Subglacial Access
Working Group

Anadakrishnan, Bay, Blankenship, Foreman, Goodge, Gulley, Holland, Jacobel, Mikucki, Powell, Rack, Stone, Truffer, Tulaczyk
Pine Island (PIG Project)

Ocean-Ice Interaction beneath the Pine Island Glacier (PIG) Ice Shelf: The Key to Ice-Sheet Stability  

Global sea level will likely rise 1 meter by 2100 displacing 145 million people and affecting the lives of 2 billion people living in coastal areas around the world. The Intergovernmental Panel on Climate Change (IPCC) identified rapidly changing ice sheets as the main source of accelerating sea level rise, but stated poor understanding of the processes responsible for recent changes prevents accurate projections of future sea level.

Antarctic land ice loss is concentrated along the Amundsen Sea coast of the West Antarctic ice sheet and is responsible for 7% of global sea level rise. Moving at 4000 meters per year (1.5 feet per hour), Pine Island Glacier (PIG) is the fastest Antarctic glacier. The pattern of PIG's thinning, acceleration and retreat indicates the ocean is forcing these changes.

Upwelling circumpolar deep water in the Southern Ocean, forced by variable circumpolar winds washes up on the continental shelf around the continental shelf until reaching the grounded glacier, causing intense basal melt in excess of 100 meters per year.

First observations beneath the ice shelf in January 2009 by a team made by Autolab (built by University of Southampton and operated by the British Antarctic Survey) and Nathan Bailey (Palmer) team. Warm water and previously unknown subglacial ridge were discovered.

Airborne gravity measurements by NASA’s IceBridge mission suggest dense warm water might access the PIG by flowing around the subglacial ridge to a deep subglacial channel.

Planned observations in 2011-12 include oceanographic, seismic and glaciological measurements. Instruments installed through holes drilled through the ice shelf will measure profiles of current, temperature and salinity in the water column to quantify the variability of warm salty water entering the sub-shelf cavity. The thickening cooler, fresher water, as well as basal melting along the underside of the ice shelf. Seismic measurements located at critical bathymetric points will determine the depth of the ocean cavity to illuminate the pattern of sub-shelf water circulation. Glaciological measurements will capture the influence of ice flow to changes in the water conditions. Instruments will continue measurements through the winter and be expanded during a second field season in 2012-13.

Ice-ocean interaction and ice dynamics
Light weight
Great science payoffs
Issues of operational access and support
- WISSARD (main, roving)
- MSLED
- MIDGE (IceMole)
- Valkyrie
- SIMPLE (Icefin)
- SCINI
- Deep SCINI
- RAID
Exploring below the Whillans Ice Stream

http://wissard.org
LOGISTICS:

Subglacial Lake Whillans Drilling Camp

First use of ‘deep field’ laboratories

Tent City

RAC Tent (Cooking, etc.)

Sediment Lab

Crane

Filtration Unit

Chemistry/clean Lab

Heating Units

Generators

Drilling Platform

Instrument workshop

Control center

Image: JT Thomas
Moonpool operations for WISSARD

Deck, HWD (x2 - melters, heaters, pumps, hoses, reels), labs (x2), clean access, crane, winches, sleds, containers, generators
The WISSARD ‘Clean Access’ Approach

- Physical removal of cells and particles (2µm and 0.2µm filters)
- UV lamps (185nm and 254nm)
- Flash pasteurization Alcoda heaters (90°C and 600psi)
- Disinfection with 3% H₂O₂

Successful at removing ~99% of microbial cells in the drilling water

Hot water ice corer at WGZ
Subglacial Lake Whillans is a hydrologically active lake along the Whillans Ice Stream.
Lake lowstand
~2.2 m water column

15 ~20-80 cm of sediment core collected
(with a multi-, piston and percussion corer)
Key borehole results beyond geophysical surveys

Active microbes in lake water and sediments


Scale bars = 2 µm
In situ filtration

Microbial diversity based on DNA sequence data

~4000 species in water column
~2500 species in upper sediments

Geothermal gradient

High heat flow

285±80 mW/m²

Significantly higher than continental and regional averages

Fischer Tulcacz et al. submit
Sediment Cores

Structurally weak, uniform, degassed till

Slow transport by shear

Low water recharge/discharge velocities

All show low sediment fluxes

Sources similar to UpB

Hodson, Powell et al. submit
Water flux m$^3$ s$^{-1}$ per 2.5 km cell
Water flux m³ s⁻¹ per 2.5 km cell
Water flux $m^3 \cdot s^{-1}$ per 2.5 km cell
Water flux m³ s⁻¹ per 2.5 km cell
Water flux $m^3 s^{-1}$ per 2.5 km cell
Water flux $m^3 \, s^{-1}$ per 2.5 km cell
Water flux $m^3 s^{-1}$ per 2.5 km cell
SLW: Subglacial Lake Whillans (2013)

WGZ: Whillans Grounding Zone (2015)
Since SCAR SALEGos and SALEG in 2000s, SCAR had interest in subglacial access for scientific exploration. 

...exploration has started with Ellsworth, Vostok, Whillans projects.

...and subglacial research interest has expanded.

