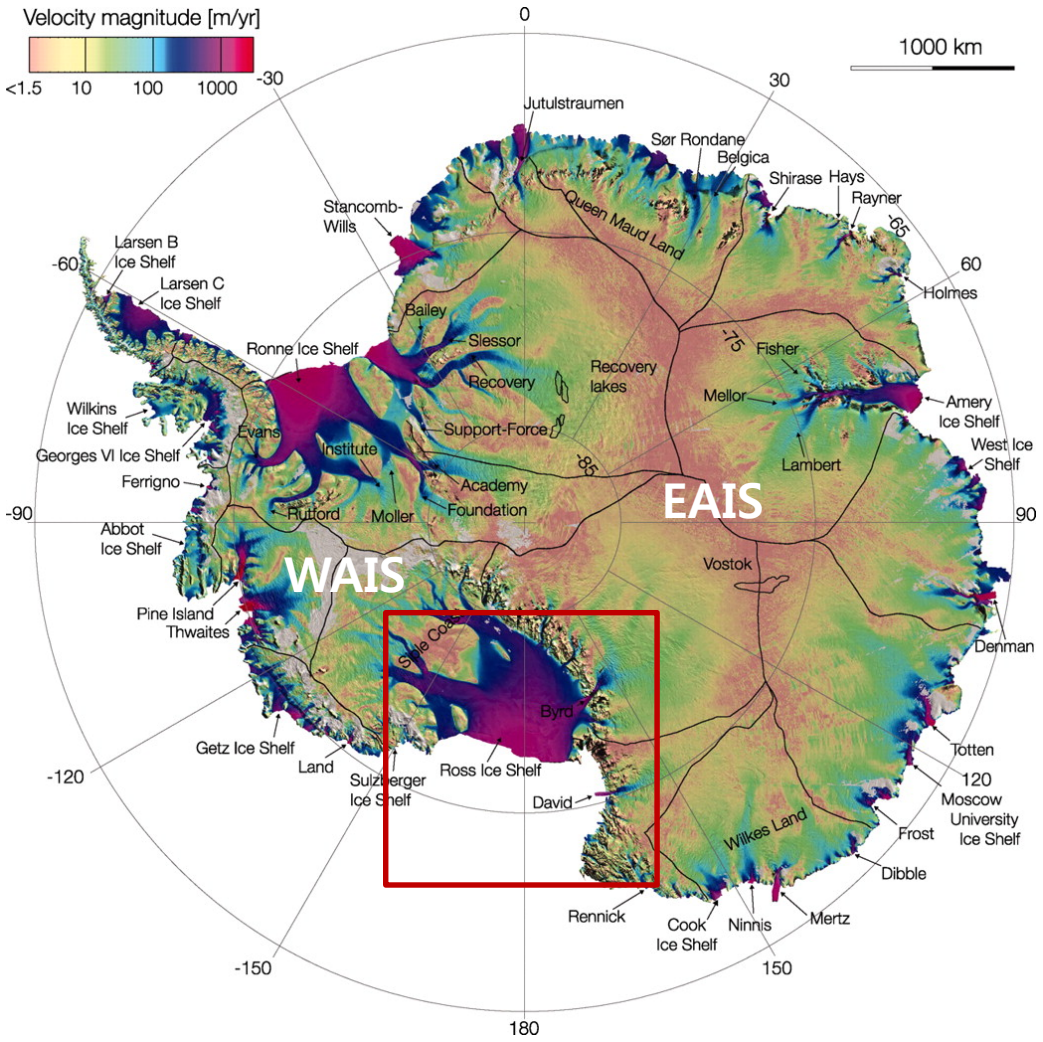
ICAMG-8
7 Oct 2015, Jeju



Presence of diatomaceous mud beneath stratified diamicton in the southwestern Ross Sea and its implication

JI Lee, HI Yoon, KC Yoo, HS Moon (KOPRI)
E Domack, C Subt, B Rosenheim (Univ South Florida)

Ross Sea Embayment



One of the most extensively studied region in Antarctica

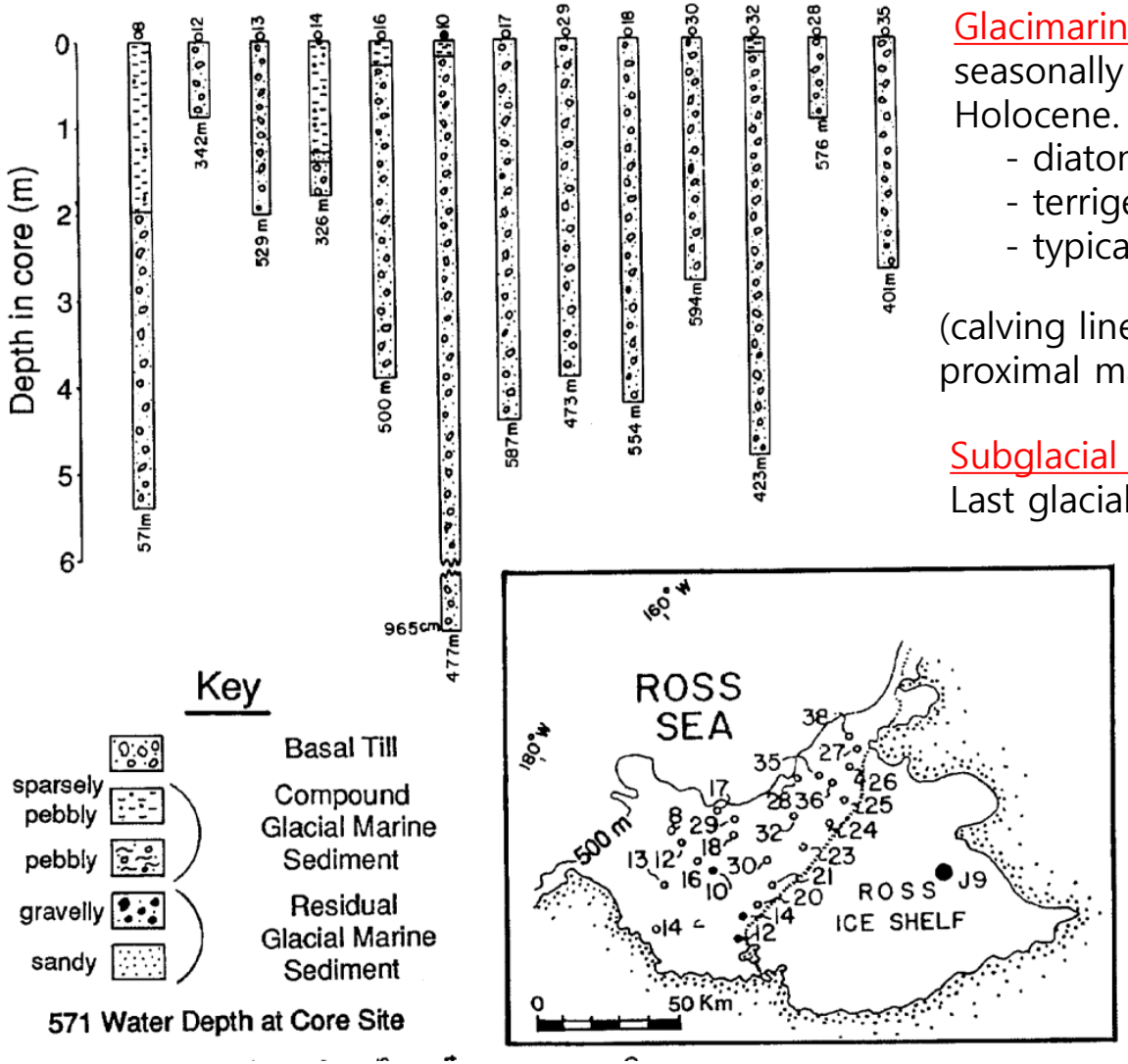
Ross Island:
McMurdo Station (US)
Scott Base (NZ)

Terra Nova Bay:
Jang Bogo Station (KOR)
Mario Zucchelli Station (ITA)
Gondwana Station (GER)

Several hundreds of piston and gravity cores
ANDRILL SMS, MIS cores

(Rignot et al., 2011, Science)

'Typical' Ross Sea sediments since LGM



(Anderson et al., 1991, GSA Spec Publ.)

Glacimarine mud: deposited in seasonally open marine condition. Holocene.

