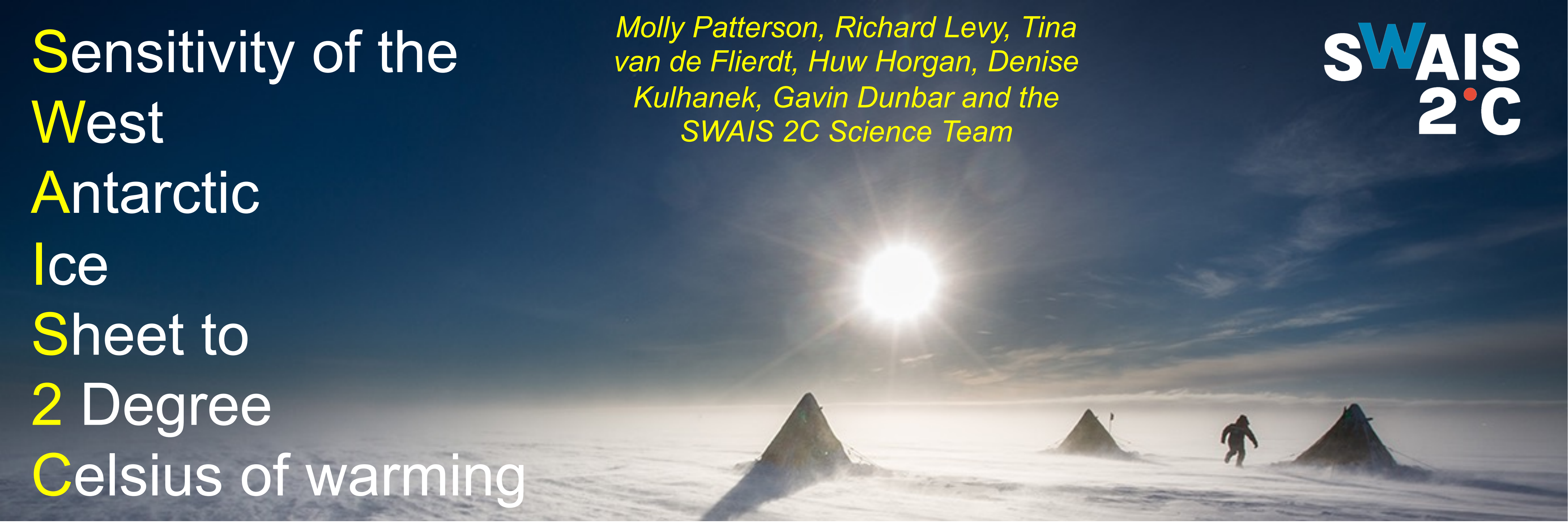


Sensitivity of the West Antarctic Ice Sheet to 2 Degree Celsius of warming

Molly Patterson, Richard Levy, Tina van de Flierdt, Huw Horgan, Denise Kulhanek, Gavin Dunbar and the SWAIS 2C Science Team

SWAIS 2°C

CSIC

BGR

AWI

IACT
INSTITUTO ANDALUZ DE CIENCIAS DE LA TIERRA

NSF

NERC
SCIENCE OF THE ENVIRONMENT

INGV

AuScope

Antarctic Science Platform

KOPRI 극지연구소

NIOZ Royal Netherlands Institute for Sea Research

Antarctica New Zealand

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

NiPR
National Institute of Polar Research

PROGRAMMA NAZIONALE DI RICERCHE IN ANTARTIDE

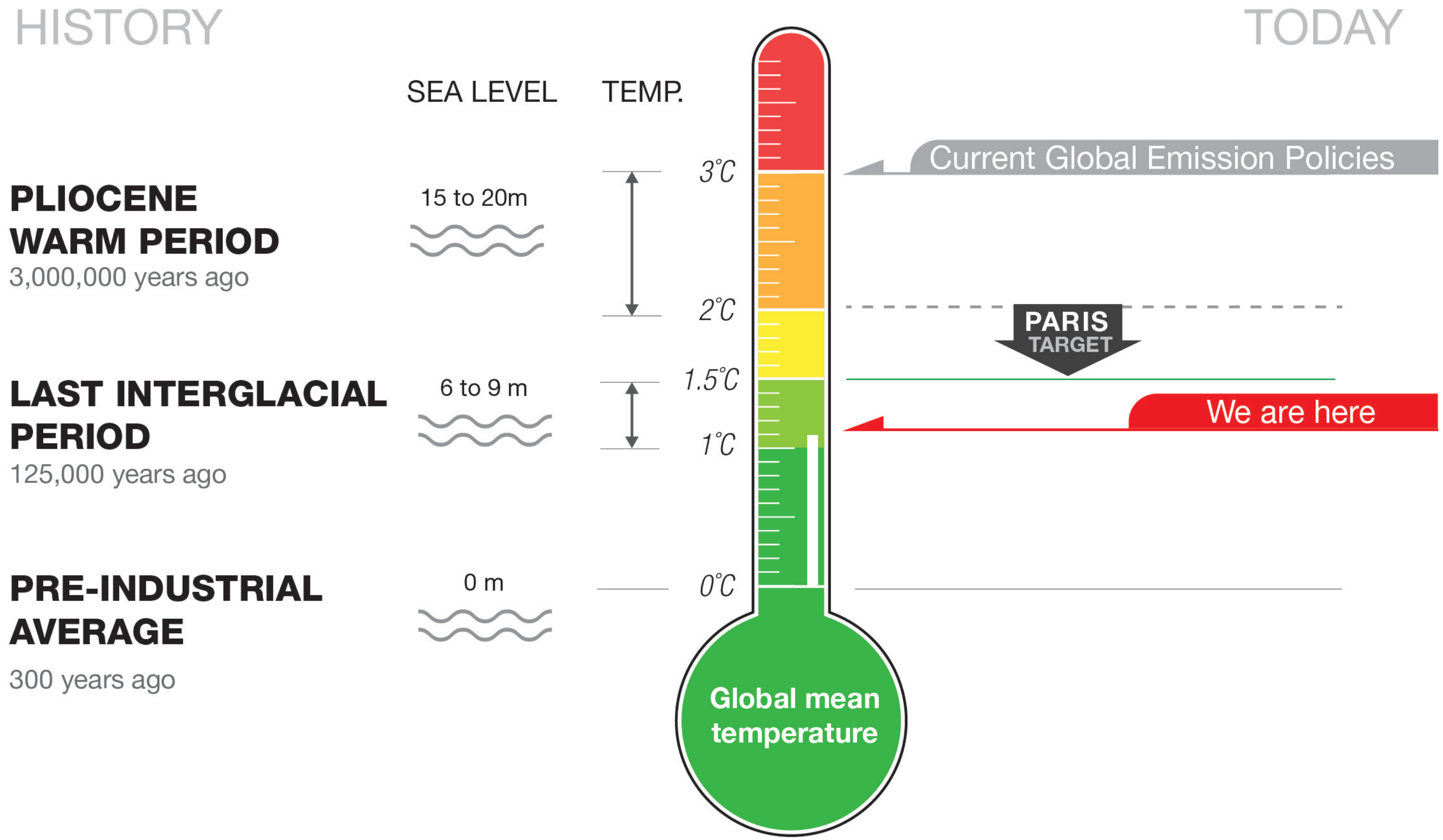
icdp INTERNATIONAL CONTINENTAL SCIENTIFIC DRILLING PROGRAM

SWAIS2C

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

(a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

https://climateactiontracker.org/



Paleoenvironmental data
Modeling studies
Modern processes studies

Climate dynamics and solid Earth processes in driving ice sheet stability resulting in sea level change

How will West Antarctica respond to a 2°C increase in global mean annual temperature?

nature
International weekly journal of science
1978

West Antarctic ice sheet and CO_2 greenhouse effect: a threat of disaster

J. H. Mercer

Institute of Polar Studies, The Ohio State University, Columbus, Ohio 43210

Fig. 3 *a*, Antarctic ice cover today, and *b*, after a 5–10 °C warming.

West Antarctic ice sheet's vulnerability to climatic warming

that are cold at sea level. They conclude that a climatic warming above a critical level would remove all ice shelves and, consequently, all ice grounded below sea level, resulting in the deglaciation of most of West Antarctica.

Previous destruction of the West Antarctic ice sheet

Considerable evidence from the Southern Hemisphere suggests that the warmest part of the last interglacial (Sangamon–Eem) was warmer than the present interglacial has been so far; for instance, subantarctic seas were then warmer than they have been since (J. D. Hays, personal communication), and in Southern Chile chemical weathering was unusually intense[40]. This warm interval—substage 5e, according to the sequence established by Emiliani[41]—was centred 120–125,000 yr ago[42]. If the West Antarctic ice sheet was absent at that time, the hypothesis that a rather moderate rise in temperature would destroy it would be strengthened.

What happened to Antarctica's MIS the last time temps were 1.5 to 2°C above PI temperature?

SWAIS2C

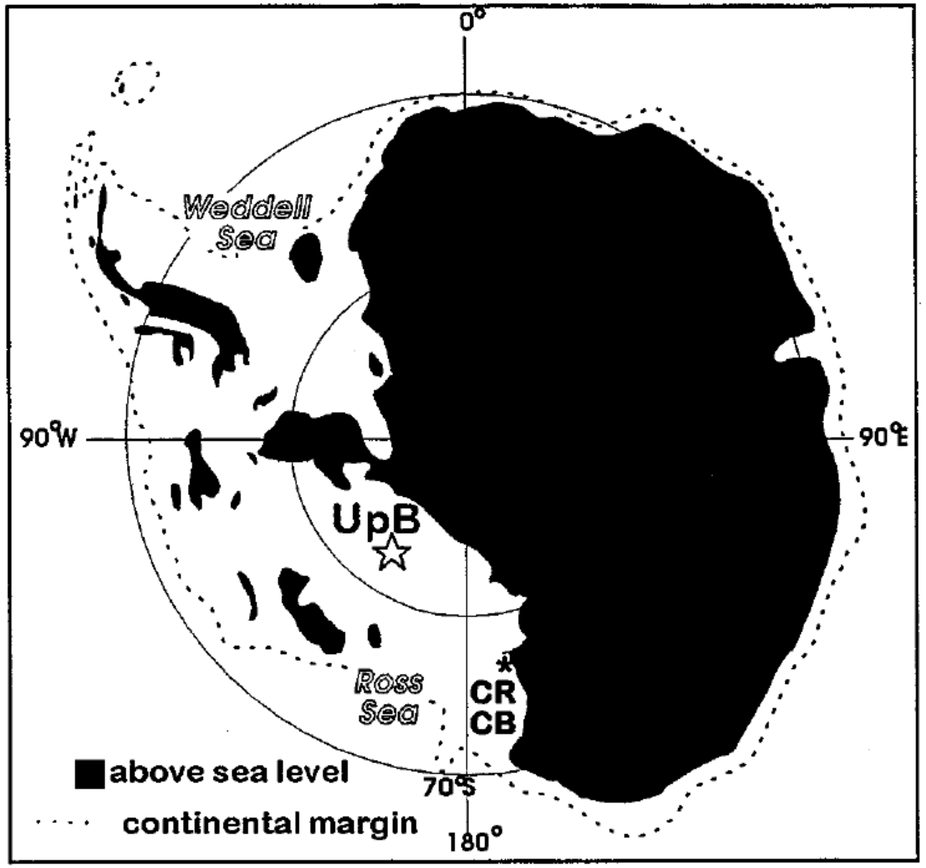
Pleistocene Collapse of the West Antarctic Ice Sheet

Reed P. Scherer,* Ala Aldahan, Slawek Tulaczyk, Göran Possnert, Hermann Engelhardt, Barclay Kamb

