Ice observatories & borehole logging

Ryan Bay
Science Advisory Board
April 16, 2015

- Ice drilling for physics
  - IceCube-Gen2
  - PINGU *(Precision IceCube Next Generation Upgrade)*
  - ARA *(Askaryan Radio Array)*
  - South Pole RF beacon
  - ARIANNA (*Antarctic Ross Ice-Shelf ANtenna Neutrino Array)*
- Borehole logging and BLWG
  - Winches and community resources
  - Recent results
  - Upcoming projects
  - Borehole maintenance
  - Drill fluids

IceCube-Gen2

http://arxiv.org/abs/1412.5106

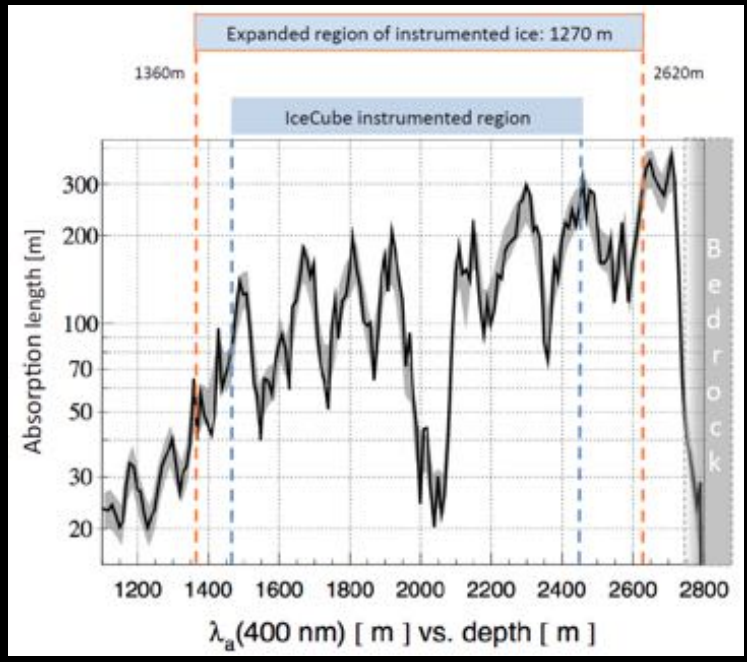
- Roughly doubles in-ice instrumentation
  - 10 km^3
  - PeV energy scale
  - High statistics ν samples
  - String spacing 125 m → 300 m

  ⇒ More mobile, efficient HW plant

  ⇒ Modular, sled-mounted drill system

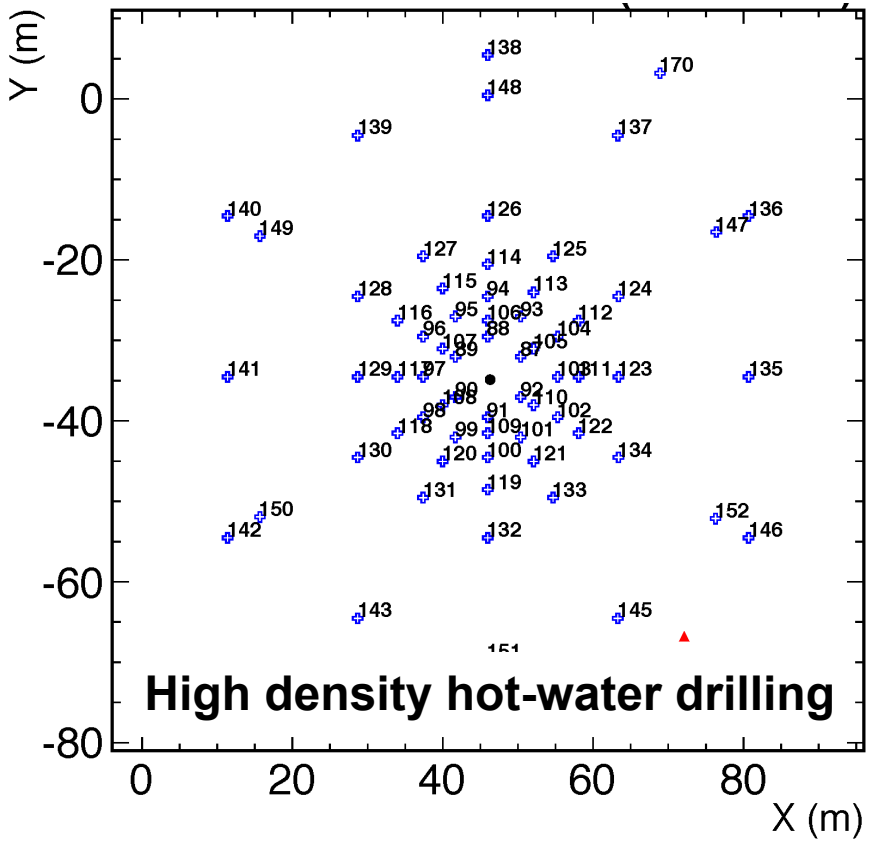
  ⇒ Reduced complexity, smaller labor force

- Filtered, degassed water for clearer refrozen ice



PINGU (Precision IceCube Next Generation Upgrade)