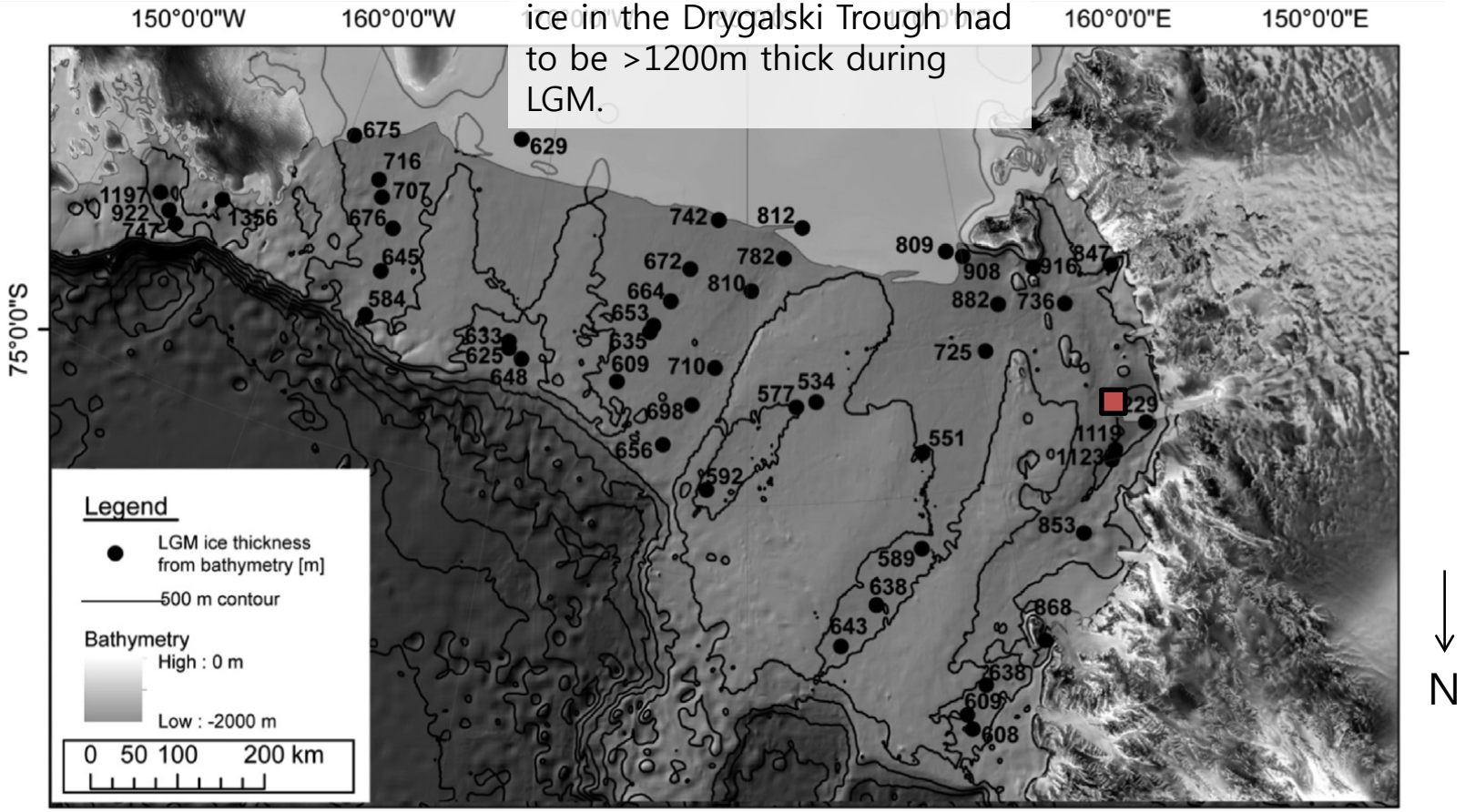
- diatomaceous mud
- terrigenous mud
- typically <1m thick

(calving line / sub ice-shelf / proximal marine)

Subglacial diamicton: Subglacial till. Last glacial period

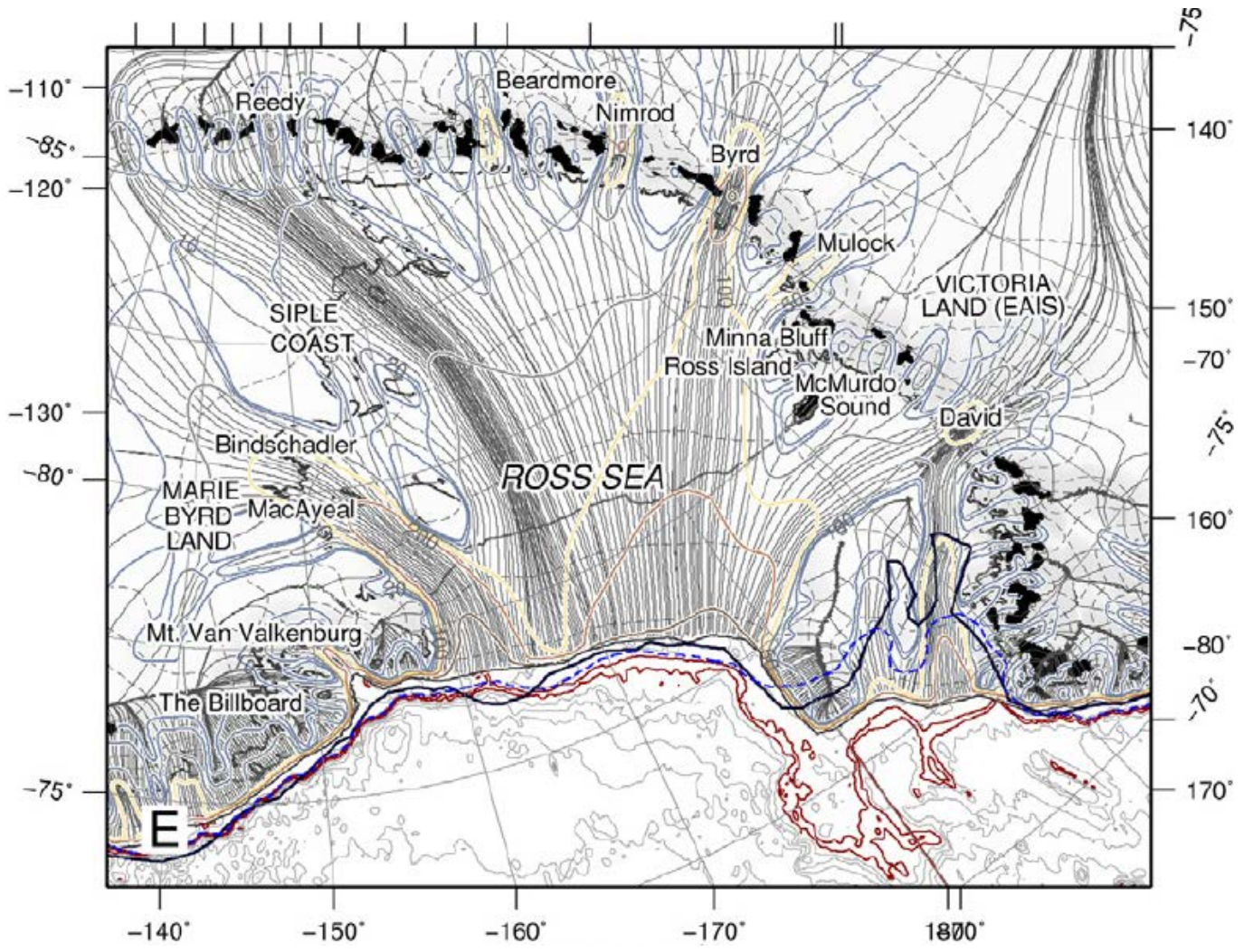
Minimum thickness of LGM ice sheet from bathymetry

In order to be grounded the ice in the Drygalski Trough had to be >1200m thick during LGM.