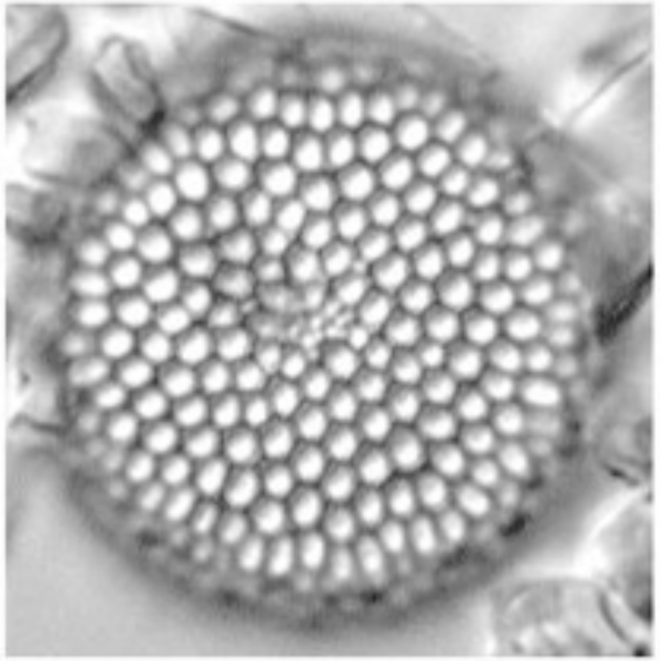
Science
1998 AAAS

Reed Scherer

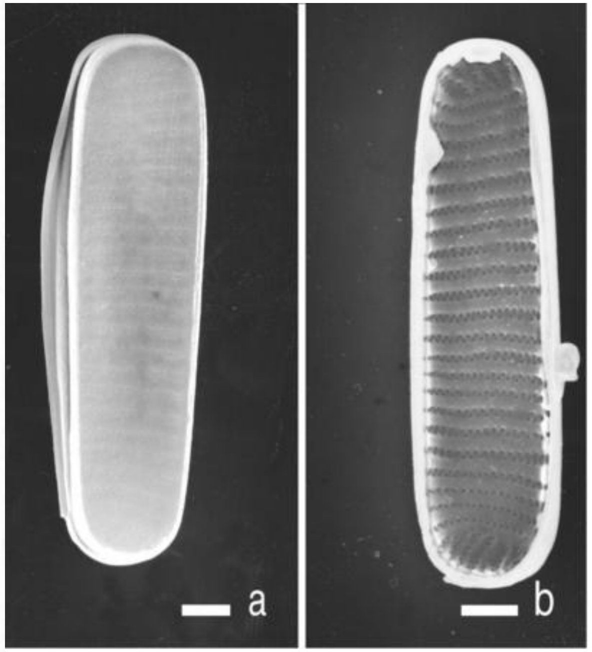
Slawek Tulaczyk



Late Quaternary marine algae in subglacial sediments



Thalassiosira antarctica

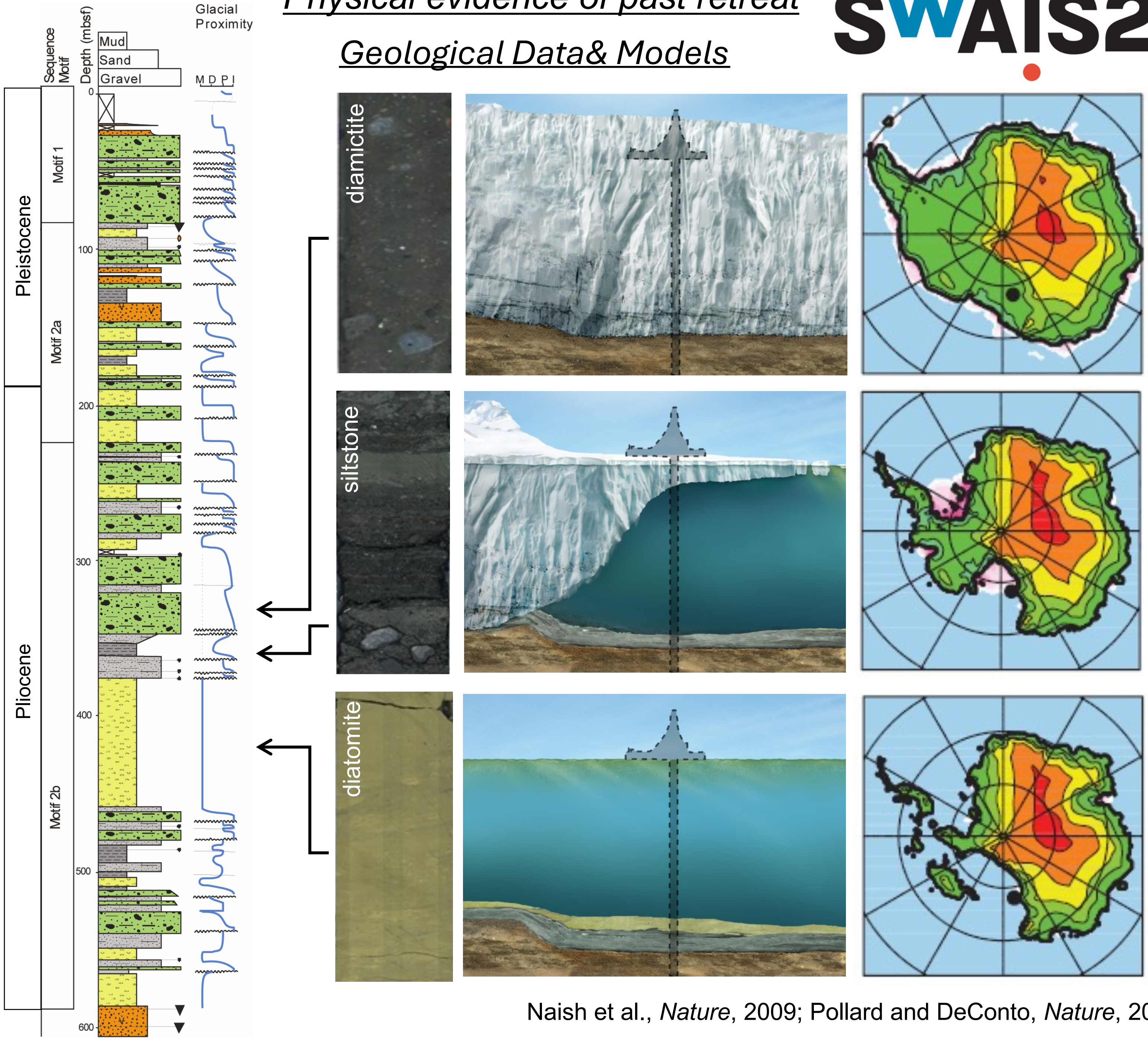


Fragilariopsis curta

- Late Pleistocene: Diamictite dominated, evidence for ice shelves
- MIS 31: First ‘thick’ diatomite (open marine conditions)
- Early Pliocene: CO_2 was last ~400 ppm:
- Average global surface temps were 2-3 °C > Pre-industrial temperature
- WAIS retreated/disintegrated?

Physical evidence of past retreat

Geological Data& Models

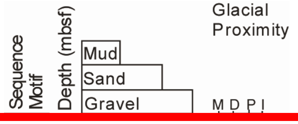


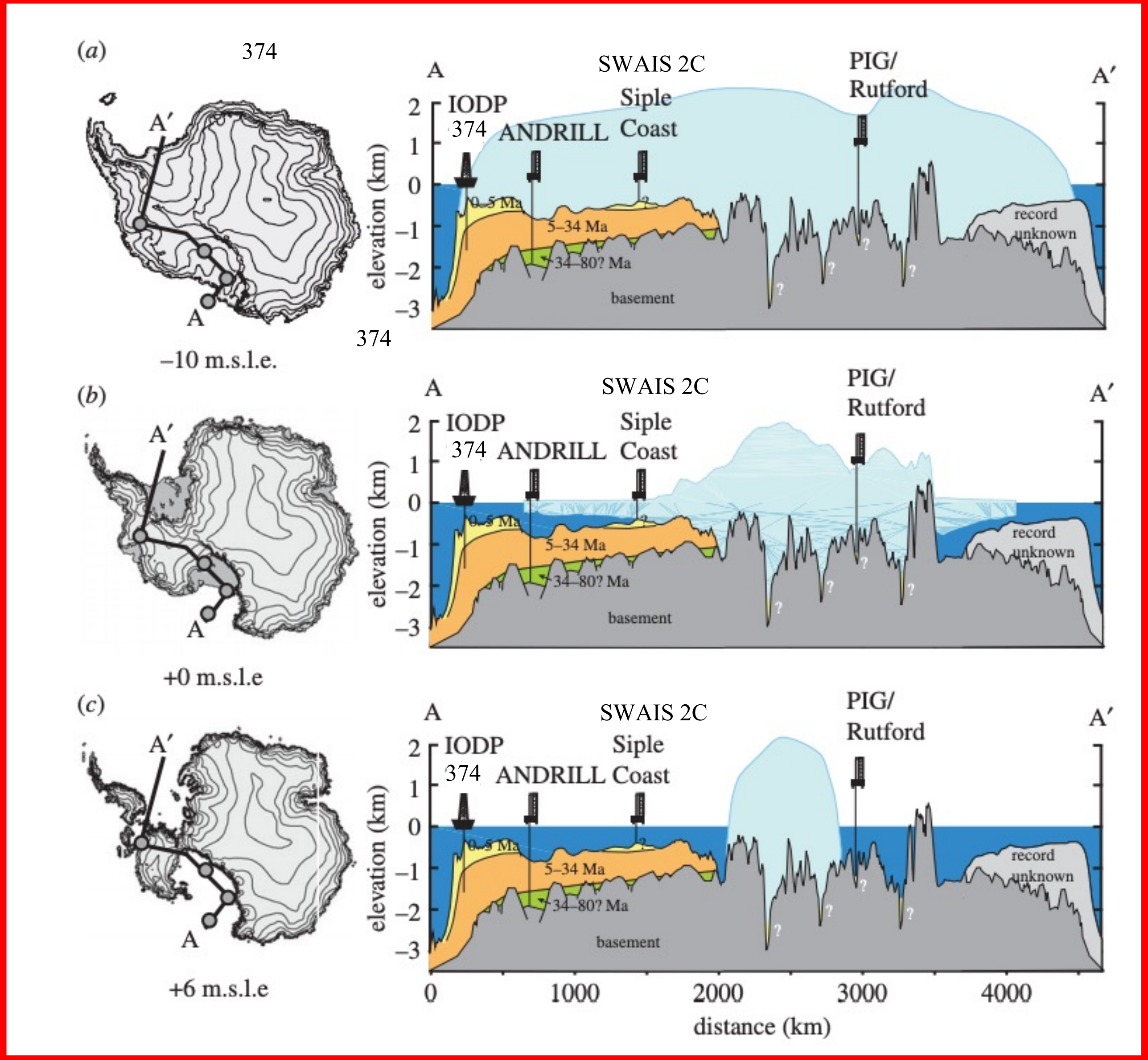
Naish et al., *Nature*, 2009; Pollard and DeConto, *Nature*, 2009