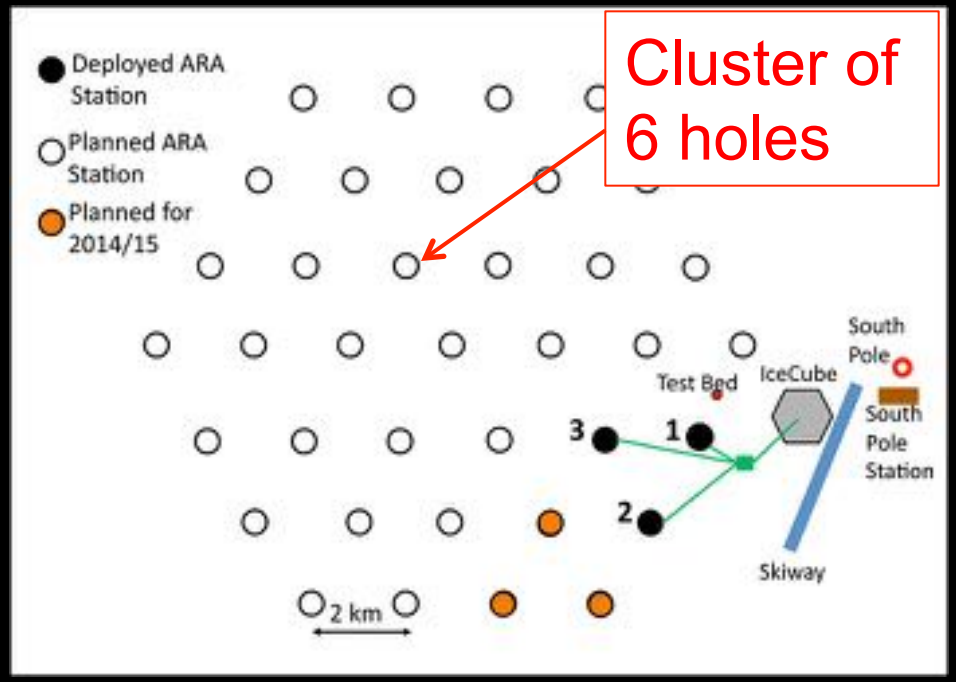
- Densely instrumented detector for lower energies (~1 GeV threshold)
- Neutrino physics, dark matter, supernovae, Earth tomography
- Close-packed HW drilling ~20 m spacing
  3-5 m vertical spacing of detectors
- Filtered, degassed water
- PINGU Letter of Intent January 2014
- Particle Physics Project Prioritization Panel (P5) report May 2014: "**Further development** of concept is **encouraged**…. to understand **systematics.**"
- New LoI in progress



Askaryan Radio Array (ARA)

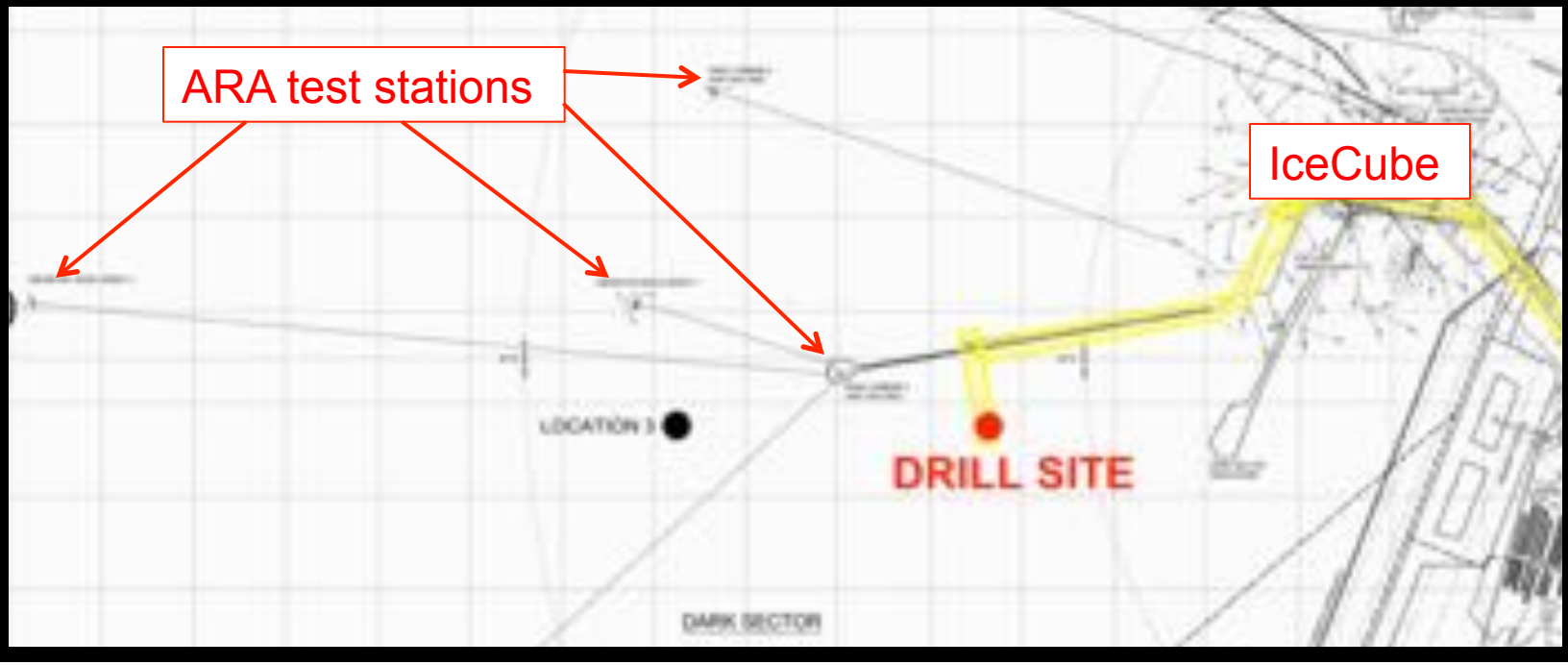
Ultra-HE ν detector of radio Cherenkov radiation (200-800 MHz)