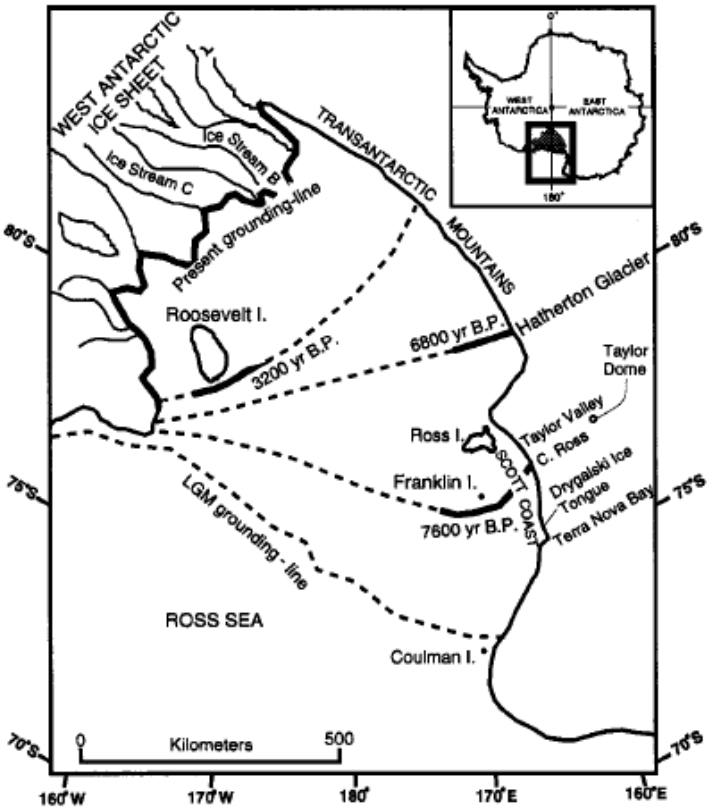
Anderson et al., 2014, QSR

LGM extent of ice sheet in the Ross Sea

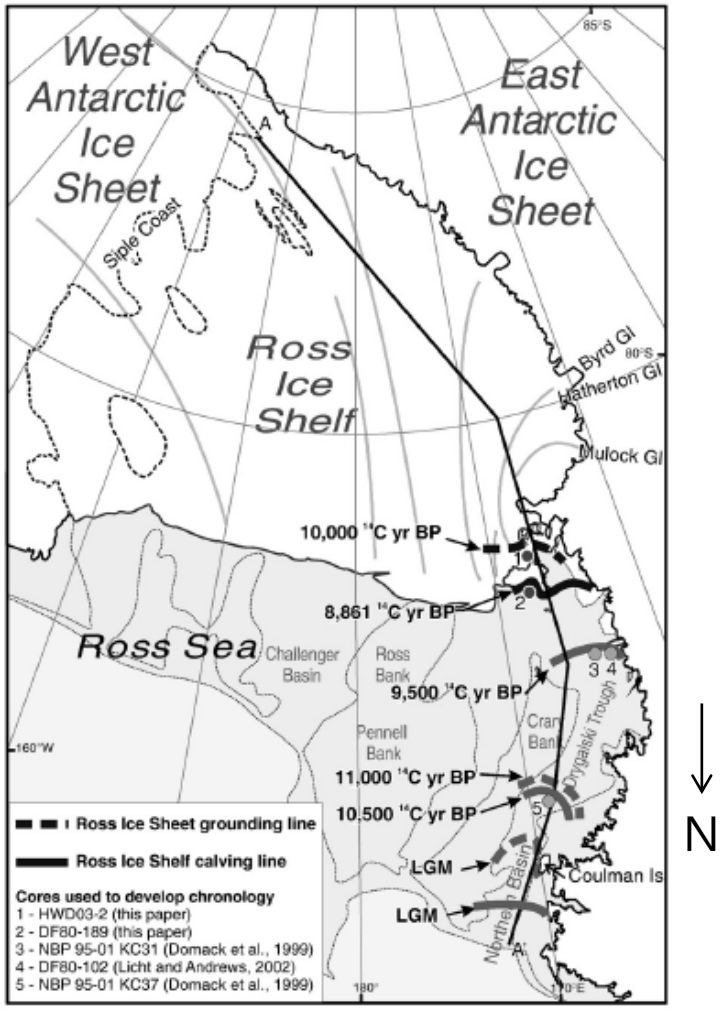


Golledge et al., 2013, QSR

Grounding Line Retreat History

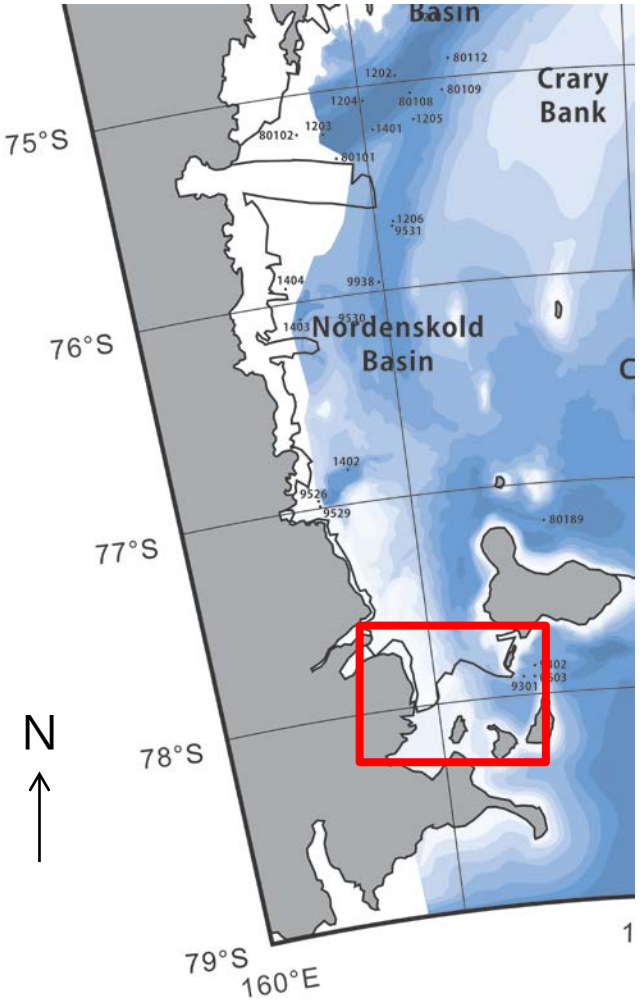


(Conway et al., 1999, Science)



(McKay et al., 2008, PPP)

LGM Ross Ice Sheet variability?



Dates of shells in debris bands on the McMurdo Ice Shelf

- Bimodal population
  - younger than 7,750 yrs BP
  - older than 20,000 yrs BP

→ "Grounded ice filled southern McMurdo Sound between 20,000 and 7750 yrs BP."

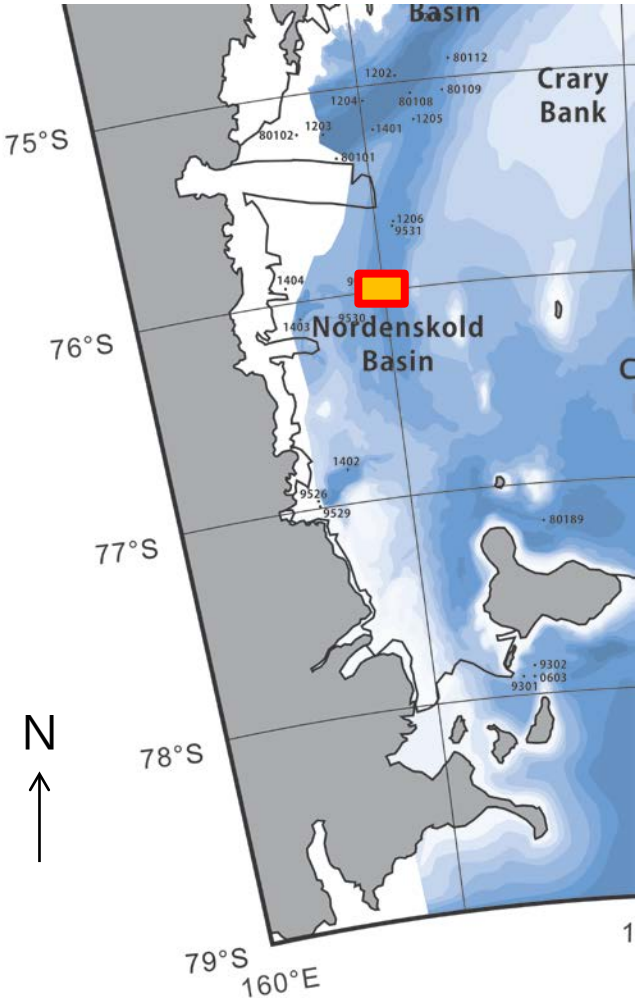
- > 20,000 yrs BP samples
  : 45.5, 35.4, 30.9, 22.1, 20.8 kyr BP

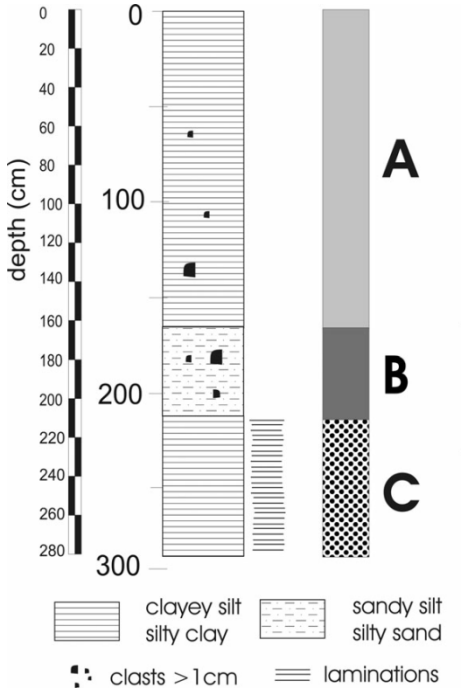
* uncorrected 14C ages

(Kellogg et al., 1990, ARS)

LGM Ross Ice Sheet variability?