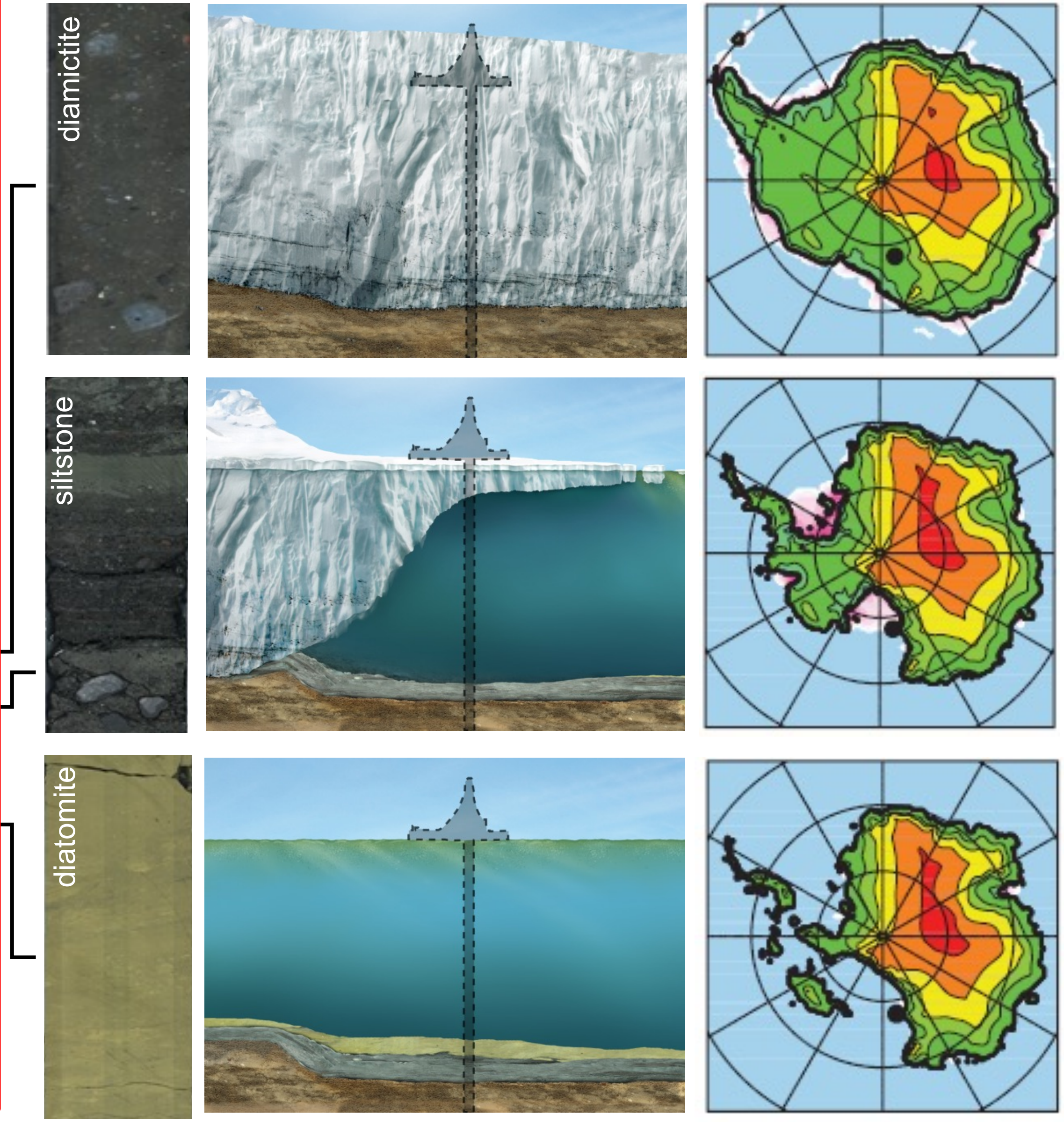
Physical evidence of past retreat

Geological Data& Models

SWAIS2C

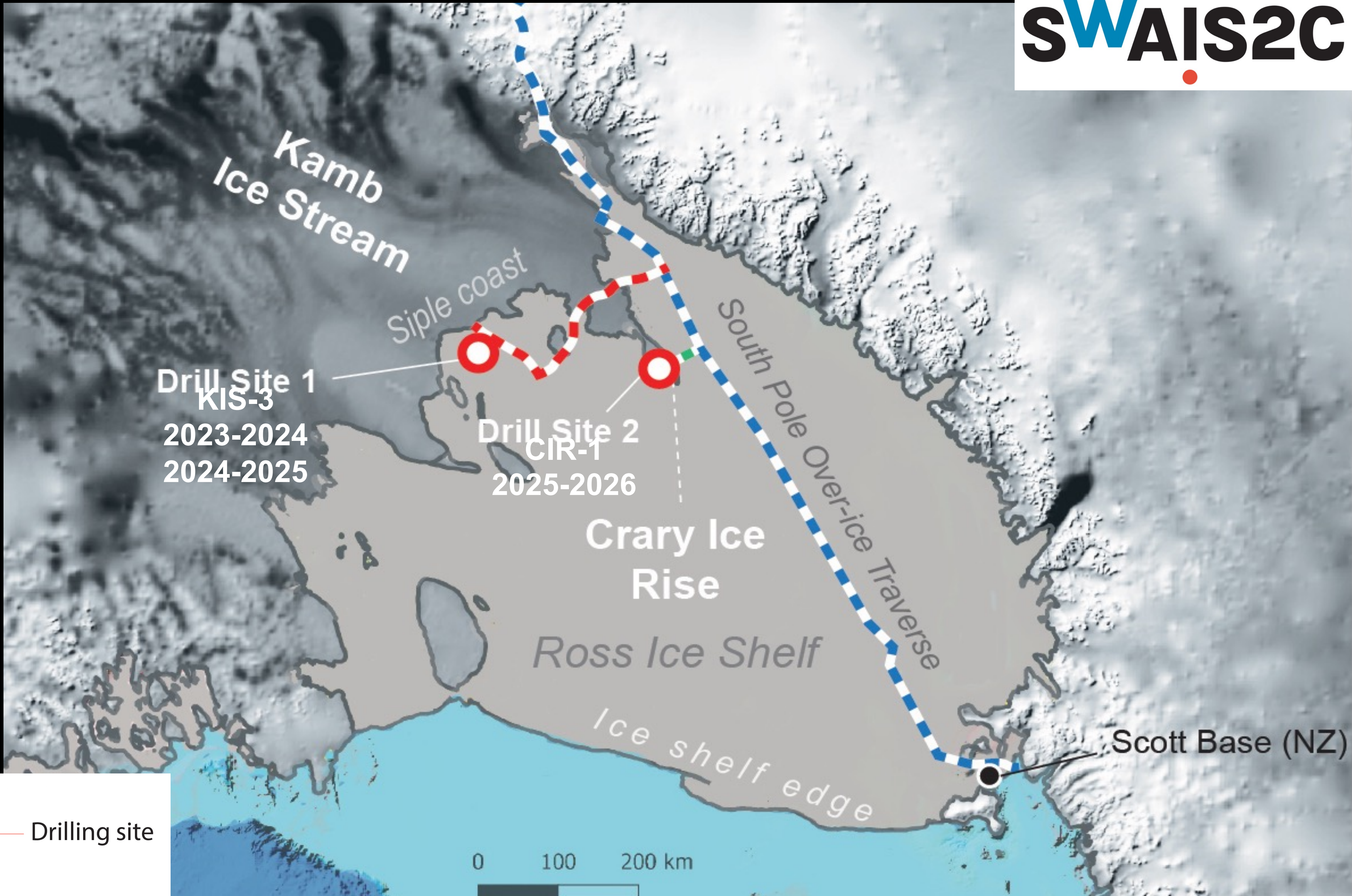




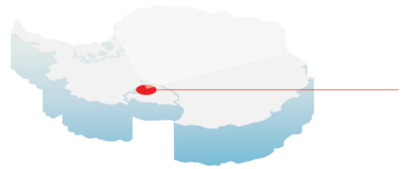


- WAIS retreated/disintegrated?

Naish et al., *Nature*, 2009; Pollard and DeConto, *Nature*, 2009



Kamb Ice Stream
Siple coast
Drill Site 1
KIS-3
2023-2024
2024-2025
Drill Site 2
CIR-1
2025-2026
Crary Ice Rise
South Pole Over-ice Traverse
Ross Ice Shelf
Ice shelf edge
Scott Base (NZ)
0
100
200 km



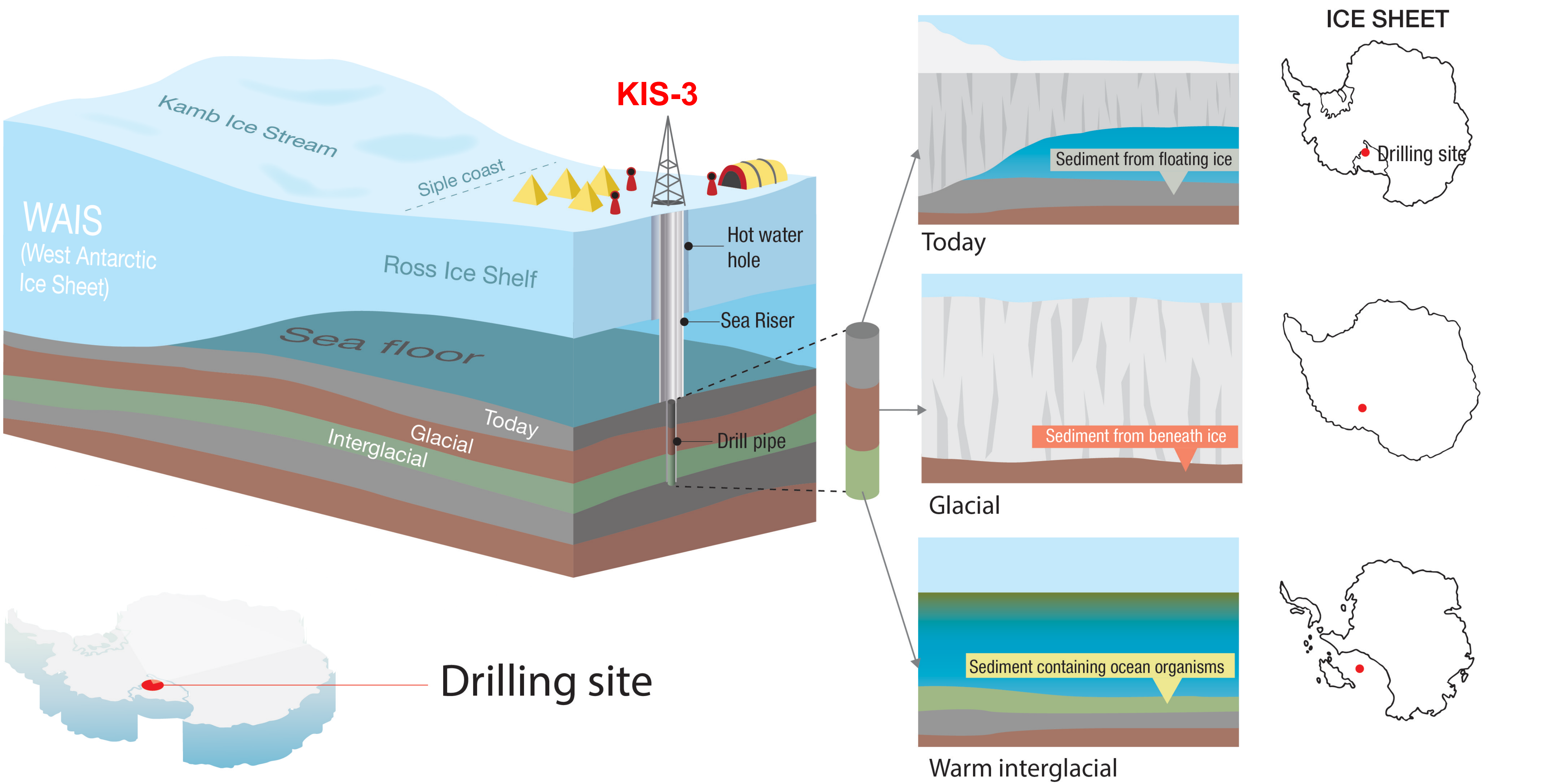
Drilling site

New Technology for remote settings that is easily transportable

Developed by the Science Drilling Office at VUW Antarctic Research Centre New Zealand

SWAIS2C

Antarctica Intermediate Depth Drilling (AIDD) System



SWAIS2C

Hotwater Drilling

Melt a hole through the Ross Ice Shelf (VUW)

Based on British Antarctic Survey designs

Used successfully for 3 seasons prior to KIS3 for ice up to 590 m thick and 350 mm in diameter

Personnel = 5

Melt rate 0.2-0,5 m/hr (6 burners)

Reaming in 600 m ice takes 10 hours

Reaming 5 hours every 24 to maintain 350 mm

AIDD

Inspired by the US ASIG System

ANDRILL ~300-350 tonnes of equipment and fuel

HW/AIDD ~90 tonnes equipment and fuel

1200 m (ice & water)

200 m into the seafloor

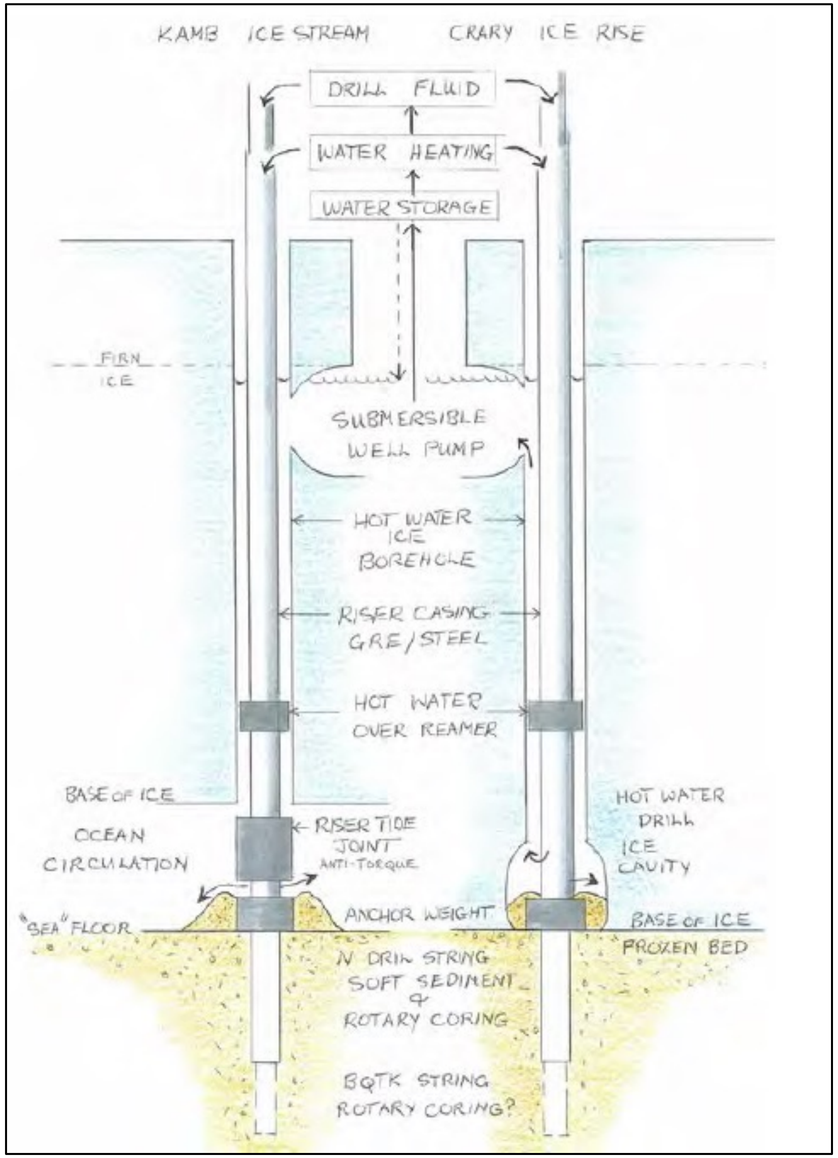
Rock drillers = 4 (24hr ops)

