Subglacial Access Community Future Science Planning Workshop 2019

Assessment of East Antarctic Ice Sheet sensitivity to warming and its potential for contributions to sea level rise

Scientific question and rationale for study

The primary question driving this program is the sensitivity of the East Antarctic Ice Sheet (EAIS) to warming and its potential contribution to sea level rise in the future. Despite intense study of the West Antarctic Ice Sheet (WAIS), little is known about the inherent dynamics of the ice contained within the marine-based Aurora and Wilkes Subglacial basins (ASB, WSB respectively). Totten Glacier, the main outlet from the ASB, is estimated to contribute 3.8 m sea level equivalent (SLE) (all estimates from Rignot et al., 2019), while the WSB is estimated to have a SLE contribution of 2.5 m, contributions that together are similar to that of the estimated WAIS contribution of 5.3 m SLE. Direct observations and sampling at the interface between the ice sheet and subglacial materials can provide the first ever assessment of past ice-sheet history and the current conditions governing glacial flow and instability. The recovery of Pliocene marine sediments from interior sectors of these subglacial basins would provide direct evidence for past large-scale retreat in these sectors during the most recent time Earth experienced modern CO_2 levels. These data will provide critical constraints to improve modeling skill regarding vulnerability for future ice margin retreat and sea level rise. This document outlines the scientific rationale for a comprehensive and collaborative study of East Antarctica that addresses these first-order problems.

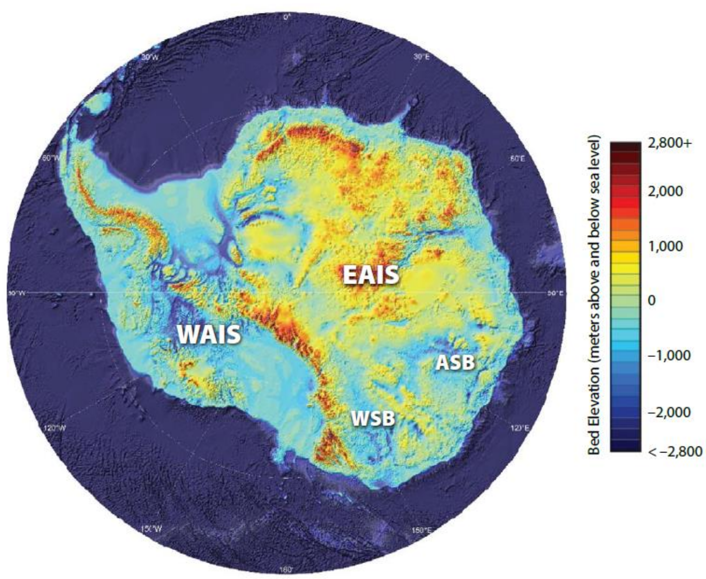

Figure 1. Bedmap2 image showing bedrock topography and highlighting regions of Antarctica where bedrock is below sea level (cool colors). Ice sheets covering bedrock include the East Antarctic Ice Sheet (EAIS) and West Antarctic Ice Sheet (WAIS); major subglacial basins in East Antarctica include Wilkes Subglacial Basin (WSB) and Aurora Subglacial Basin (ASB). From Escutia et al. (2019), after Fretwell et al. (2013).

The most recent time period when atmospheric CO_2 levels were at modern levels of >410 ppm was during the Pliocene Epoch. Recent modeling efforts (e.g., de Boer et al., 2015; Pollard et al., 2018) provide insight into the contributions of different sectors of EAIS to global sea level under warm Pliocene conditions. Pollard et al. (2018) suggest sensitivity of the Wilkes Subglacial Basin, in particular, to time periods of elevated CO_2 and greater warmth. Marine geologic and geophysical data from IODP efforts along the East Antarctic margin indicate significant glacial retreat in the WSB during the Pliocene (Williams et al., 2010, Cook et al., 2013; Patterson et al., 2014; Bertram et al., 2018). In contrast, much less is known about Pliocene behavior of ice in the ASB, primarily because no subglacial or seafloor drilling has been conducted on the proximal shelf and slope along the Sabrina Coast. Short piston cores from two shelf sites from the Sabrina Coast collected sediments as old as late Paleocene (Gulick et al., 2017). The Sabrina Coast continental shelf and slope, as well as the George V Coast shelf, are under consideration as sites for future IODP drilling efforts.