"Pre-LGM open water conditions"





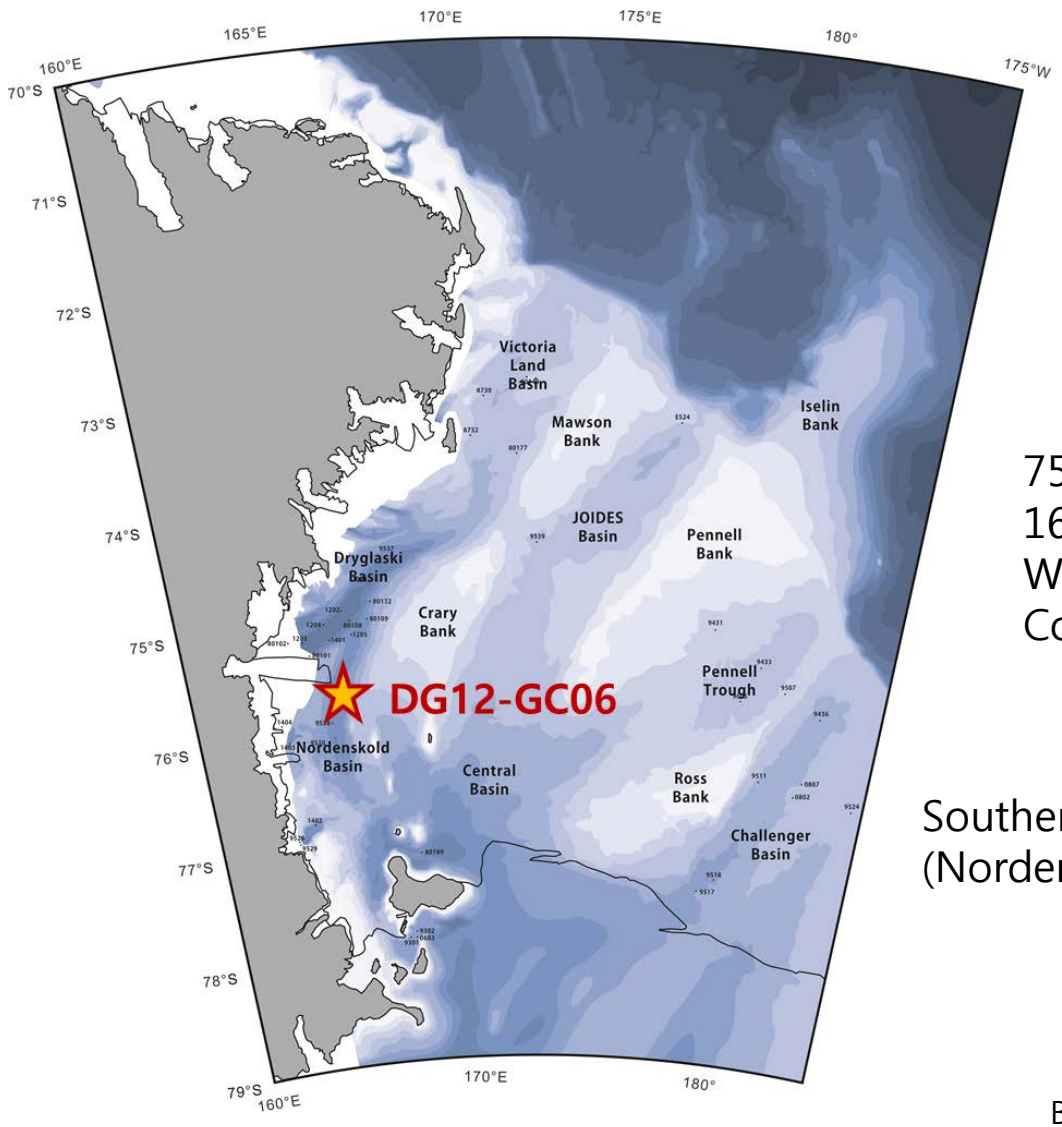
Unit C: olive-pale yellow biosiliceous mud

Table I. AMS ^{14}C ages of ANTA99-cD38 core, based on acid insoluble organic matter. Corrected ages by subtraction of 3000 yr (Andrews *et al.* 1999, see text).

Level (cm)	Lab code	Uncorrected age (yr BP)	± 1σ	Corrected age (yr BP)
162–163	GX-30079	12 270	40	9 270
227–228	GX-30080	29 550	240	26 550
283–283.5	GX-3133	28 070	300	25 070

(Finocchiaro et al., 2007, AS)

Sample Location



75° 39.57′ S
165° 23.84′ E
Water depth 859m
Core length 3.96m

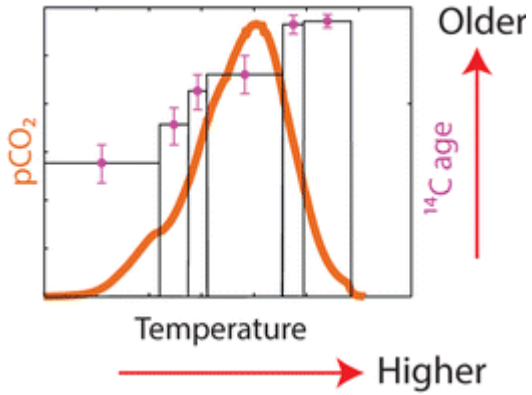
Southern Drygalski Trough
(Nordensköld Basin)

Bathymetry from Davey, 2004

Age Dating

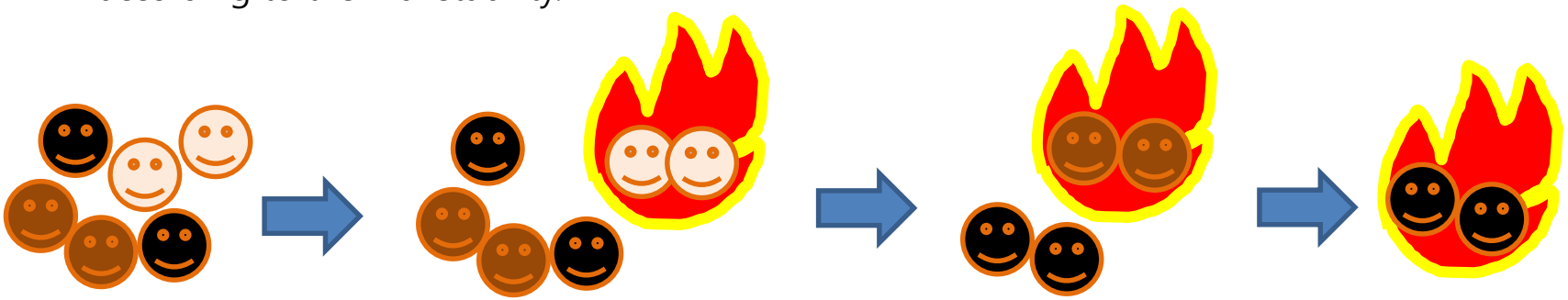
Problems in dating Ross Sea (Antarctic) sediments

1. Few carbonate → AIO (acid-insoluble organic matter) ^{14}C dating
2. AIO ^{14}C dates for Ross Sea sediments are usually much older than depositional ages due to presence of older, recycled organic matter.

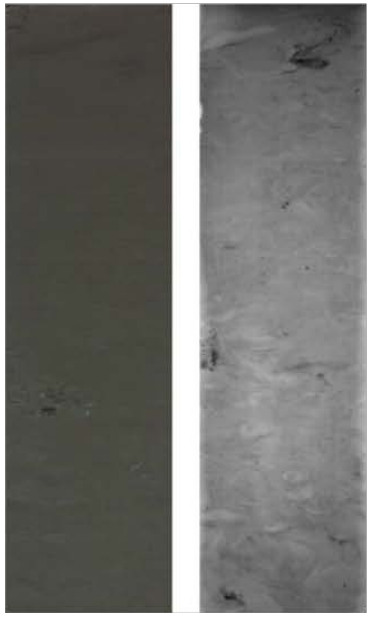


Ramped Pyrolysis radiocarbon dating of organic carbon

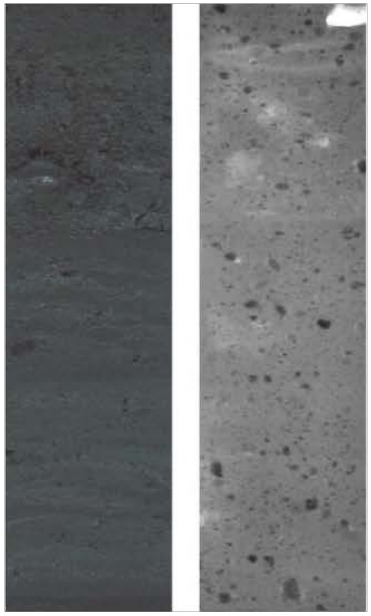
RP targets distinct components of organic C according to thermal stability.