Darcy Mandeno

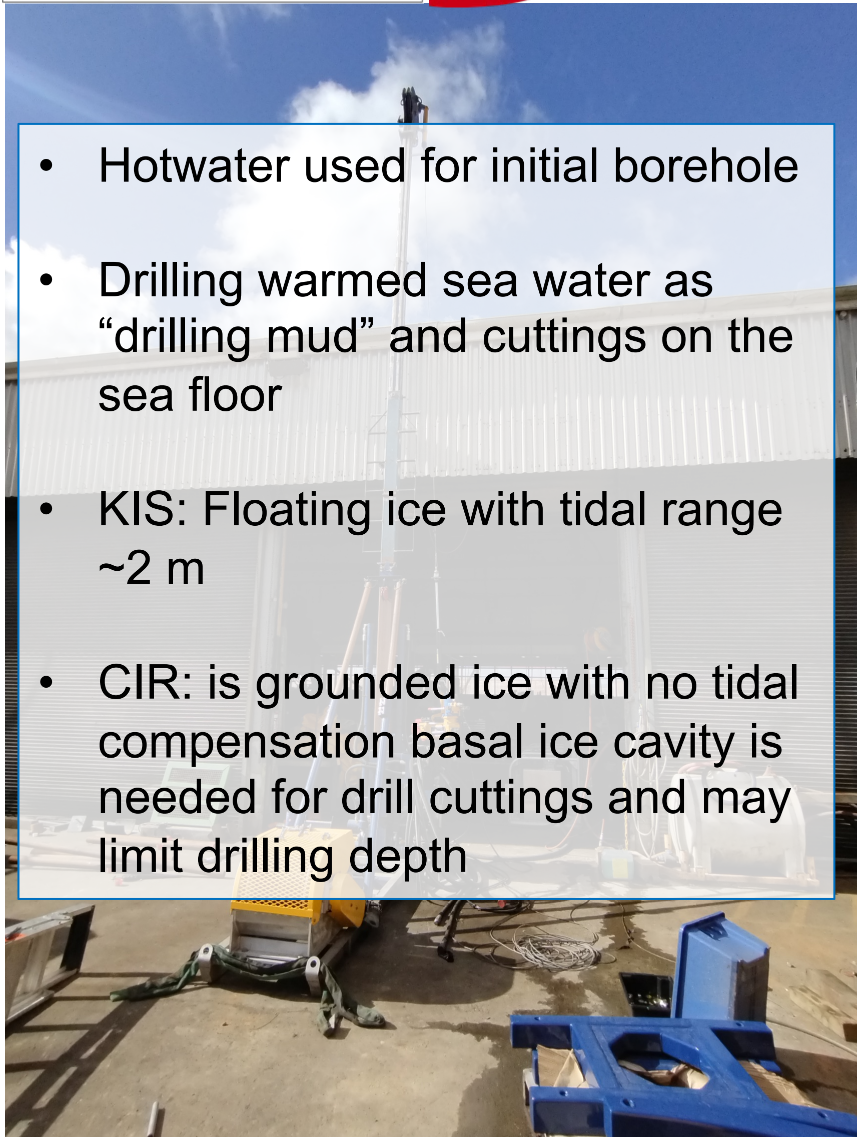
Alex Pyne

James MacPhail

Adam Rutten



- The combined rig, drill pipe and casing package weighs ~30tonnes, making it feasible to deploy within the constraints of existing Antarctic science support programs.
- small logistical footprint (including limited personnel onsite)



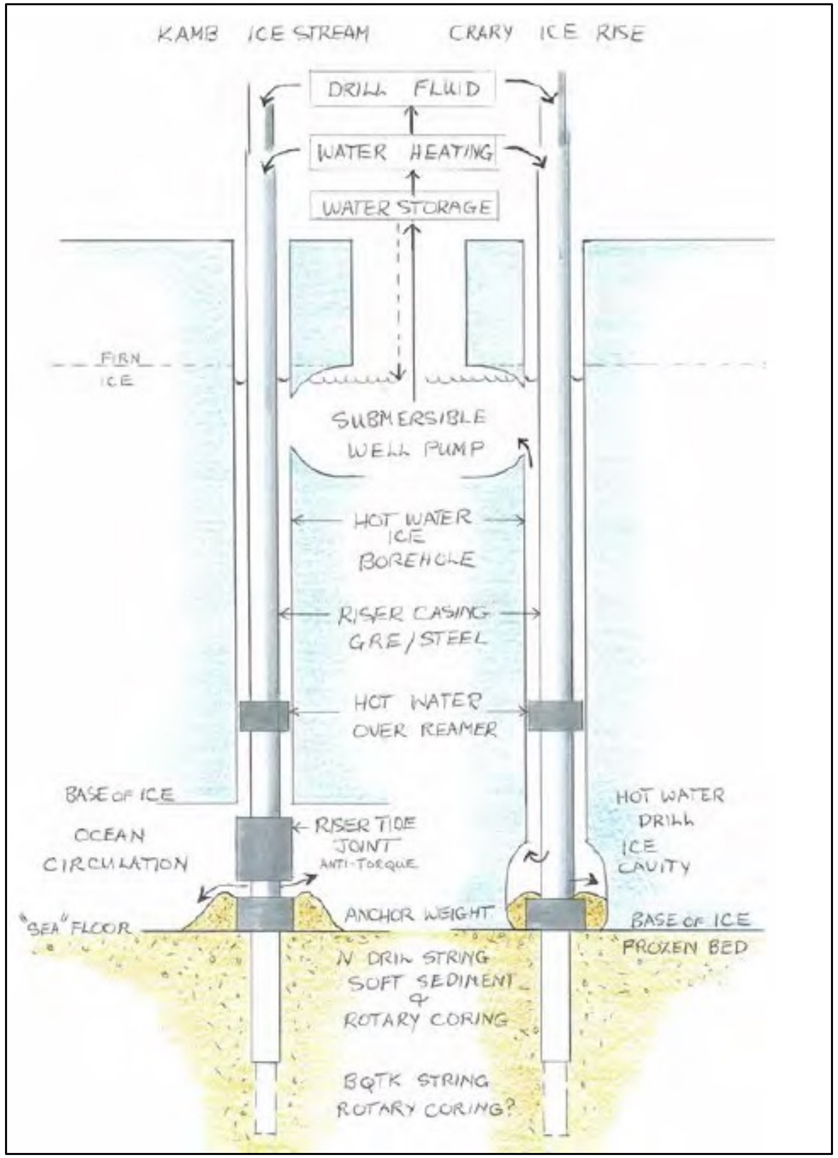
- Hotwater used for initial borehole
- Drilling warmed sea water as “drilling mud” and cuttings on the sea floor
- KIS: Floating ice with tidal range ~2 m
- CIR: is grounded ice with no tidal compensation basal ice cavity is needed for drill cuttings and may limit drilling depth

Darcy Mandeno

Alex Pyne

James MacPhail

Adam Rutten



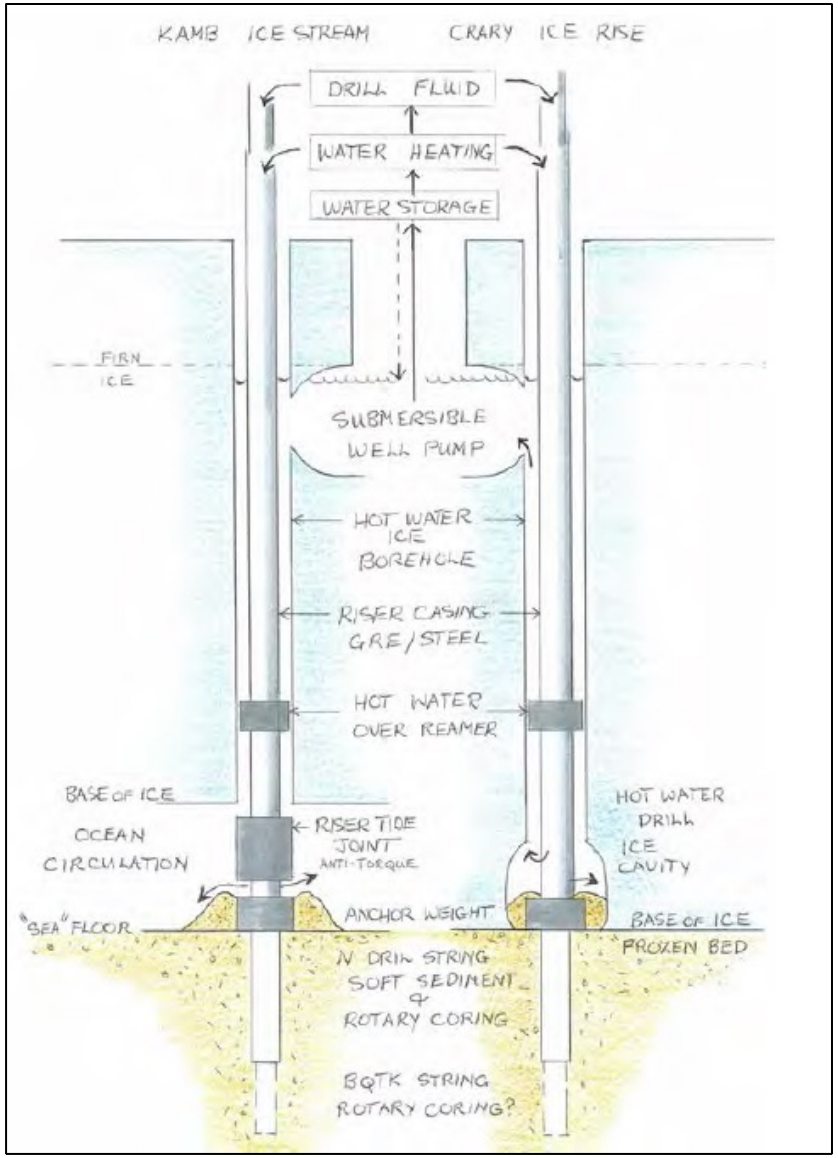
- Soft sediment tooling has been specifically designed for the small N size drill string
- Hydraulic Piston Corer (HPC) (1.5 m)
- Extended Bit ('punch corer')
- Full Hole Bit (clean the bottom of the bore hole of cutting and clasts)
- NQTK rotary coring (3 m)
- 46-51 mm diameter core (IODP is 60 mm)
- ICDP memory tools for logging

Darcy Mandeno

Alex Pyne

James MacPhail

Adam Rutten

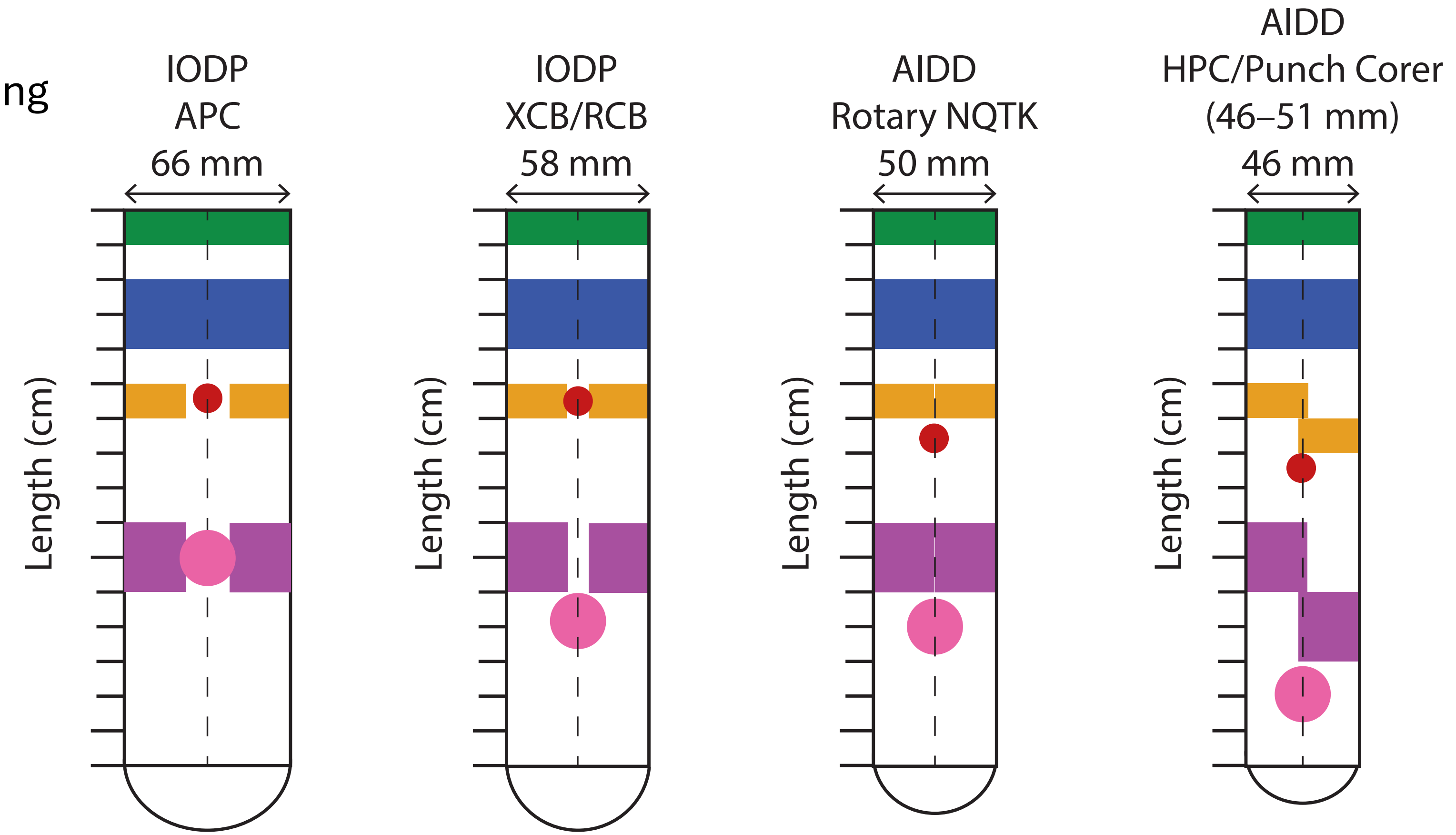


Core Diameter and Sample Sizes

SWAIS 2C core diameter is significantly smaller than IODP core diameter or standard piston coring core diameter!