- ~100 PeV, **80** km^2 area, strings spaced ~ few 100s m
  - $\Rightarrow$ 222 holes, dry, minimum 6" $\varnothing$, 200 m deep
  - $\Rightarrow$ Drill with hot water and pump dry while drilling
- Closed-loop glycol firn drill, camera for hole qualifying
- Two stations taking data
- Prelim. analysis (~10 mos.) demonstrates potential
- Hardware ~80% built
- Awaiting NSF approval



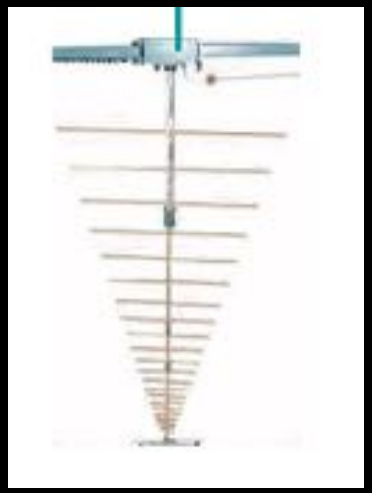
South Pole radio beacon

- SPICEcore is situated close to ARA, IceCube
- SPICE borehole is access point for calibration beacons
- Ice radio studies (ν astronomy and basic radioglaciology)
- Ice permittivity at 100-1000 MHz vs depth; birefringence
- SP lake?
- May require specialized cable

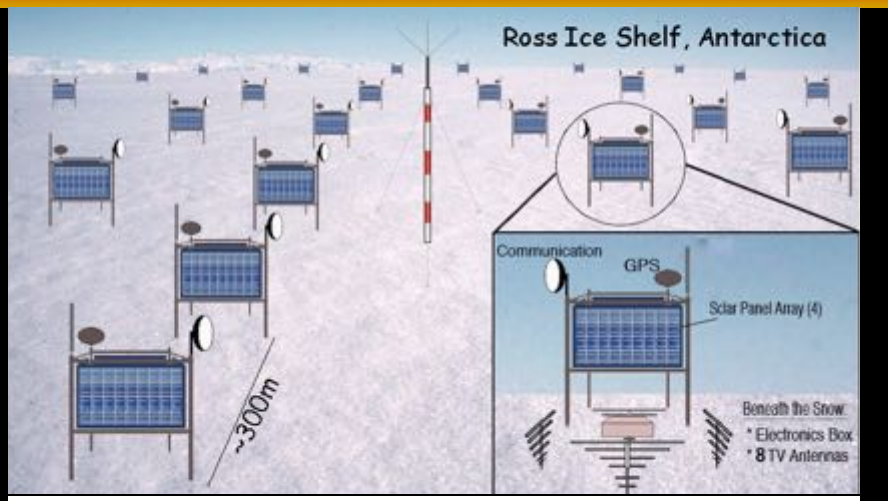


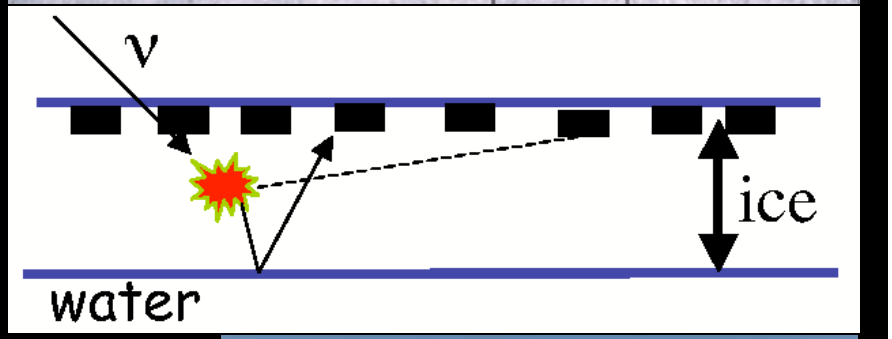
ARIANNA (Antarctic Ross Iceshelf ANtenna Neutrino Array)

- Surface antenna ν array on RIS
- 6 per station => ~10,000 pits
  Each 6' x 6' x 0.5'
  Hexagonal geom.
  Backfilled
  15-20 minutes