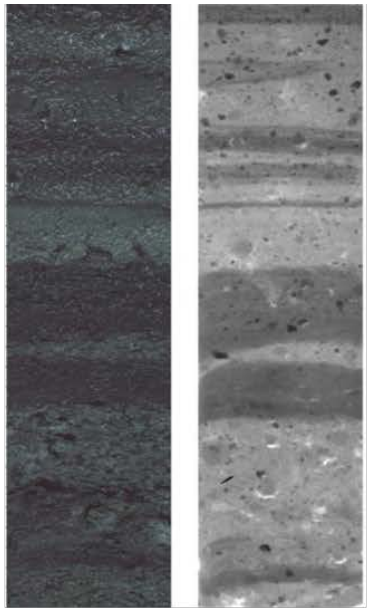
Sediment Facies



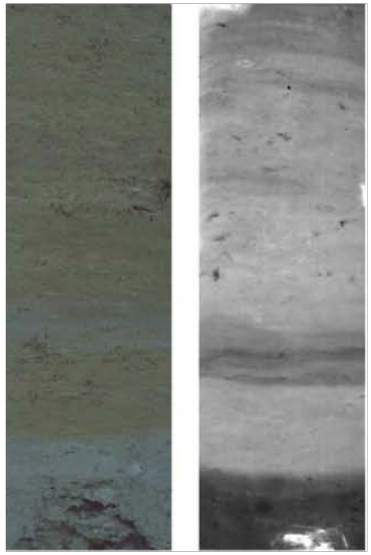
0-30cm : bioturbated light olive gray diatomaceous mud



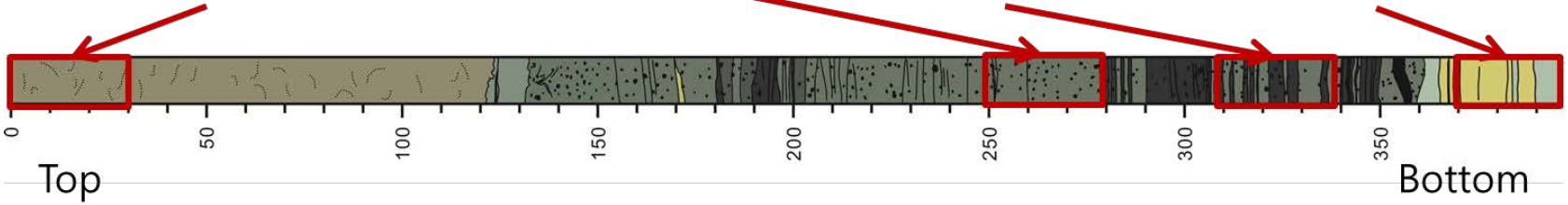
249-279cm: crudely stratified dark greenish gray diamicton