A typical IODP "10 cc" sample taken from a 2 cm interval of the working half uses:

- APC = less than 1/3 of the core diameter
- XCB/RCB = just over 1/3 of the core diameter
- AIDD = 1/2 (or a little more) of the core diameter



Core recovery with a small diameter RCB will likely be quite low (15–20%)

		IODP - APC	IODP - XCB/RCB	AIDD	AIDD
		66 mm	58 mm	50 mm	46 mm
Quarter round	1 cm	9 cc	7 cc	5 cc	4 cc
Half round	1 cm	18 cc	13 cc	10 cc	8 cc
Quarter round	2 cm	18 cc	13 cc	10 cc	8 cc
Half round	2 cm	36 cc	27 cc	20 cc	16 cc

Science Drivers and Research Aims

SWAIS2C

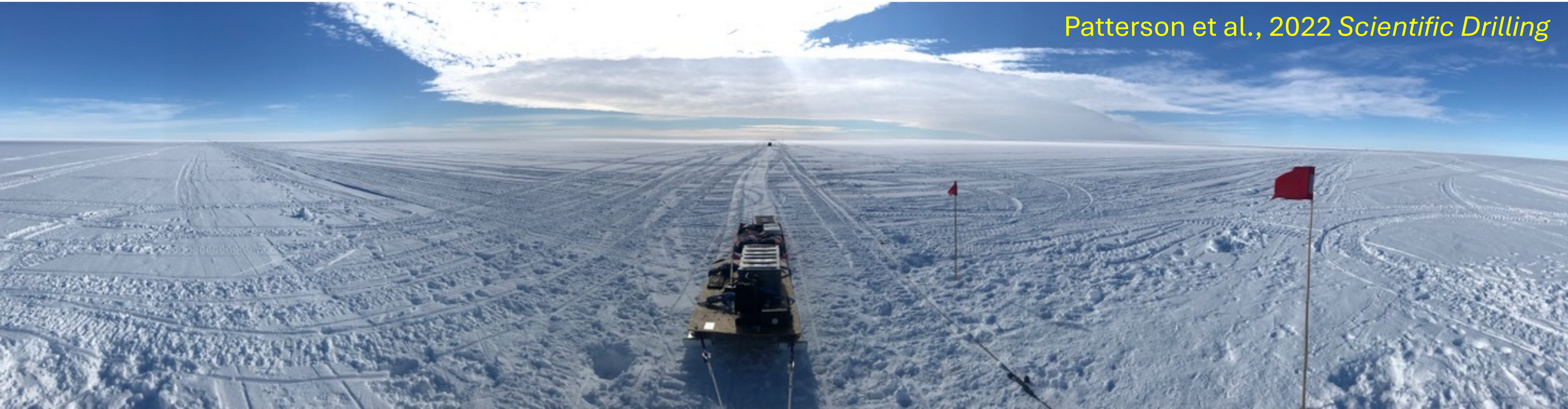
Research Aim 1: Holocene Ice Dynamics

Research Aim 2: Quaternary WAIS Dynamics + contribution to sea level (1.5 to 2°C)

Research Aim 3: Climate Thresholds and WAIS instability through the Pliocene (2 to 3°C)

Research Aim 4: Late Oligocene – Miocene variability and the role of tectonics and carbon cycle feedbacks (3 to 4°C)

Research Aim 5: Determine the taxonomy and activity of both living and inactive microbial populations in sediments to provide insights to modern element cycling and past environmental conditions



Patterson et al., 2022 *Scientific Drilling*

Holocene: Ice-sheet/solid-Earth interactions influenced ice dynamics along the Siple Coast on a multi-millennial timescale during the Holocene

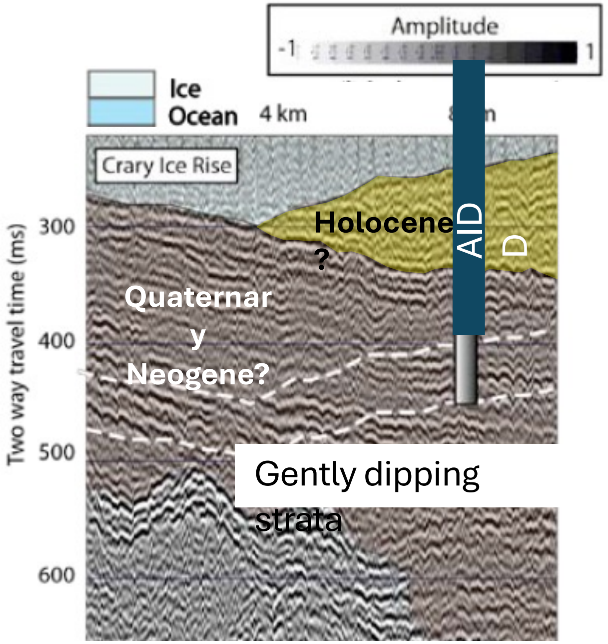
SWAIS2C

Early to mid Holocene retreat at Mercer and Whillans ice streams

?

Grounding of CIR ~1100 years ago

*Explore Holocene grounding line dynamics
*Assess timing of grounding line re-advance
*Grounding before 1100 years ago?



Courtesy of J. Paul Winberry (first-order interp.)

Key Questions:

(1) Does the geothermal heat flux beneath KIS and CIR support isostatic rebound influenced grounding line re-advance during the Holocene?

(2) Is CIR a previous (Holocene) grounding zone wedge made up of remnant Neogene marine sediments, remobilized from upstream Whillans Ice Stream?

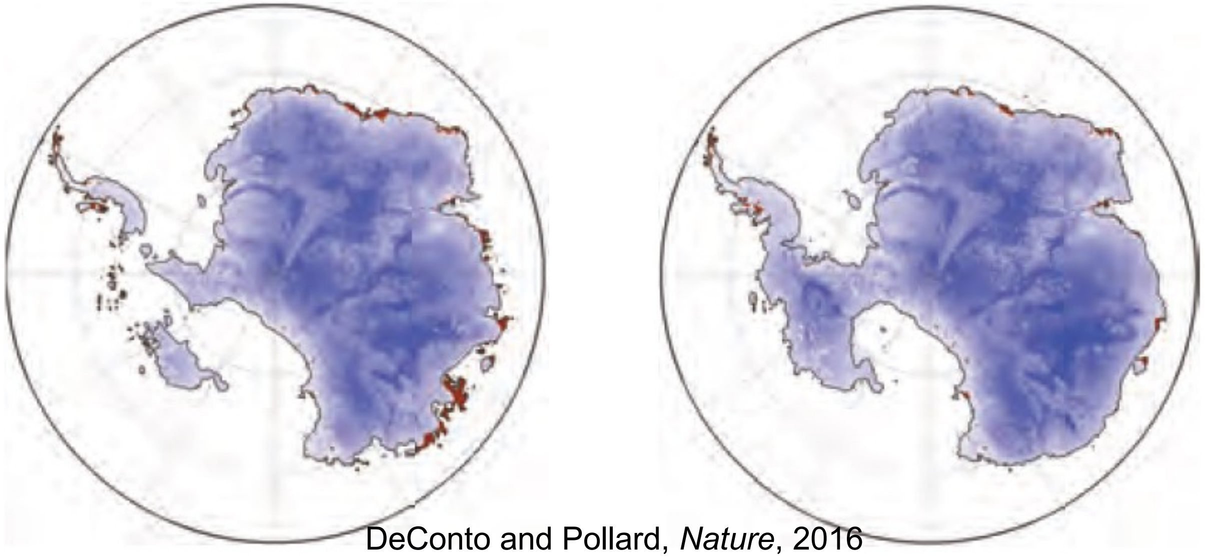
(3) Do the physical and geochemical constituents in CIR sediments provide evidence of repeated grounding and ungrounding events during the Holocene and were they driven by climatological and/or glaciological processes?

Antarctica vs. Greenland: WAIS melted during the LIG – or did it?

SWAIS2C

Model-based hypotheses to be tested

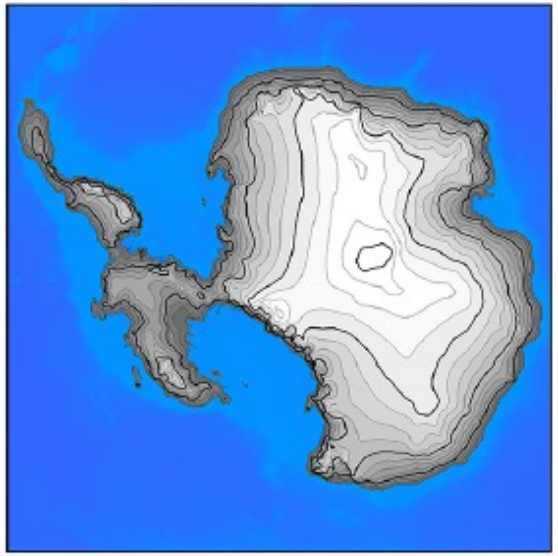
+7.5 (0) m s.l.e.



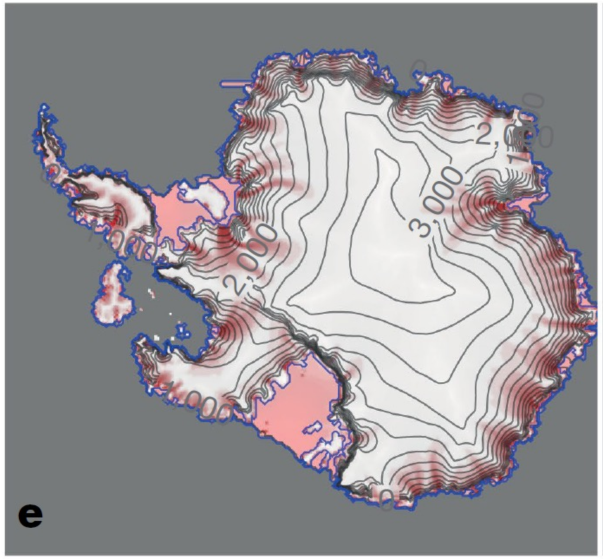
+1 (6.5) m s.l.e.

DeConto and Pollard, *Nature*, 2016

+4.4 (3) m s.l.e.



Goelzer et al., *Climate of the Past*, 2016

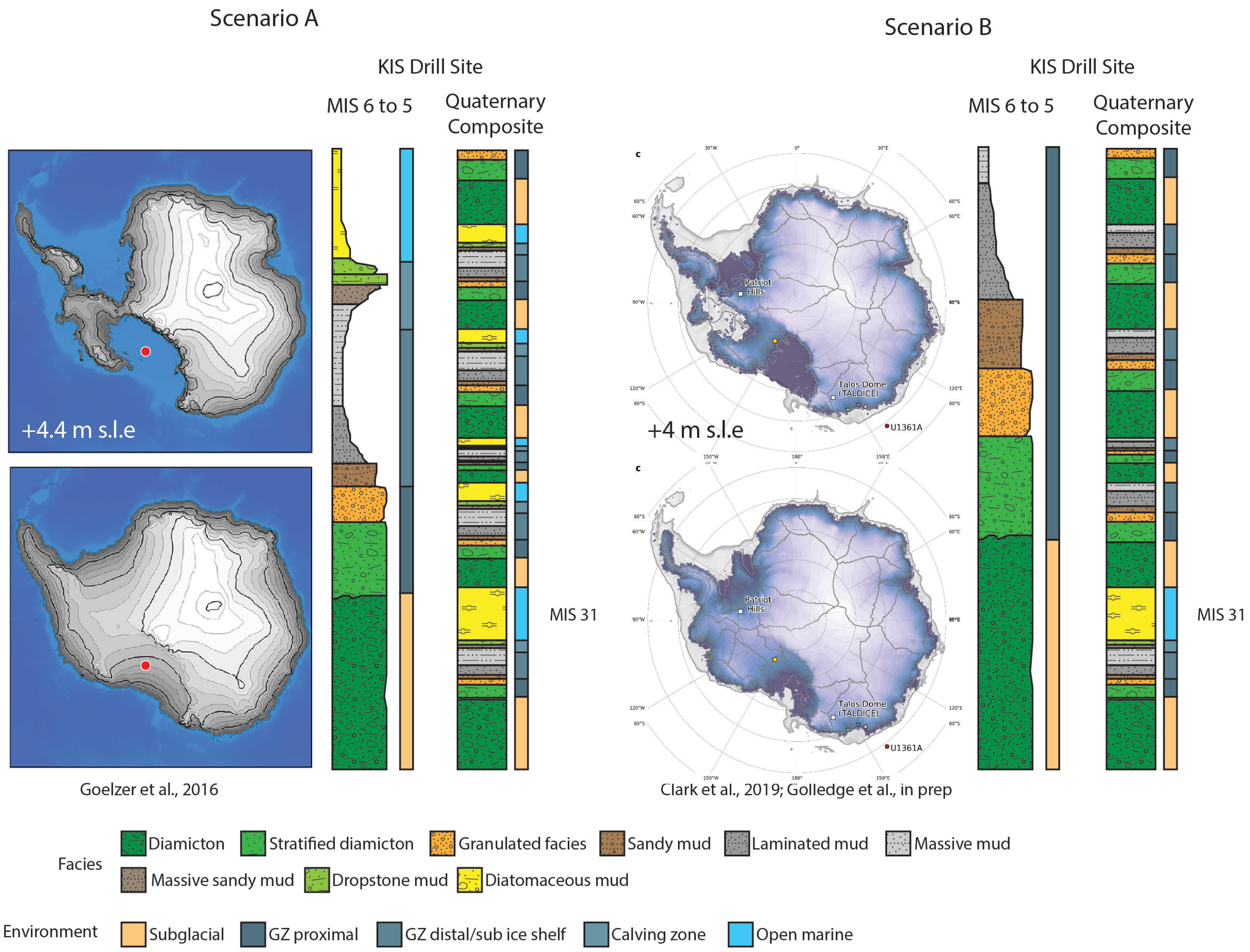


Clark et al., *Nature*, 2019

+3 (4.5) m s.l.e.