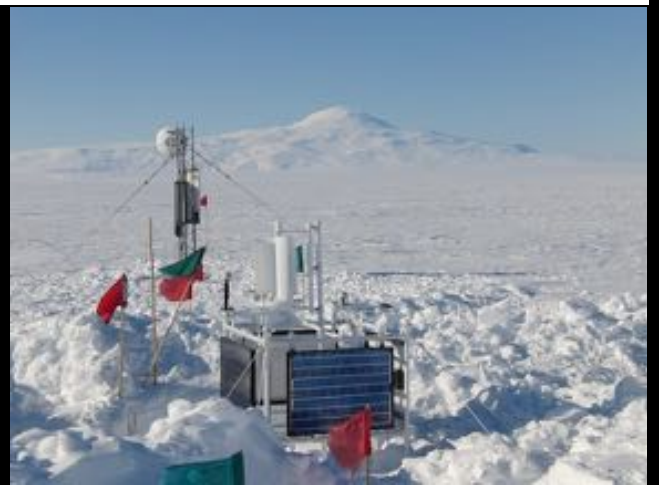


  Chain saw?
  Auger?
  Portable backhoe?

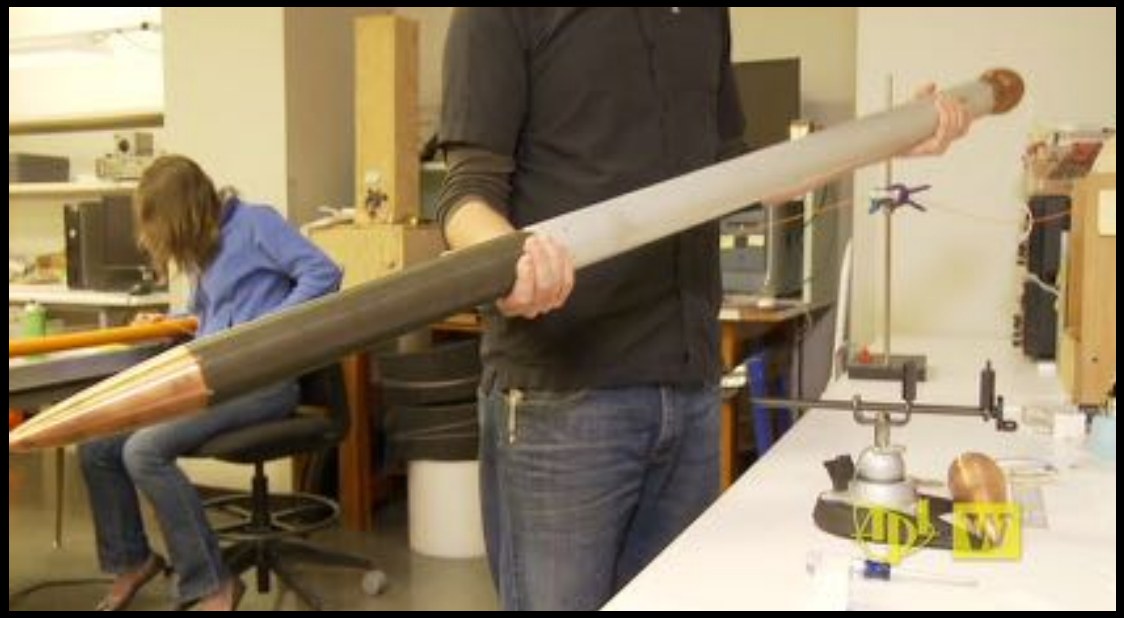




- 2 x 100 m cores 4"-6", for firn study & hole-to-hole radio tomography
- One 500 m hole 4-6"



Ice Diver



- Tim Elam & Dale Winebrenner, University of Washington Applied Physics Lab
- 6 kW melter probe with onboard telemetry cable
- Proposing to deploy Raman DTS fiber to 600-1000 m as proof of concept

SUBGLACIOR, RADIX and oldest ice

- LGGE (Grenoble)
- Mechanical drilling + semi-autonomous melter
- Gases and water vapor analyzed by laser spectrometer
- Penetrates to bed in one season