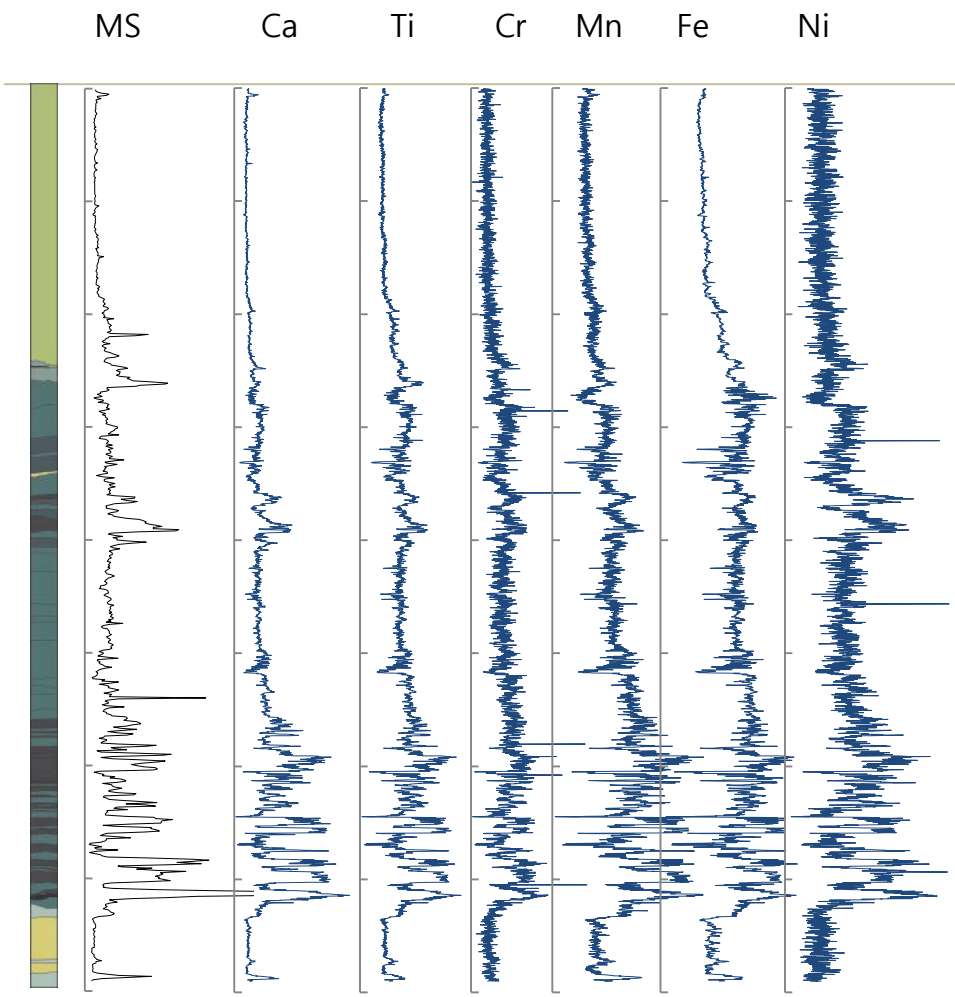


308-338cm: Stratified dark greenish gray mud/dark gray diamicton



369-396cm: Greenish gray/greenish yellow diatomaceous mud



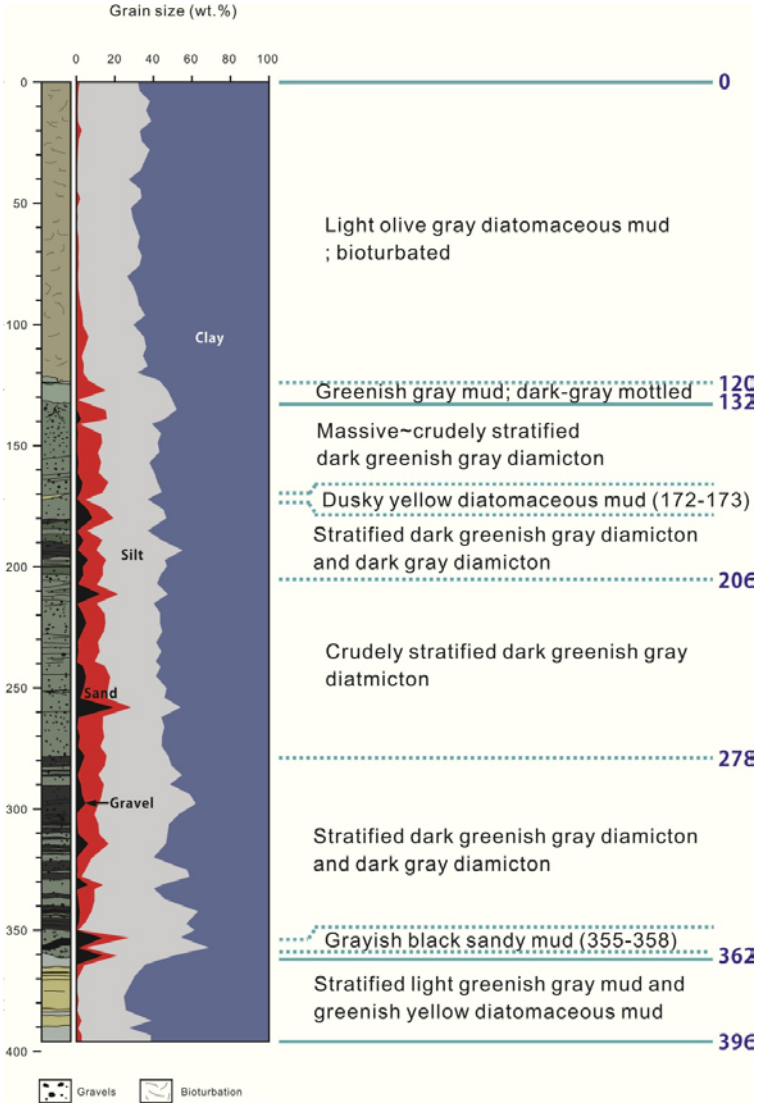


Dark gray layers in stratified diamicton facies

- High MS
- High in Ca, Ti, Cr, Mn, Fe, and Ni

Increased sediments of volcanic sources

Sediment Facies

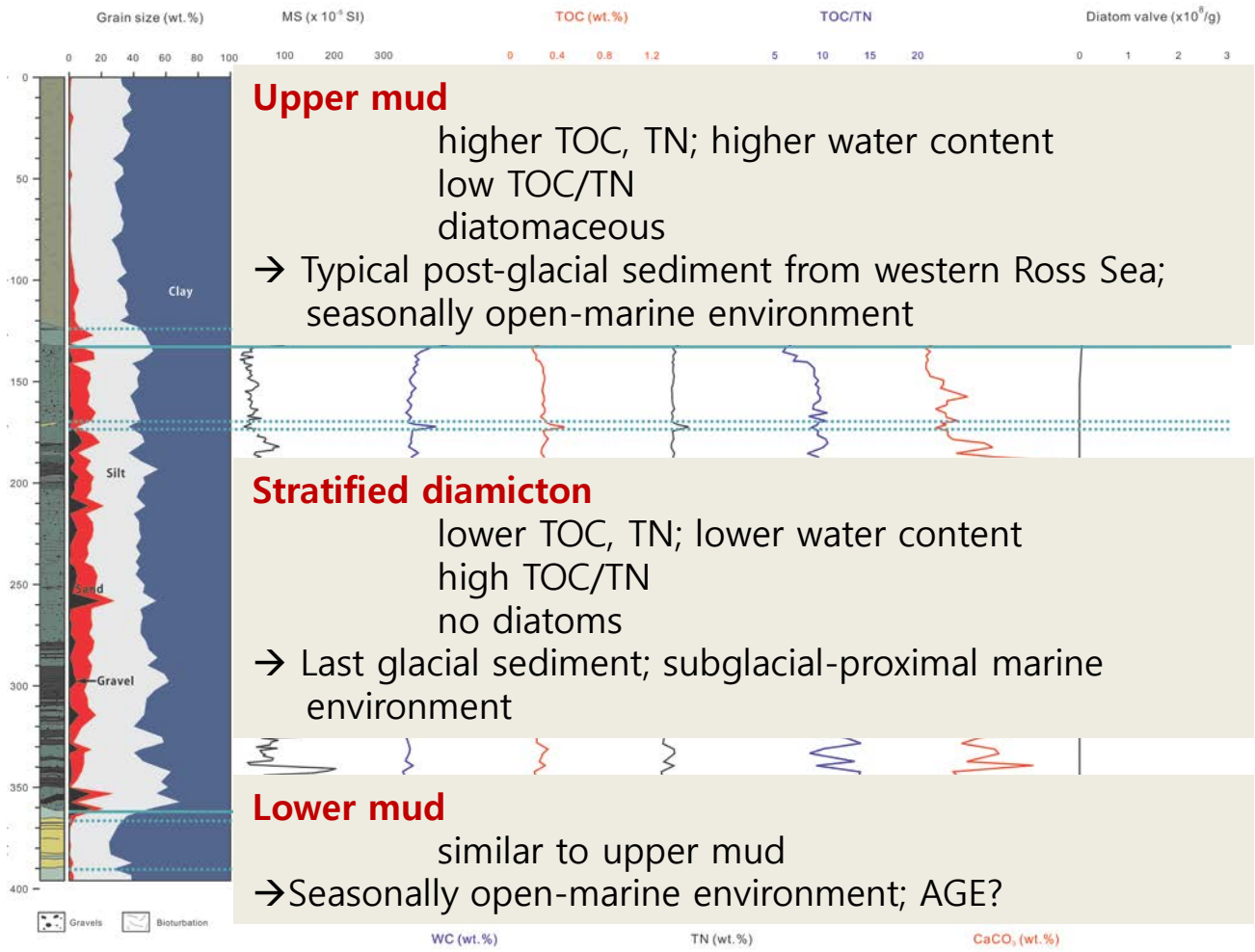


"upper" mud

Stratified diamicton

"lower" mud

Grain size, MS, TOC, TN, carbonate content, and diatom abundance



Upper mud

higher TOC, TN; higher water content
low TOC/TN
diatomaceous

→ Typical post-glacial sediment from western Ross Sea; seasonally open-marine environment

Stratified diamicton

lower TOC, TN; lower water content
high TOC/TN
no diatoms

→ Last glacial sediment; subglacial-proximal marine environment

Lower mud

similar to upper mud

→Seasonally open-marine environment; AGE?

Radiocarbon Ages

Cf. Global ice-sheet expansion ~26.5 to 19 ka BP (Clark et al., 2009)

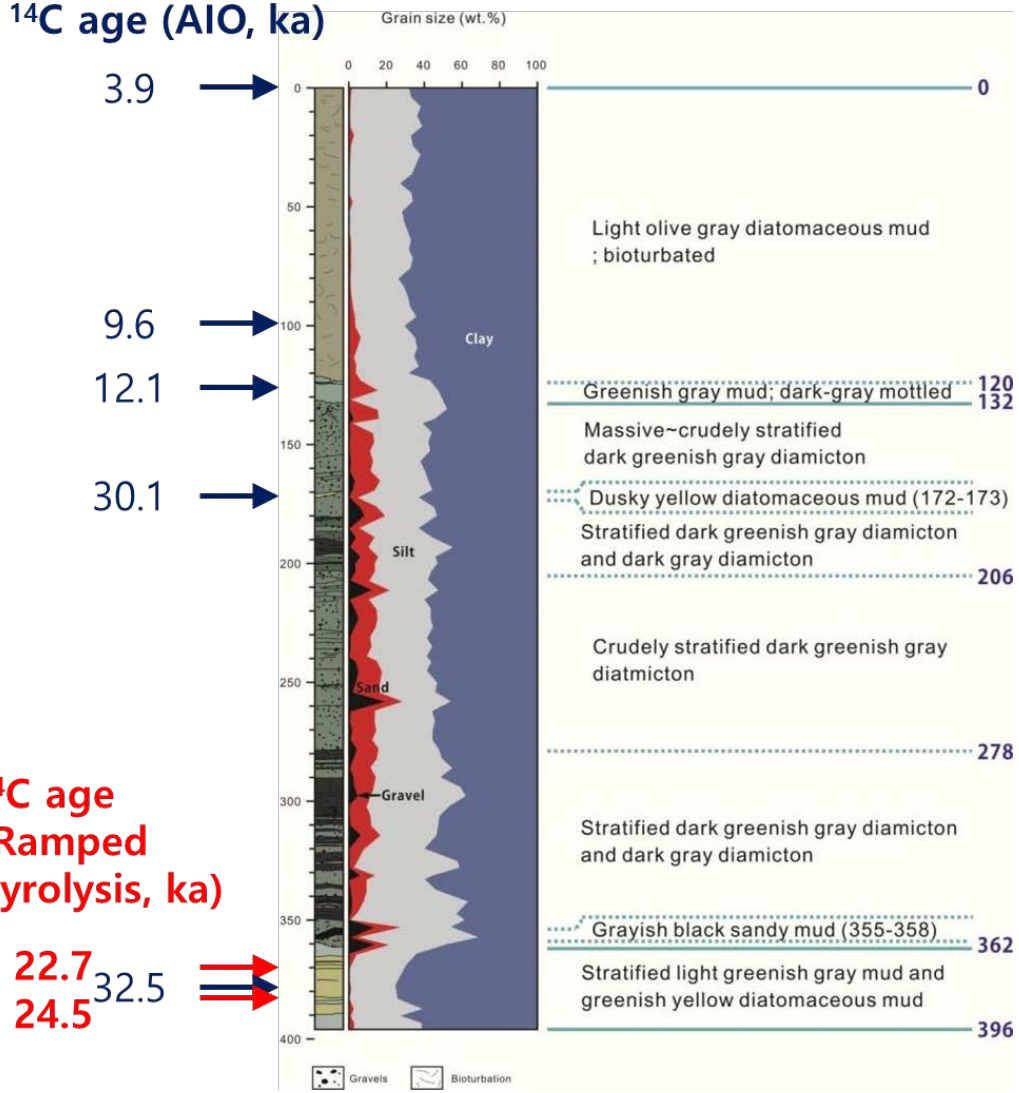
(Berkman and Forman, 1996)

Reservoir Correction 1.3 ka:

21.4
23.2

^{14}C age (Ramped Pyrolysis, ka)