Antarctica vs. Greenland: WAIS melted during the LIG – or did it?

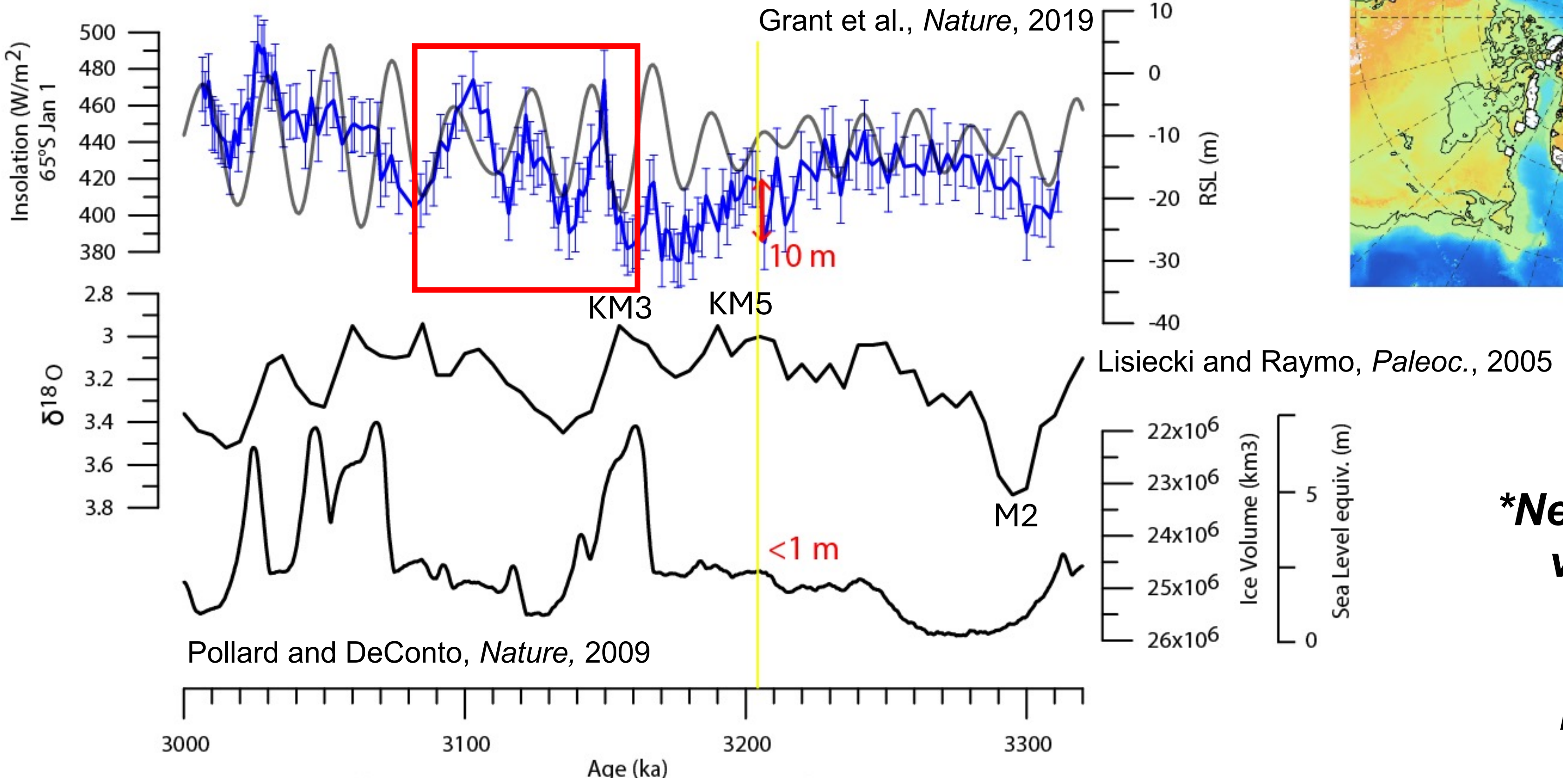
Model-based hypotheses to be tested

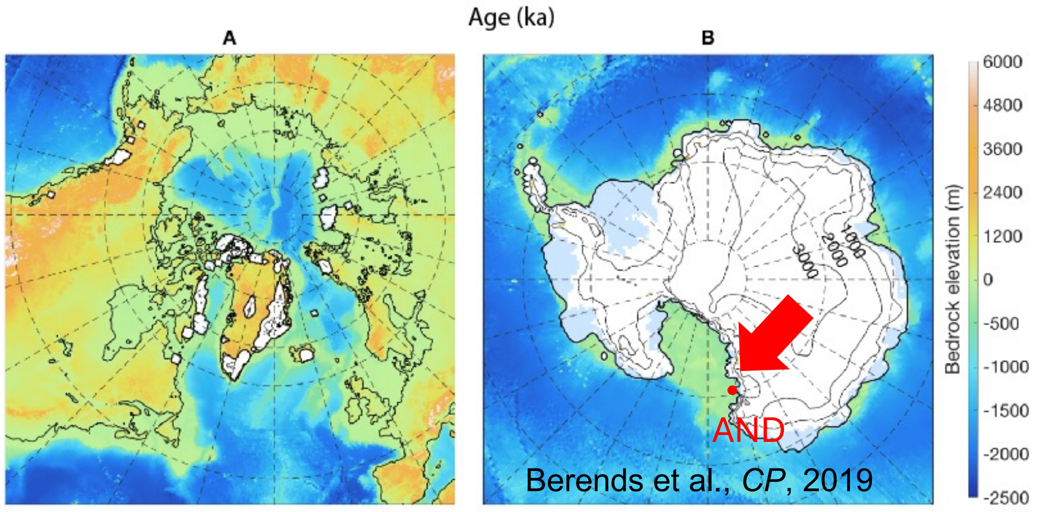


Pliocene Ice Sheet Variability

Reconciling Far Field - Near Field Records - Models

Pliocene
2 to 3 C warmer than PI





***Need direct records of Ice Sheet variability from 'inner' WAIS**

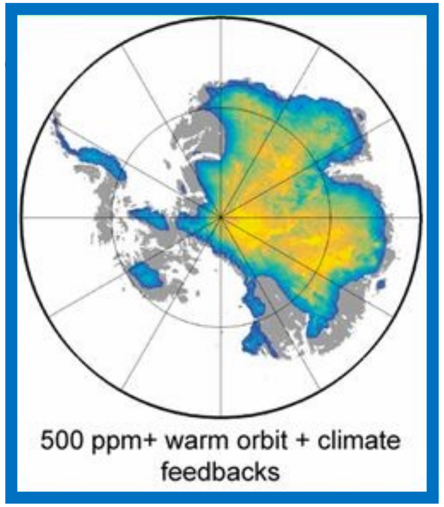
***Magnitude of variability? Drivers of I/G cycles (P/O)?**

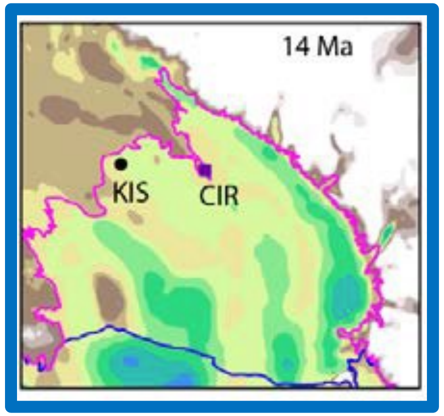
Miocene Ice Sheet Variability

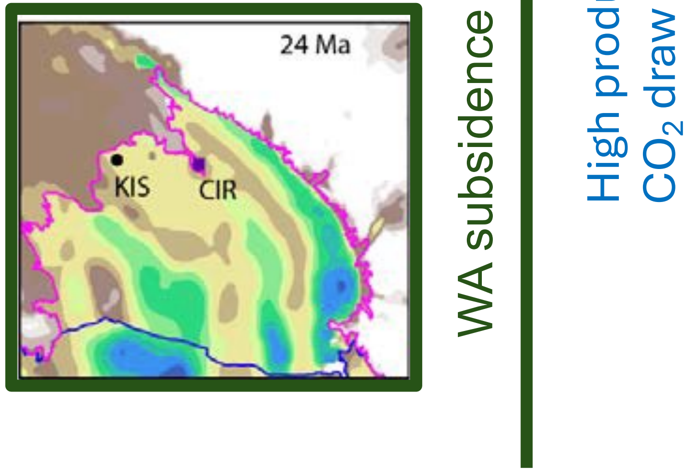
Tectonics & carbon cycle feedbacks - Models

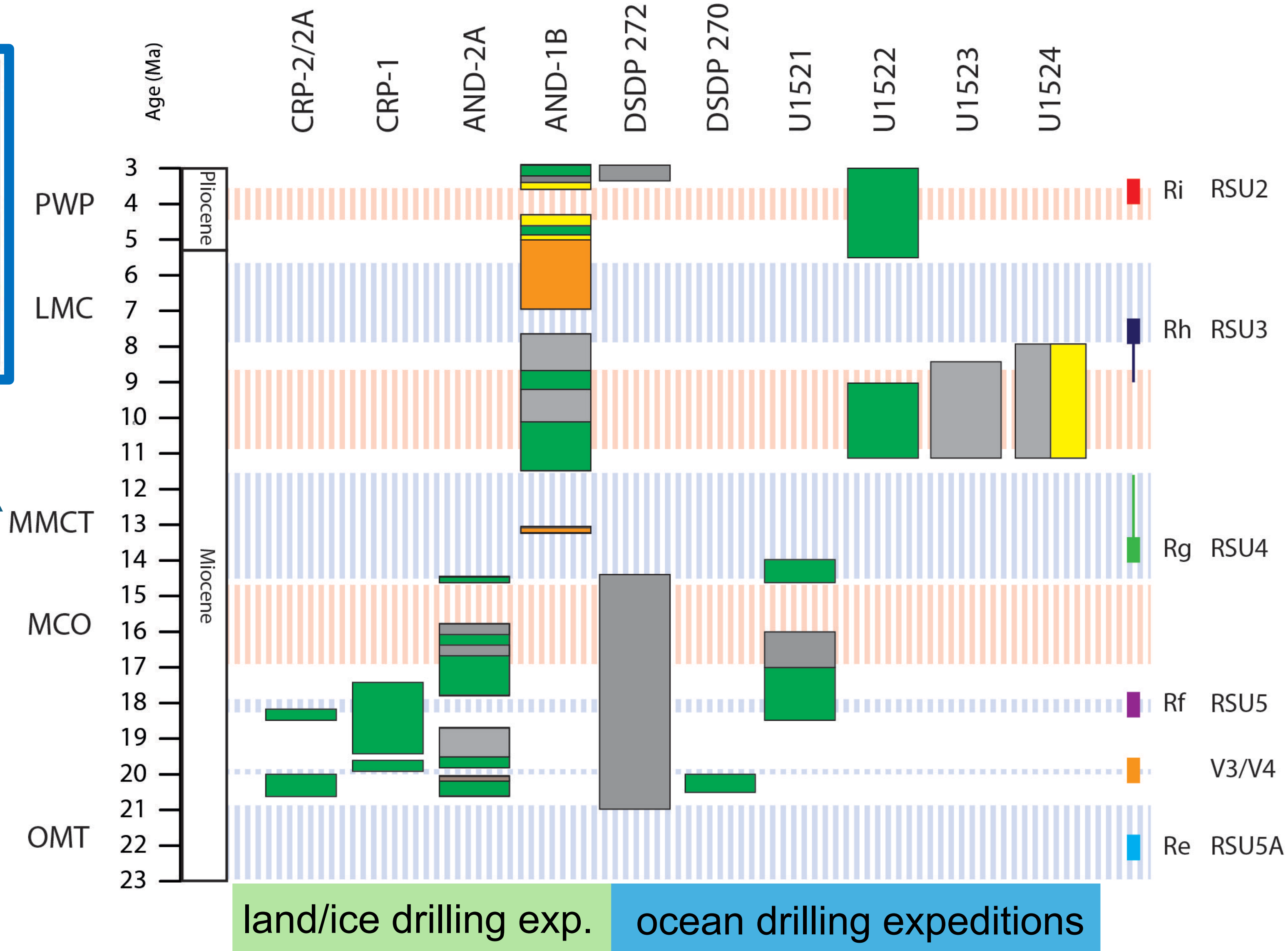
ANDRILL-2A
+
ice sheet model

MMCO Scenario ~16 Ma









Microbiology: Determine the taxonomy and activity of both living and inactive microbial populations in sediments to provide insights to modern element cycling and past environmental conditions