RADIX

- Bern
- Mechanical 2 cm borehole
- Chips returned to surface for water isotopes

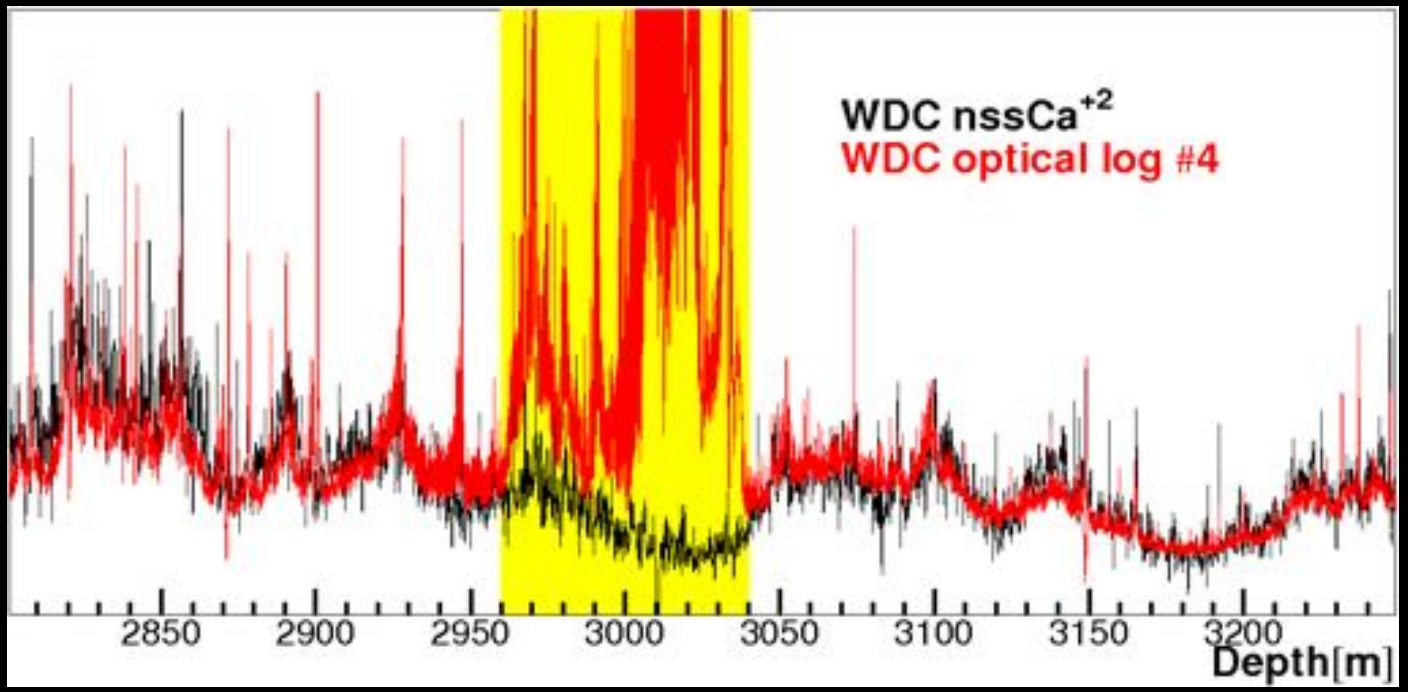
Borehole Logging Working Group

Current WG members:

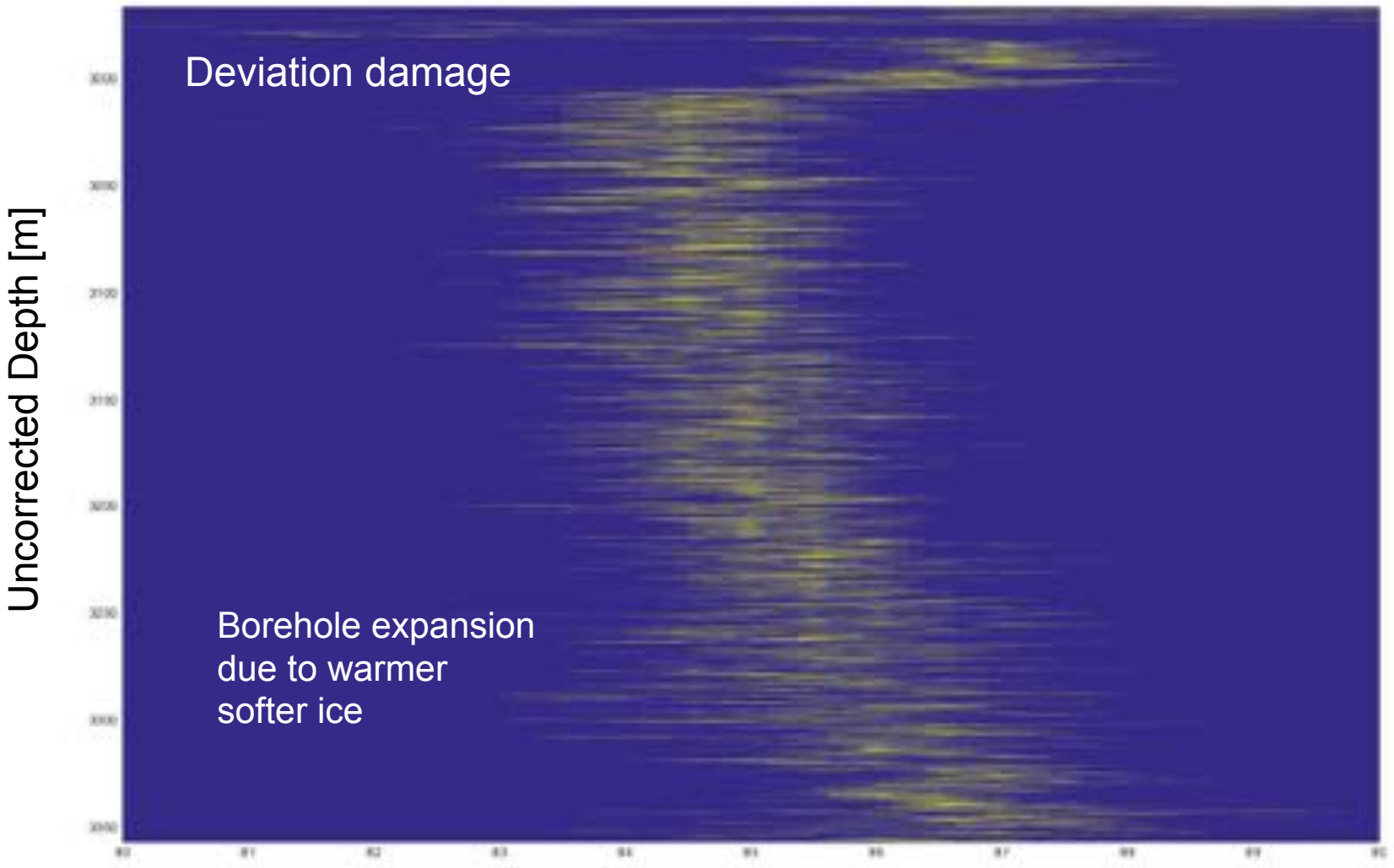
Sridhar Anandakrishnan
Ryan Bay
Gary Clow
Paulo Gabrielli
Jason Gulley
Bob Hawley
Lora Koenig
Atsu Muto
Rachel Obbard
Leo Peters
Erin Pettit
Frank Rack
Hideaki Motoyama
Jeff Severinghaus
Shin Sugiyama
Joey Talghader
Don Voigt
Ed Waddington
Trevor Williams