DISCUSSION

- Are there similar science objectives and targets?
- Build international community similar to ice core community.
- Share burden of logistics and costs.
Countries represented

China
Italy
NZ
Russia
UK
USA
Discussion Points:
1. Synthesize current projects and identify near-term plans
2. Assess science goals that could be of collaborative interest
3. Discuss possible targets to address the goals
4. Clarify joint logistic possibilities

Moving Forward:
• Establish working groups for science targets?
• Develop a structure for future collaborations - Propose a SCAR SRP (Science Research Program)?
Subglacial Antarctic lake exploration: first results and future plans

Monday 30 - Tuesday 31 March, 2015

Royal Society Kavli Centre, Chicheley Hall, Buckinghamshire

Organized by
Martin Siegert, Irina Alekhina, Berry Lyons, John Priscu, Jemma Wadham
Wide variety of science objectives and targets
US Community meeting

- February just back from field
- March UK meeting
- April NSF deadline and SAB

- So next Fall
Community needs for on-going subglacial access research

Geophysical support
- Airborne surveys
  - IceBridge – NASA
  - Bassler – Blankenship
  - C130 – Bell (ICEPOD)
  - UAVs – CReSIS
  - Airborne Electromagnetics (SKYTEM)
- Ground
  - Shot-core seismics – Anandakrishnan
  - Vibroseis – Speece
  - Radar – Jacobel et al.
  - Phase-sensitive radar

Traverse equipment
- tractors, decking, sleds, containers, crane, winches, generators, labs, fixed wing support, etc.
Community needs for on-going subglacial access research

Hot water & access drills
- WISSARD – large clean access (hose, reel, heaters, pumps, clean access units)
  – roving drill (“dirty”)
- RAID mobile mining rig hot water/geological drill
- ANDRILL hot water drill, then km-long geological cores
- Scalable hot water access drill, then short geological cores
- narrow borehole hot water drills, university owned
- agile sub-ice geological drill
- agile lake ice drill

Clean Access
- WISSARD
- more portable
- drilling fluid for deep ice
- protocols for new situations
Community needs for on-going subglacial access research

Instrumentation Development
- various projects mentioned previously

Regular community meetings
- data exchange
- planning
- collaborating
- international group through SCAR?

On-going support
- drill/engineering facility
- program facilities/coordination office
HOT WATER Drills to meet our needs?

Scalable/Roving Drill capabilities
• up to ~1000-1500m
• up to 30-40 cm
• Mobile and clean capabilities

Medium drill (WISSARD) part I
• up to ~1000-1500m
• Diameter less 50 cm
• Clean capabilities
• Stationary facilitates the drilling

Medium drill (WISSARD) part II
• up to ~1000-1500m
• Diameter up to 100 cm
• Clean capabilities
• Stationary facilitates the drilling

Deep Access Drill
• >3000m
• Engineering to sample (keep hole open)
• Targets like Ellsworth, Vostok, Deep sedimentary basins
ANTARCTIC ICE SHEET AND SEA LEVEL

24. How does small-scale morphology in subglacial and continental shelf bathymetry affect Antarctic Ice Sheet response to changing environmental conditions?

25. What are the processes and properties that control the form and flow of the Antarctic Ice Sheet?

26. How does subglacial hydrology affect ice sheet dynamics, and how important is it?

27. How do the characteristics of the ice sheet bed, such as geothermal heat flux and sediment distribution, affect ice flow and ice sheet stability?

28. What are the thresholds that lead to irreversible loss of all or part of the Antarctic ice sheet?

29. How will changes in surface melt over the ice shelves and ice sheet evolve, and what will be the impact of these changes?

30. How do oceanic processes beneath ice shelves vary in space and time, how are they modified by sea ice, and do they affect ice loss and ice sheet mass balance?

31. How will large-scale processes in the Southern Ocean and atmosphere affect the Antarctic Ice Sheet, particularly the rapid disintegration of ice shelves and ice sheet margins?

32. How fast has the Antarctic Ice Sheet changed in the past and what does that tell us about the future?

33. How did marine-based Antarctic ice sheets change during previous inter-glacial periods?

34. How will the sedimentary record beneath the ice sheet inform our knowledge of the presence or absence of continental ice?
35. How does the bedrock geology under the Antarctic Ice Sheet inform our understanding of supercontinent assembly and break-up through Earth history?

36. Do variations in geothermal heat flux in Antarctica provide a diagnostic signature of sub-ice geology?

37. What is the crust and mantle structure of Antarctica and the Southern Ocean, and how do they affect surface motions due to glacial isostatic adjustment?

38. How does volcanism affect the evolution of the Antarctic lithosphere, ice sheet dynamics, and global climate?

39. What are and have been the rates of geomorphic change in different Antarctic regions, and what are the ages of preserved landscapes?

40. How do tectonics, dynamic topography, ice loading and isostatic adjustment affect the spatial pattern of sea level change on all time scales?

41. Will increased deformation and volcanism characterize Antarctica when ice mass is reduced in a warmer world, and if so, how will glacial- and ecosystems be affected?

42. How will permafrost, the active layer and water availability in Antarctic soils and marine sediments change in a warming climate, and what are the effects on ecosystems and biogeochemical cycles?
Appendix 3
Estimated Costs for Equipment Development and Upgrade Projects
PY 2014 - PY 2019

<table>
<thead>
<tr>
<th>Development or Upgrade Project</th>
<th>PY 2014 (Current)</th>
<th>PY 2015</th>
<th>PY 2016</th>
<th>PY 2017</th>
<th>PY 2018</th>
<th>PY 2019</th>
<th>Total PY 2014-2019</th>
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Equipment Development
Maintenance & Upgrade

HWD only 15% of budget projected out to 2019