SWAIS2C

Key Questions

1. *Which organisms characterize the microbial communities and the structure of microbial food webs in the extreme subglacial and sub ice-shelf environments,*
2. *What is the functional potential for microorganisms in these environments, which metabolic pathways do they encode, and how do they contribute to major and trace element cycling and carbon burial?*
3. *How do microbial communities respond to varying environmental conditions (e.g., temperature) and inputs in organic matter (i.e., open vs. ice-covered conditions, discharge from subglacial lakes) over time?*
4. *What do inactive members of subsurface communities likes cysts, spores, other inactive cells, as well as extracellular DNA tell us about past environmental conditions?*

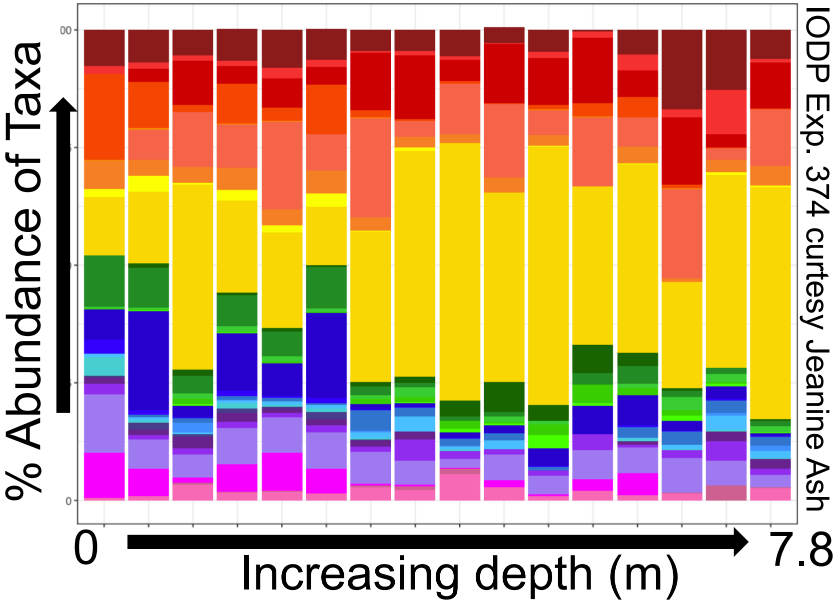
Building on the success of previous micrbio. studies in the Ross Sea

Carr et al., 2013

Christner et al., 2014
Vick-Major et al., 2020

Ash et al., 2019

Hawkings et al., 2020
Priscu et al., 2021



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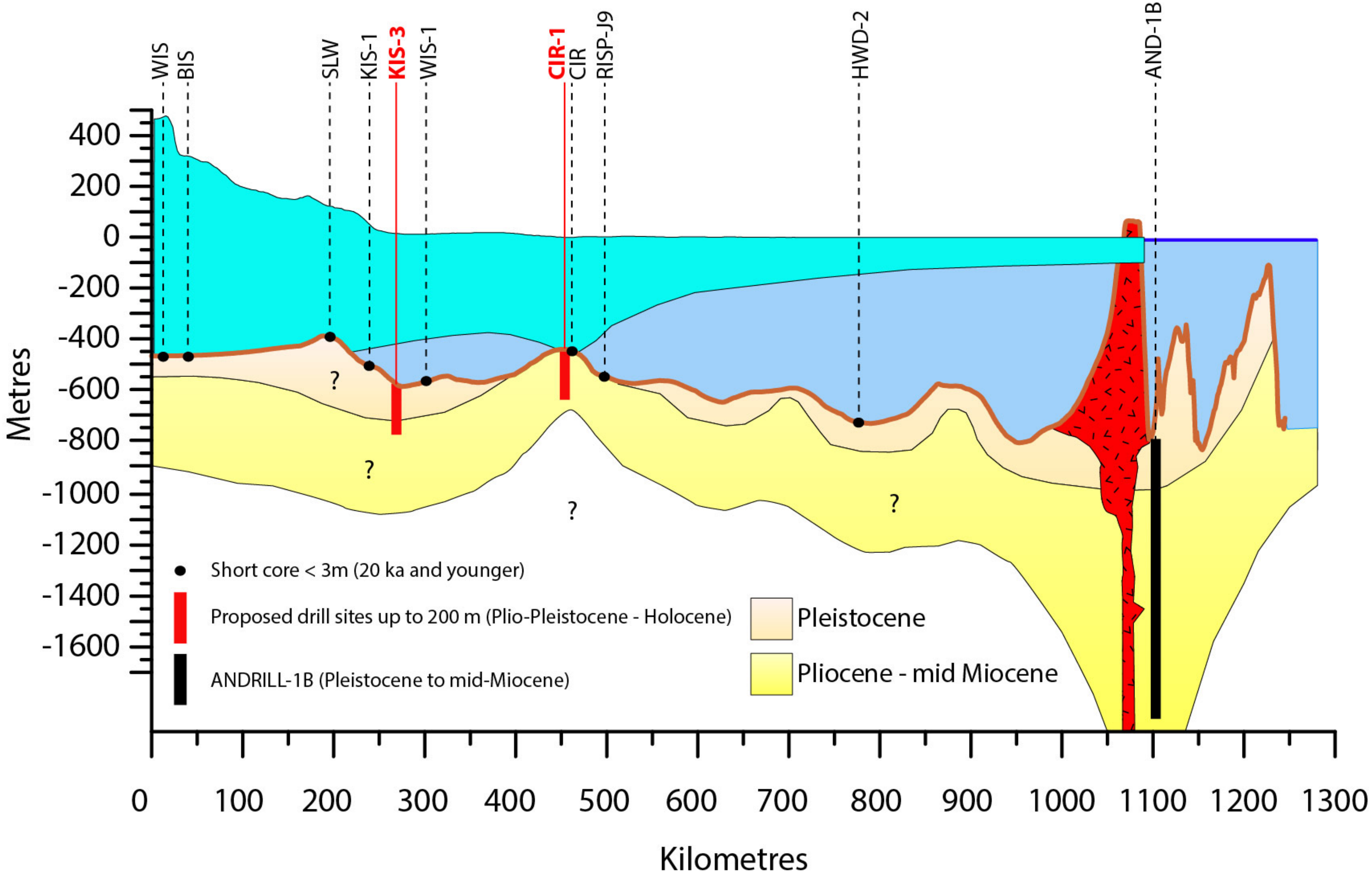
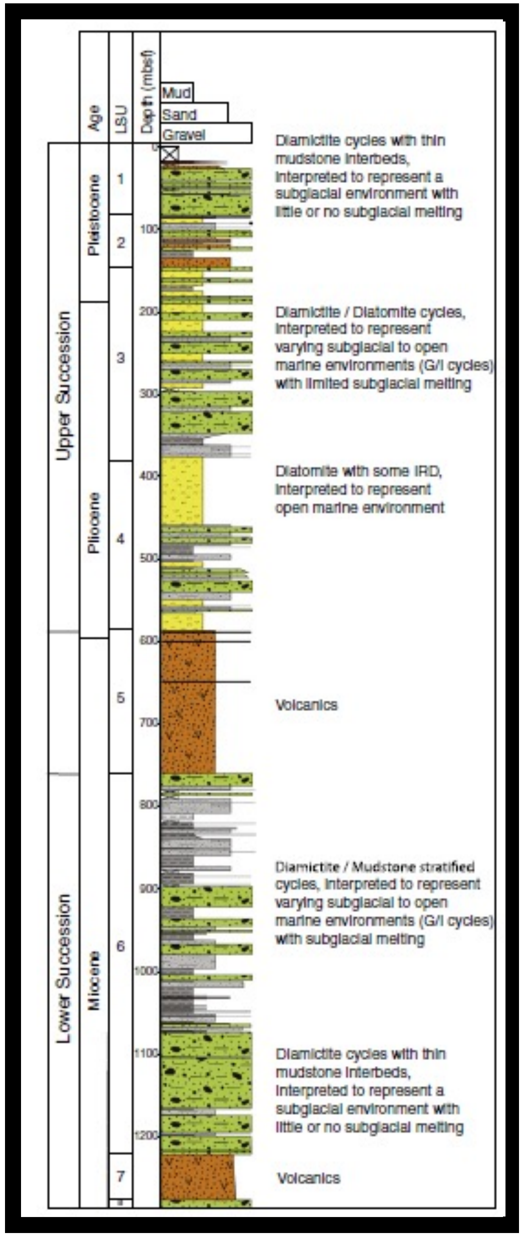
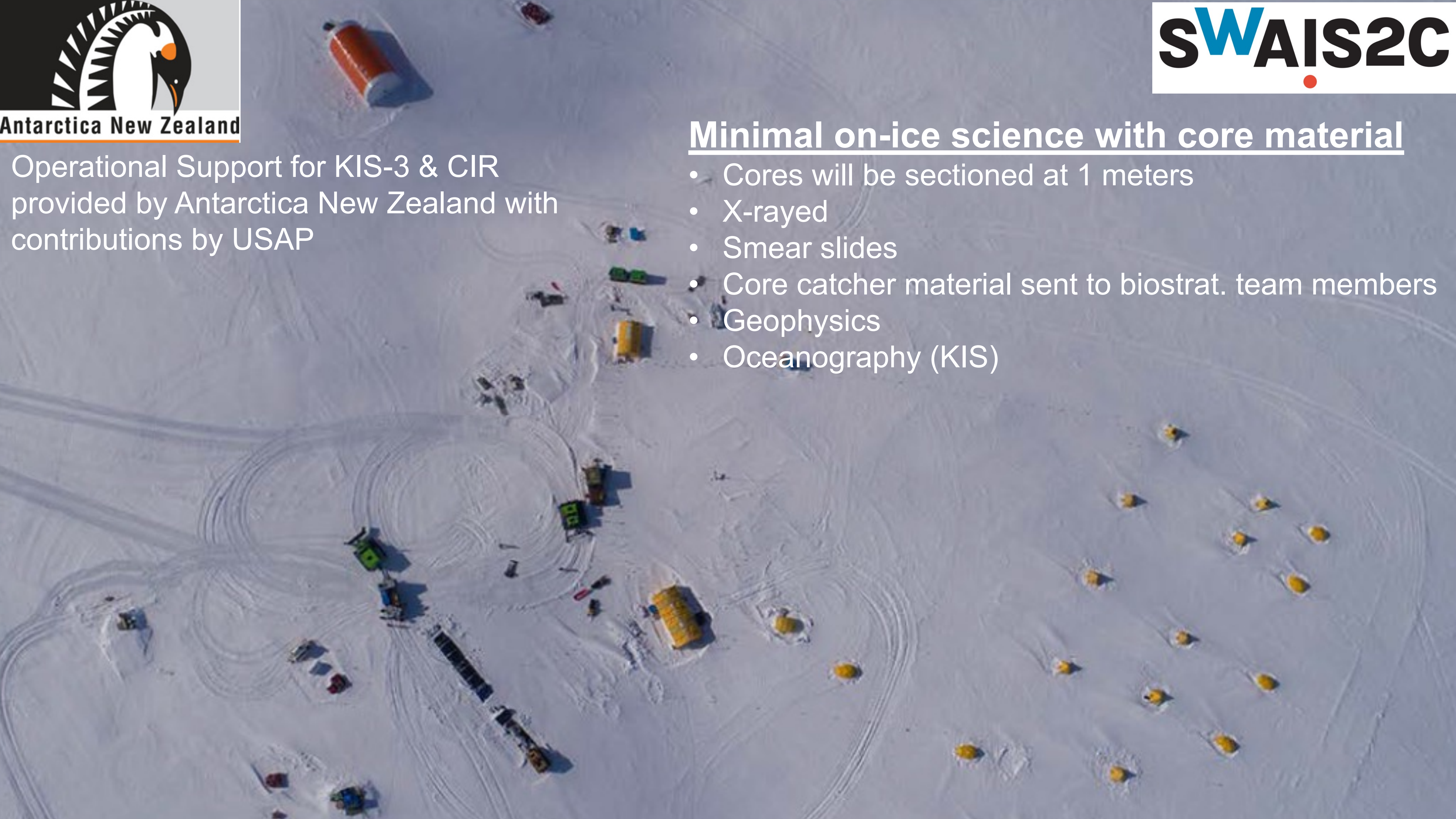
Regional Stratigraphy