22.7
24.5 32.5

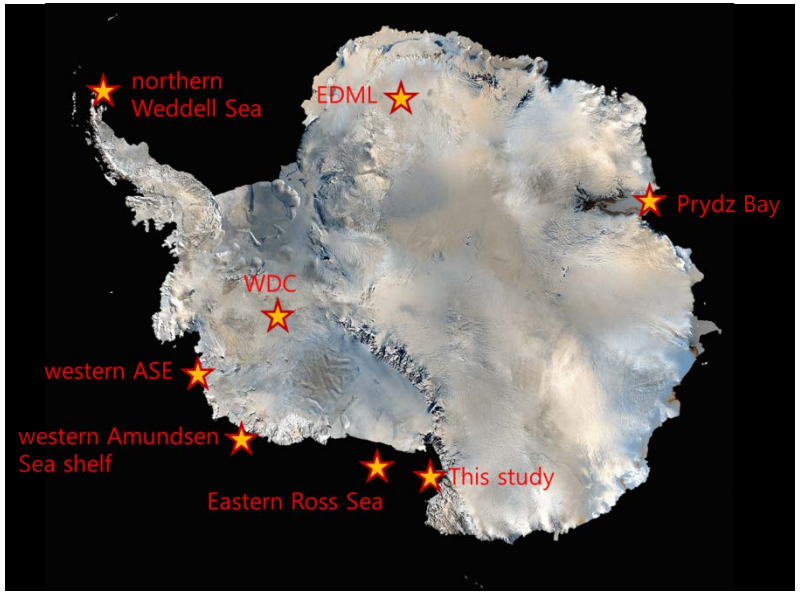


Implications and Questions

- Open marine environment in the western Ross Sea during the LGM:
  → questioning the stability of the LGM Ross Ice Sheet

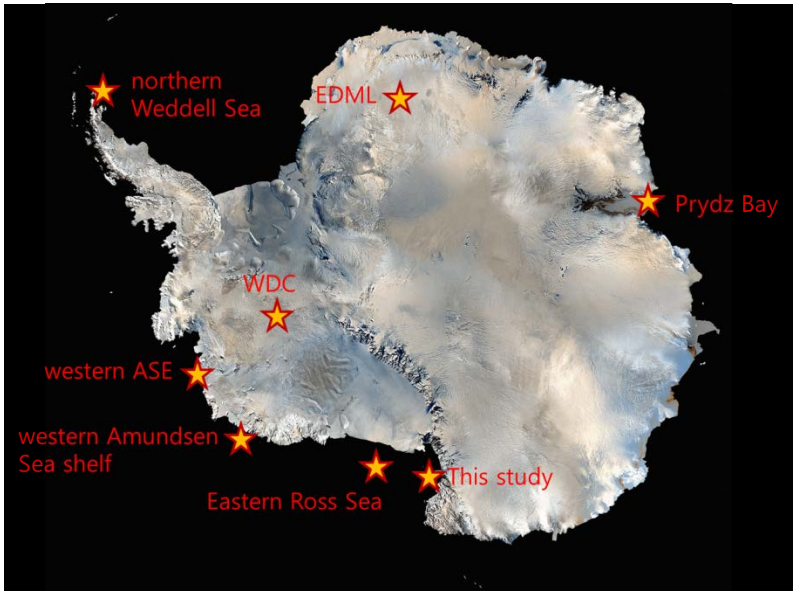
- Warmer condition during the 'global LGM' period?
  → Was it local? regional? Or AA-wide?

  - Prydz Bay
  - eastern Ross Sea
  - Amundsen Sea
  - Weddell Sea
  - Antarctic Ice core record



AA sediment records questioning a stable and prolonged LGM ice sheet

- Prydz Bay (East AA): Diatom ooze beds beneath LGM marine deposits (Domack et al., 1998, AS)
- Amundsen Sea shelf: WAIS retreat during/prior to the global LGM (~23 to 19 cal ka BP) (Klages et al., 2014, QSR)
- Western Amundsen Sea Embayment: deglaciation as early as 22.4 cal ka BP (Smith et al., 2011, QSR)
- Northwestern Weddell Sea: foraminifera during 20.3-28.5 cal ka BP (Smith et al., 2010, EPSL); widespread occurrence of polynyas along the AA continental margin during the last glacial period
- Eastern Ross Sea: retreat of WAIS at 27.5 ^{14}C ka BP from middle shelf (Bart and Cone, 2012, PPP)

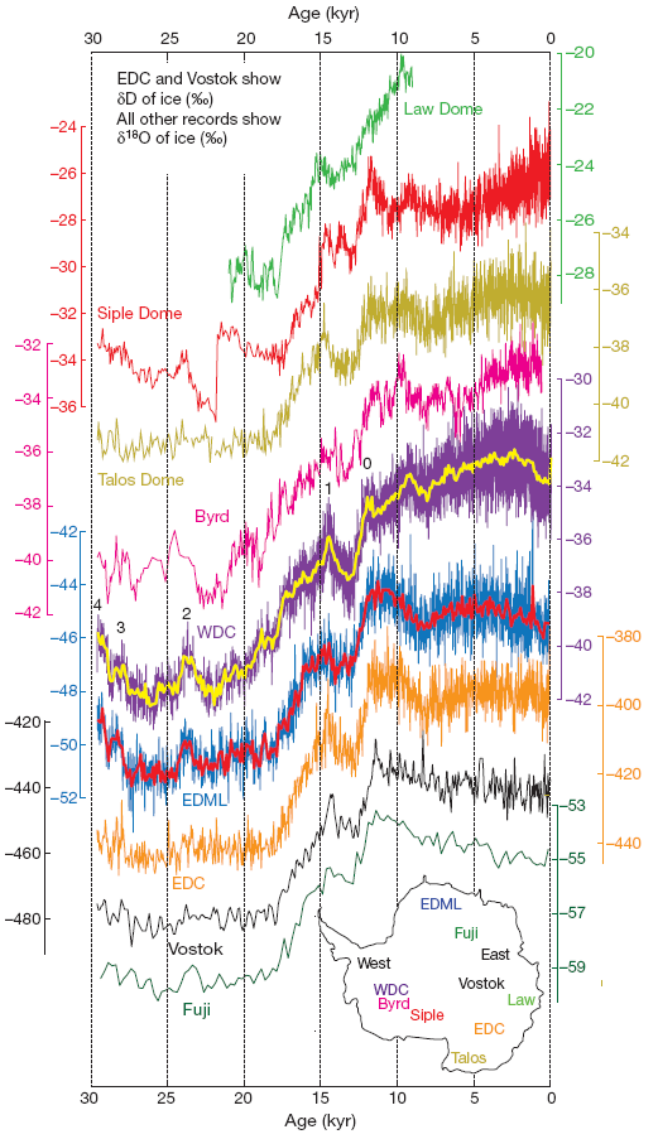


Ice Core Records indicate a warm period at 24~23 ka BP

WAIS Divide Ice core record

(WAIS Divide Project Members, 2013, Nature)

- The coldest period: 28~22 kyr BP
- interrupted by AIM 2 (Antarctic Isotope Maximum 2)
  - : 1000-yr warm period (24~23 kyr BP)
  - : also prominent in the EPICA Dronning Maud Land (EDML) ice core