Recent logging projects – WAIS Divide

- WAIS Divide 2014-15
  - Significant adverse flight delay in MCM (19 days)
  - Logging projects
    - Clow (temperature)
    - Pettit/Obbard (MHz sonic caliper) + 2016-17
    - Peters/Riverman (seismic)
    - Bay/Talghader (optical x2)
  - Four deviations, five replicate channels in borehole
  - Acoustic tool stuck at ~3000 m, going slowly helped



Acoustic Televiewer – WAIS Divide



IDDO Winches

- Two heavy (4 km) winches
  - USGS winch transferred to IDDO
  - New IDDO heavy winch not yet field tested
- Intermediate (1500 m) winch
  - Performed well at SDM 2013-14 (Bay/Talghader)
  - Goetz/Morton operators
- Pre-deployment testing
  - Ideally telemetry tested on winch to be used
  - IDDO can save $ and effort leaving winches deployed
  - Testing on “electrically similar” winch/cable
  - IDDO to design and build winch simulators?
- Winch operator/engineer deployed with any IDDO winch
  - Ensures safety, preserves winch & borehole
  - WAIS Divide 2014-15 – two engineers deployed
  - Cost impacts PI grants
  - What about long (>12 hour) logs?
    Require two engineers?

Upcoming logging projects

- SPICEcore (South Pole ice core)
  - Drilled to 736 m 2014-15, goal is >1500 m
  - Second drilling season 2015-16
  - Third season?
  - Optical dating log at end of 2015-16? Likely 2016-17

- RAID (Rapid Access Ice Drill)
  - Antarctic system test 2016-17
  - First science season 2017-18 – Titan Dome? Herc Dome?
  - Qualifying logger to immediately follow drill
    - Severinghaus & Bay proposal to Glaciology & Instrumentation
    - Dedicated logging winch 3600 m depth capacity
    - Pressure, temperature, optical dating, inclination, camera
  - High value project for borehole logging science
    - ~5 holes per season, ~40 total
  - BLWG to coordinate future logging projects

Borehole Logging Working Group

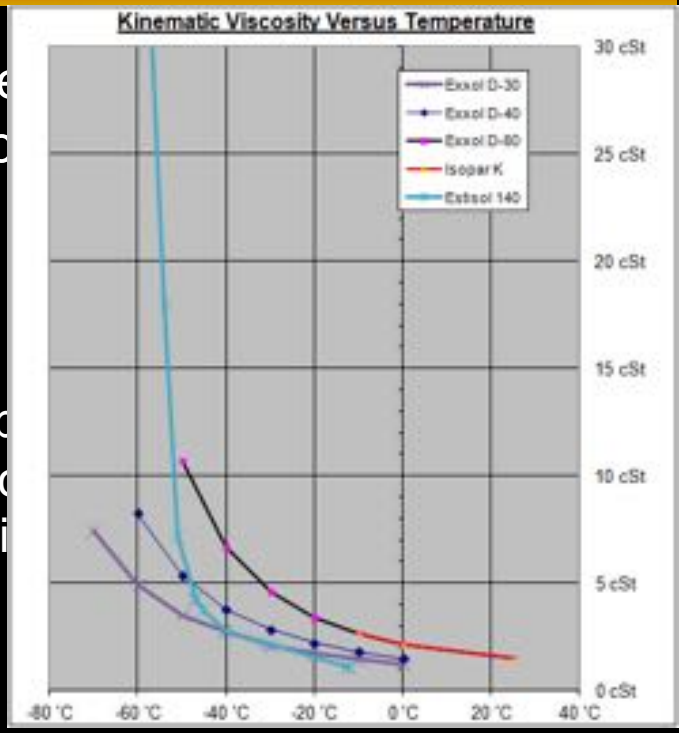
- Borehole logging “allocation committee”
  - Manage resources: winch time, operator time, borehole time
  - Pre-deployment testing and review
    - Ensure tools are safe, projects ready to deploy
    - Involve IDDO engineers
- IDDO tasked with borehole maintenance
  - Casing extension and integrity
  - BLWG consulted on casing/extension design
  - Ice plug removal; towers and sheaves needed for access
  - Fluid compensation
  - BLWG prioritizes borehole preservation
- RAID borehole preservation will require careful choices
  - Science vs. logistics
  - Preserving every borehole impractical
  - Short-term (<5 years) vs. long-term