AND-1B





Antarctica New Zealand

SWAIS2C

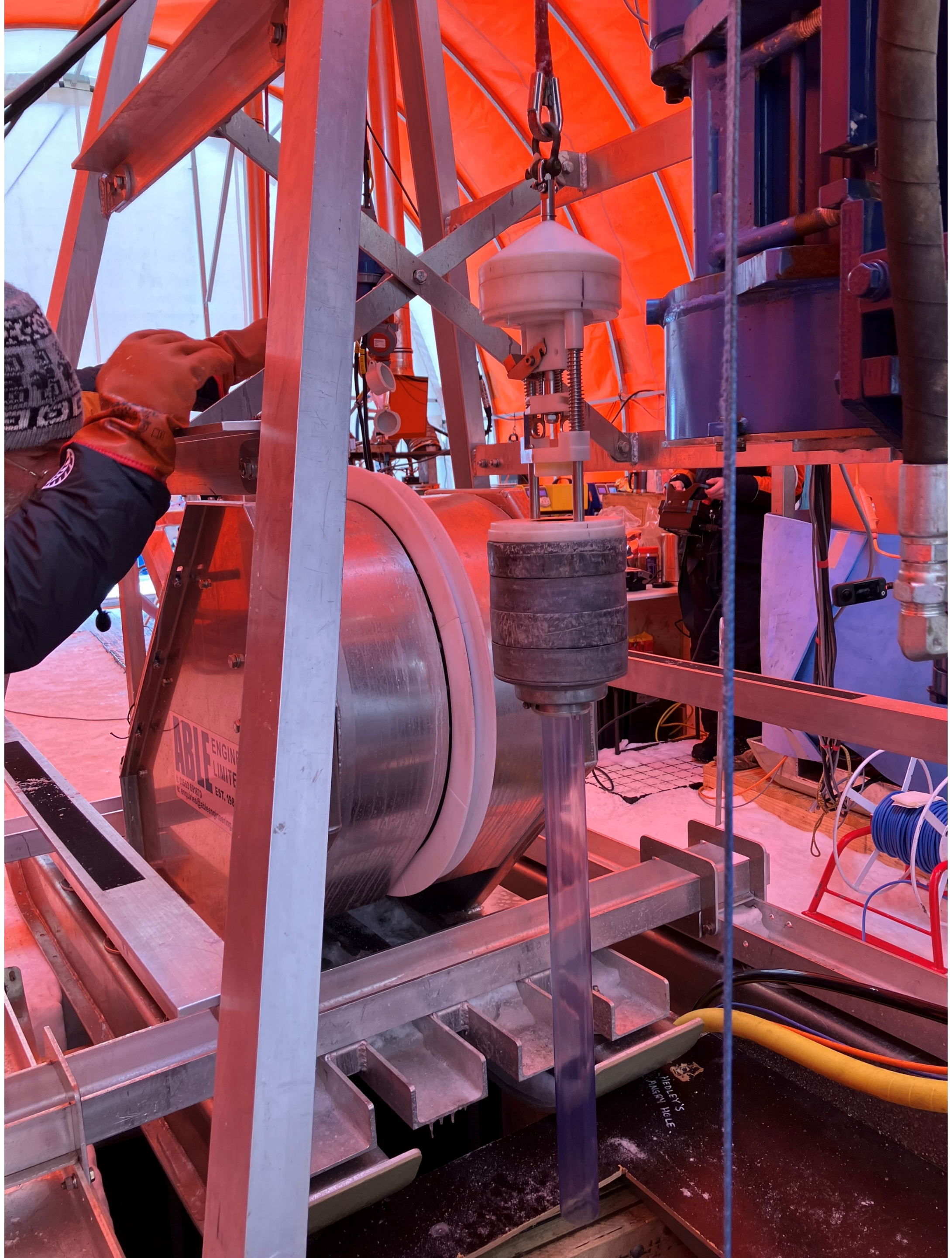
Operational Support for KIS-3 & CIR provided by Antarctica New Zealand with contributions by USAP

Minimal on-ice science with core material

- Cores will be sectioned at 1 meters
- X-rayed
- Smear slides
- Core catcher material sent to biostrat. team members
- Geophysics
- Oceanography (KIS)

SWAIS2C

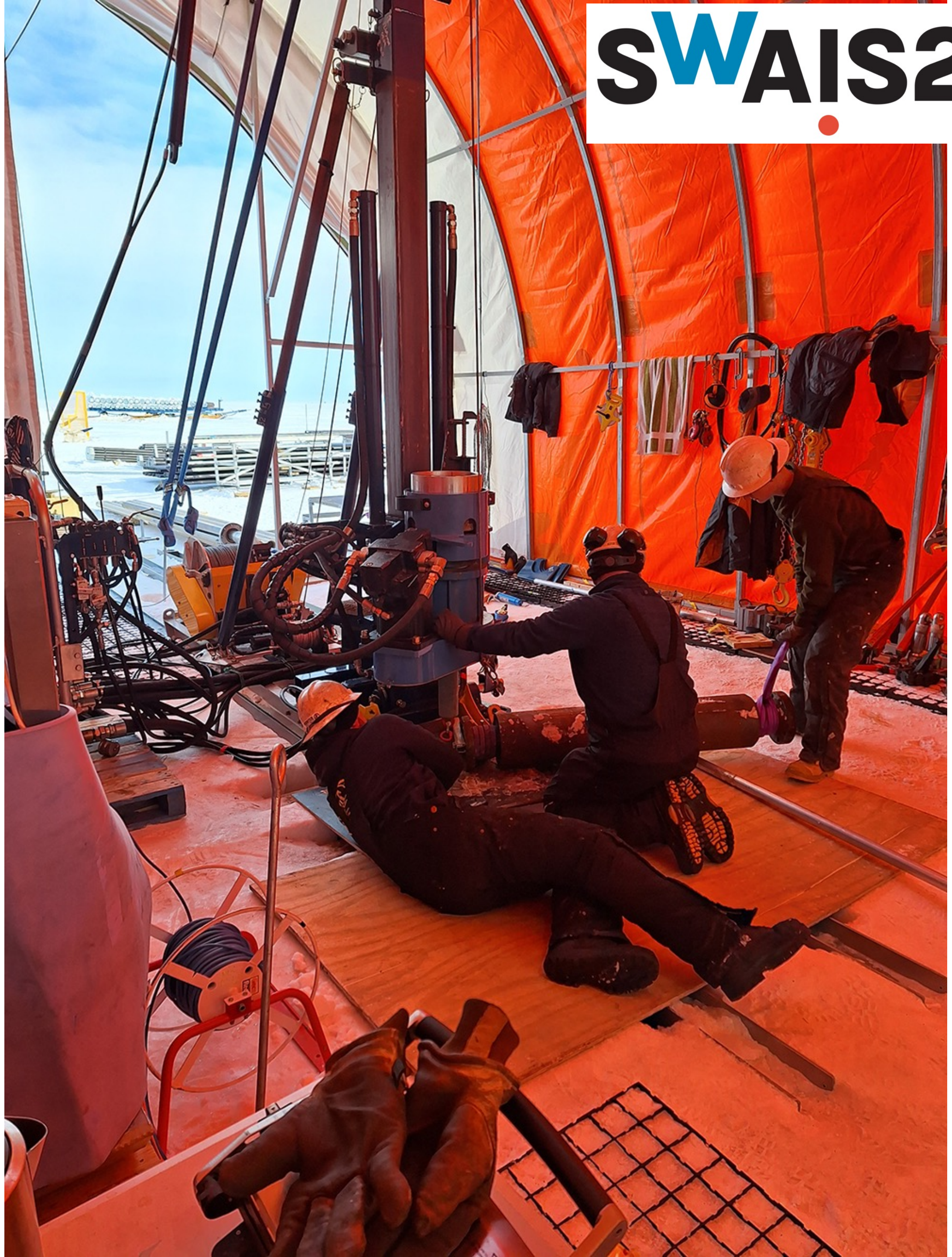
Gravity Coring



Microbiology and Geochemistry

Video Captures and Oceanography

SWAIS2C



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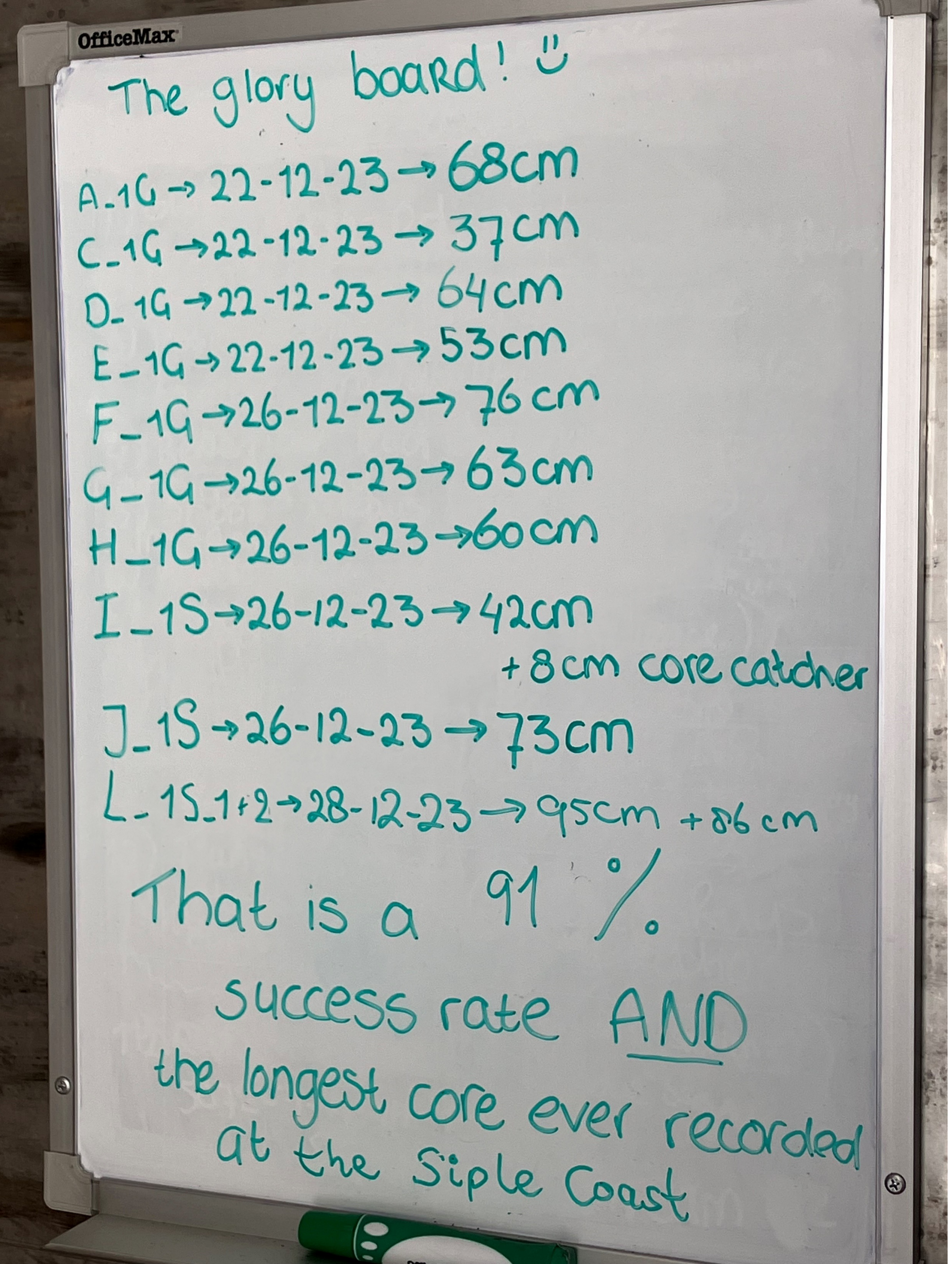
Modified Hammer Coring.

SWAIS2C

The longest sediment core from the Siple Coast ☺.

SWAIS2C



SWAIS2C

Some of the science highlights

- Critical knowledge on how to set up hotwater & sediment drilling systems successfully in one operation
- Collected critical oceanographic and geophysical observations + installation of long term observatories
- 10 sediment cores (37 to 192 cm long); include the longest sediment core from the Siple Coast
- we know we can piston core the sediment
- We know we can deploy temperature probe and logging tools
- SWAIS 2C objectives 1 (Holocene) and 5 (Microbiology) can now be addressed

Come back to KIS-3 in 24/25 to get 200 m core !

Off-Ice Description Workshop

SWAIS2C

GEOTEK Multisensor Core Logger
Computed tomograph (CT) Scanning
COX Analystical Itrax X-ray Fluorescence core scanner
X-ray imaging
Visual core description
Cyrogenic rock magnetometer
Micropaleontology (age) and paleoecological info.
Geochemistry (total carbon, total nitrogen, total organic carbon, XRD, etc.)

Otago Repository for Core Analysis
University of Otago
Dunedin, New Zealand

Core curation facility at Oregon State University – home to the Antarctic Marine Geology Research Facility cores

19-23 August 2024

2024 OPEN SCIENCE CONFERENCE
XI SCAR
PUCÓN-PUNTA ARENAS-CHILE

SCAR

ABOUT US SCIENCE POLICY ADVIC

PALEOCLIMATE RECORDS FROM THE ANTARCTIC MARGIN AND SOUTHERN OCEAN

The goal of the PRAMSO (Paleoclimate Records from the Antarctic Margin and Southern Ocean) Action Group is to provide a forum to initiate, promote and coordinate scientific research drilling around the Antarctic margin and the Southern Ocean to obtain past records of ice sheet dynamics and ice sheet ocean interactions that are critical for improving the accuracy and precision of predictions of future changes in global and regional temperatures and sea level rise.

PRAMSO has links with the current research programme INSTANT (INStabilities and Thresholds in ANTarctica) and the recently-ended research programme PAIS (Past Antarctic Ice Sheet dynamics).

To get involved, contact the group leaders: Carlota Escutia and Richard Levy.

Opportunities to discuss future initiatives