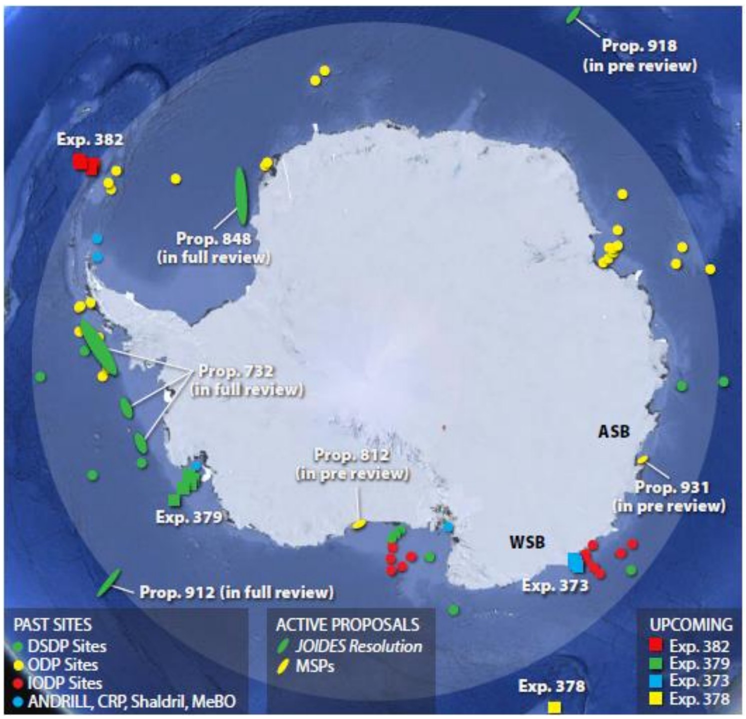

Figure 2. Past and future scientific ocean drilling sites around Antarctica. Past sites are marked by colored circles. Green ellipses are regions targeted in active proposals to be drilled with JOIDES Resolution, and yellow ellipses indicate regions targeted to be drilled with mission-specific platforms. Three proposals have been submitted as “pre-proposals” and three are full proposals being considered or revised. Proposed drilling sites for IODP expeditions completed in 2019 and scheduled expeditions are marked by colored squares: Expedition 379, 01-02/2019 - Amundsen Sea (green, JOIDES Resolution), Expedition 382, 03-04/2019 - Iceberg Alley (red, JOIDES Resolution). Note the locations of previous IODP missions that have targeted the East Antarctic margin, as well as upcoming missions, including Expedition 373 (George V Coast continental shelf), and Proposal 931 (Sabrina Coast continental shelf). WSB = Wilkes Subglacial Basin, ASB = Aurora Subglacial Basin. From Escutia et al. (2019).

Recent data highlight concerns regarding modern ice instability in the Aurora Subglacial Basin. Independent, space-based platforms indicate accelerating mass loss of Totten Glacier (e.g., Khazendar et al., 2013; Li et al., 2016; Mohajerani et al., 2018; Rignot et al., 2019). Aerogeophysical surveys of the ASB, which contains the deepest ice in Antarctica and drains into the Totten system, provide the subglacial context for measured surface changes and show that Totten Glacier as the most significant drainage pathway for at least two previous ice flow regimes (Young et al, 2011). Totten Glacier is considered vulnerable to warming because of the observed presence of relatively warm modified Circumpolar Deep Water (mCDW) on the adjacent continental shelf and at the ice-front (Greenbaum et al., 2015; Rintoul et al., 2016; Silvano et al., 2016, 2017; Nitsche et al., 2017; Rignot et al., 2019). Li et al. (2015) show a 1-3 ± 0.1 km retreat in the grounding line of Totten Glacier; however, their data suggest that further thinning of the ice and greater retreat of the grounding line may not destabilize Totten Glacier because of bed topography, although more satellite data are needed to map the grounding line and bed topography on the eastern side of the Totten Glacier. Additional data on bathymetry are also needed closer to the Totten ice-front and to the west of Law Dome (Figure 3).

Geographic and geological context

The Wilkes Subglacial Basin is a broad region with ice thickness ranging from 2500 m to 3400 m that extends inland of the Transantarctic Mountains and drains through the George V Coast between Northern Victoria Land and Terre Adélie. The basin overlies relatively thin crust between the Terre Adélie craton to the east and the Transantarctic Mountains to the west. Contrasting models for origin of the basin include continental rifting, crustal flexure, and development of a broad back-arc basin in the transition between the Precambrian craton and the Ross Orogen (Ferraccioli et al., 2009). Although most of the deeper sub-basins are likely Cenozoic in age, an older Cretaceous and Jurassic history of deformation and basin filling is indicated by geophysical data and igneous and sedimentary records. The deep sediment-filled troughs host fast-flowing outlet glaciers.

The Aurora Subglacial Basin comprises at least two extensive but well-confined deep basins (with ice thickness estimates of up to 4000 m), flanked by highlands (with ice thickness of ~2200 m) in the region inland of Totten and Denman glaciers. Between the ASB system and the coast lies the Sabrina Basin, where airborne gravity data indicate evidence of extensive denudation (Aitken et al., 2016). Basin connections to the coast include subglacial fjords between the ASB through ‘Highland B’ to the deep Vanderford Trough and Totten Glacier; and a deeper, narrower connection between Denman Glacier, passing ‘Highland A’ (Young et al., 2011). ASB is underlain by Mesoproterozoic cratonic crust equivalent to that found in in Western Australia. Major granitic bodies have been hypothesized on the basis of sparse aeromagnetic data (Aitken et al., 2014; Golynsky et al., 2018), but lack confirmation.