Estisol 140

Estisol viscosity causes severe problems for te
Estisol has exhibited a tendency to cloud optic
Estisol is difficult to remove from the core
Estisol is aggressive to plastics and classified

SPICEcore report Jan. 11, 2015:

> "Drillers complain of prolonged headaches, b
> throats from working in the drill trench and c
> periods. This, despite the relatively low readi

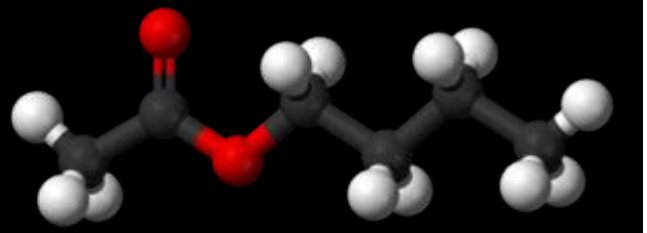


SUBGLACIOR [Triest and Alemany 2014]:

"…Estisol 140 very quickly dissolved and leaked through a plastic beaker and a tray…and had a strong unpleasant smell. This led to a skeptical view on working with it in large quantities over a prolonged period….Estisol 140 is considered one of the most promising drill fluids….Therefore [it was evaluated] despite initial negative impressions concerning material compatibility and handling."

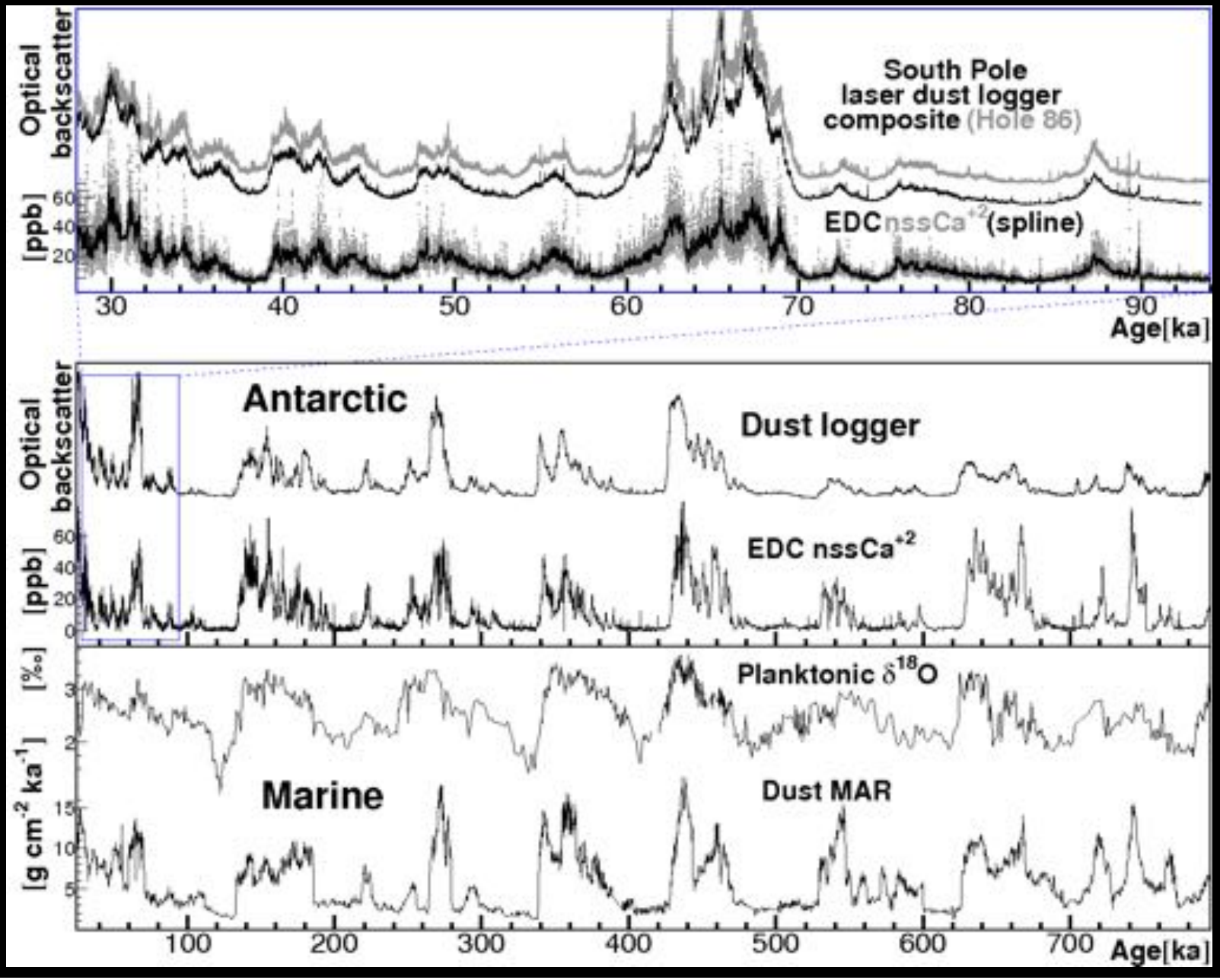
SUBGLACIOR chose silicone (PDMS)