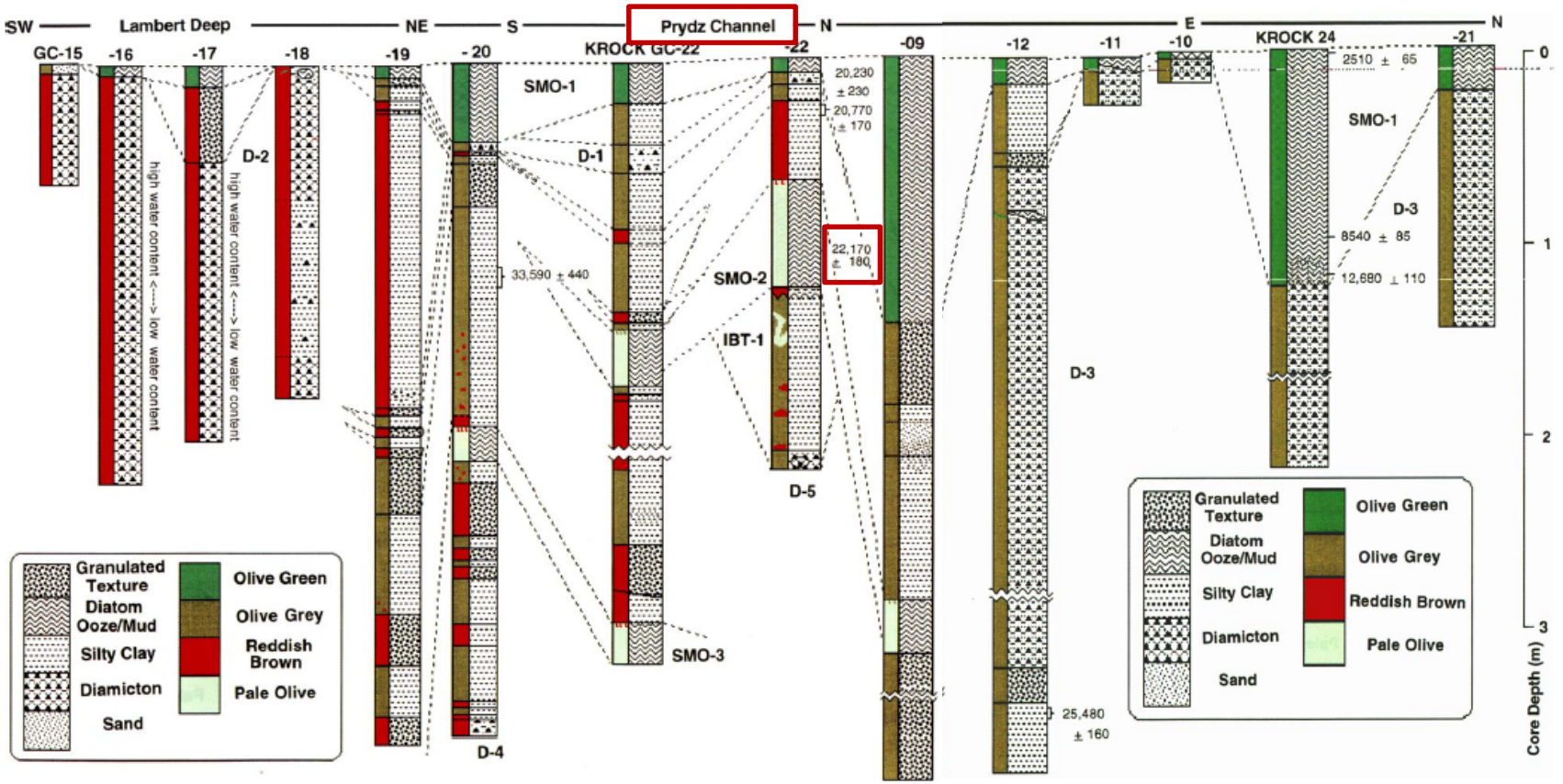


Conclusions

- LGM ice sheet on the western Ross Sea retreated to make a seasonally open marine environment in the Southern Drygalski Trough at ~24ka (corrected ^{14}C), and re-advanced at ~21ka (corrected ^{14}C).
- The latest ice sheet was thinner than the previous ice sheet, so diatomaceous mud ("lower" mud) deposited between the glacial events was preserved in some deeper part of the Southern Drygalski Trogh.
- The timing of retreat of the ice sheet suggests that the retreat might be a response to a warming of Antarctic Isotope Maximum 2 period.


Thank you for
your attention

Diatom ooze beds beneath LGM marine deposits in Prydz Bay (Domack et al., 1998, AS)



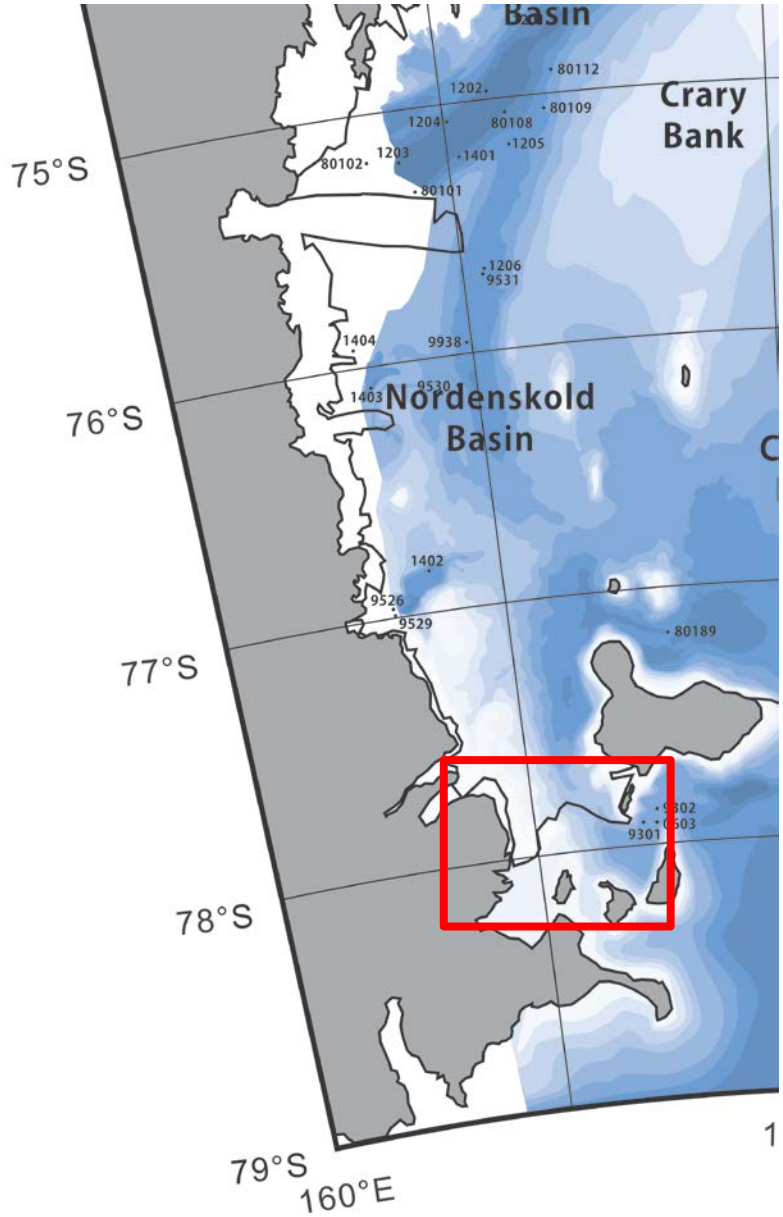
Amundsen Sea Embayment and Amundsen Sea shelf

- The timing of maximum grounded ice extent occurred before ~20.88 cal. ka BP. WAIS retreat from the outer Amundsen Sea shelf was already underway during or even prior to the global LGM (~23-19 cal. ka BP) (Klages et al., 2104, QSR)

- Deglaciation of the western ASE was probably underway as early as 22,351 cal yr BP (Smith et al., 2011, QSR)

- However, in DG12-GC06 case, it's not a simple 'deglaciation-started-earlier' case – we have diamicton 'above' the lower mud, indicating the deglaciation followed by an ice readvance and final deglaciation.

Dates of shells in debris bands on the McMurdo Ice Shelf (Kellogg et al., 1990, ARS)



- Bimodal population
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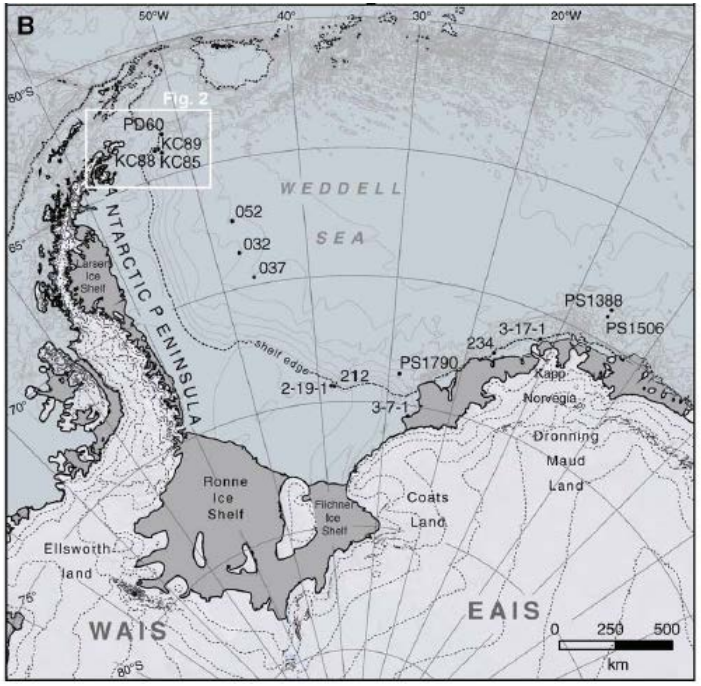
→ "Grounded ice filled southern McMurdo Sound between 20,000 and 7750 yrs BP."

- > 20,000 yrs BP samples
  : 45.5, 35.4, 30.9, 22.1, 20.8 kyr BP

* uncorrected 14C ages

The presence of polynyas in the Weddell Sea during the Last Glacial Period (Smith et al., 2010, EPSL)



- Foraminifera (N. pachyderma) ^{14}C dating
- ages spanning
  - the Last Glacial Maximum (LGM) and Marine Isotope Stage (MIS) 2 (20,319–28,543 cal yr BP) and the middle part of MIS 3 (41,349–43,242 cal yr BP),

"we argue that previously published data from the southern, southeastern and southwestern Weddell Sea as well as the Ross Sea may indicate the widespread occurrence of polynyas along the Antarctic continental margin during the Last Glacial Period."