Rehabilitating Butyl Acetate

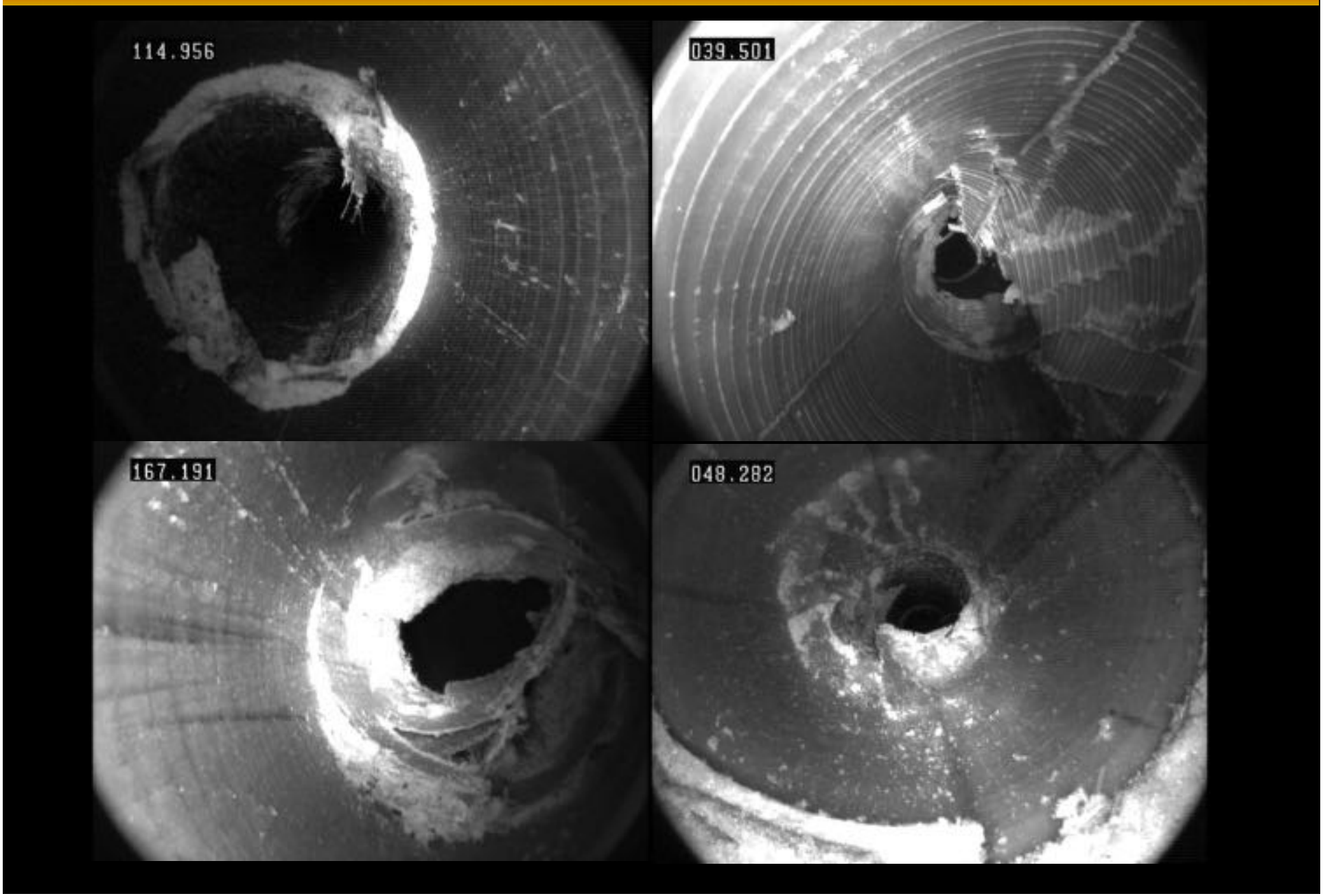


- Inexpensive
- Great density for borehole compensation
- Low viscosity, great for temperature logging
- Good refractive match to ice, great for optical logging
- Found in many types of fruit, used as a flavoring in candy, ice cream, cheese, and baked goods.
- Not carcinogenic. Low toxicity. Safe as for use in cosmetics.
- Animal testing failed to demonstrate any effect on reproduction.
- Evaporates quickly at room temperature (from cores, people), lower volatility at cold temps
- Used at Dome F and planned for use at Dome A
- Odor is objectionable above 300 ppm
- An attractive option, particularly at cold sites

Dating and oldest ice with optical logging



GISP2D as of 2007



SDM ice plug

- Removing the plug did not pose a problem
- Plug formed from snow entering multiple joints of the casing