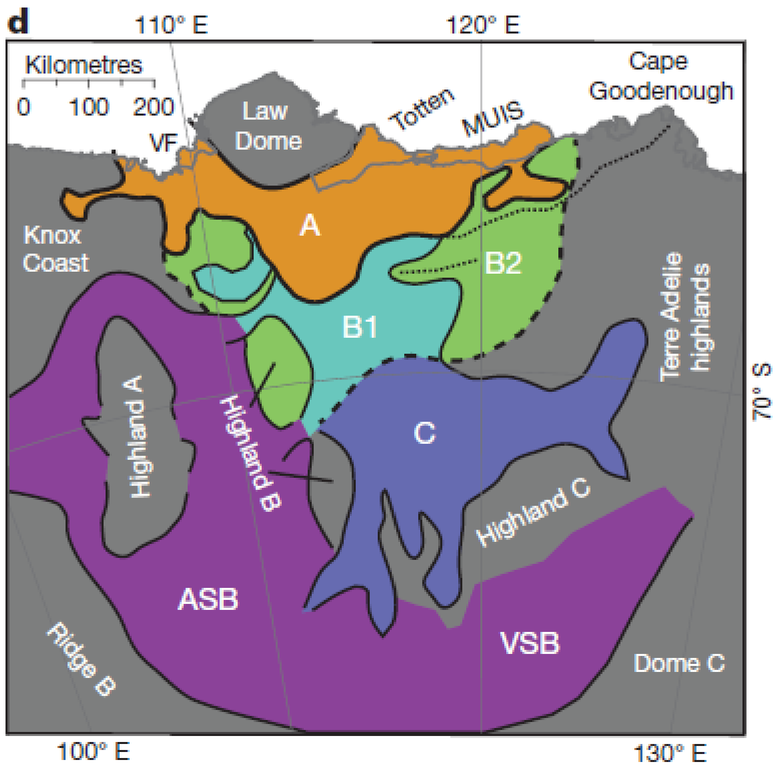

Figure 3: Figure from Aitken et al. (2016, Figure 1d), showing regions discussed in text. ASB = Aurora Subglacial Basin, VSB = Vincennes Subglacial Basin. Regions A, B1, B2 and C are distinct sedimentary regions within the Sabrina Subglacial Basin, which is rimmed by Highland B, Highland C, and Terre Adélie Highlands. VF = Vanderford Fjord, MUIS = Moscow University Ice Shelf.

Between the basins lies a complex of subglacial mountains and sediment filled intermontane basins (including the Adventure Subglacial Trench and the Astrolabe Subglacial Basin) that strike perpendicular to the coast. At present, these basins lack fast flowing ice, but host active subglacial hydrology (Wingham et al., 2006; Carter et al., 2007; Smith et al., 2009). This complex subglacial terrain is associated with variations in hydrology and glacial flow; low smooth surfaces lying upon inferred sedimentary basins show evidence of well-distributed hydrologic systems, whereas over rough highlands of inferred basement the flow is more focused (Wright et al., 2012; Aitken et al., 2014). The subglacial highlands are thought to comprise Precambrian cratonic rocks that likely played a key role in the tectonic evolution of Rodinia and Gondwana and growth of the East Antarctic Ice Sheet, yet little is known about the ice-covered geology. Outcrops along the George V Coast and Terre Adélie consist mainly of Neoarchean and Paleoproterozoic high-grade gneisses and metaigneous rocks (Peucat et al., 1999; Oliver and Fanning, 1997, 2002; Ménot et al., 2005; Gapais et al., 2008; Goodge and Fanning, 2010). Coastal areas expose high-grade metasedimentary and migmatitic rocks with ages of about 1.69 Ga, and there are also heterogeneous Archean paragneisses and granitoids, including felsic granulites, amphibolites, orthogneisses, marbles, and quartzites with metamorphic ages of about 2.50–2.42 Ga. Shear zones juxtaposed the Archean and Paleoproterozoic blocks at ca. 1.7 Ga (Duclaux et al., 2008). Outcrops of Beacon Supergroup strata, cut by intrusions of Ferrar dolerite, occur east of Ninnis Glacier at Horn Bluff. In general, this assemblage of Neoarchean and Paleoproterozoic terrains, referred to as the Terre Adélie craton (Ménot et al., 1999), corresponds to geologic units in the Gawler craton of South Australia (Oliver and Fanning, 1997, 2002; Goodge and Fanning, 2010; Williams et al., 2019). Notably, equivalent regions in Australia have locally elevated heat flow due to concentrated radiogenic elements (e.g., McLaren et al., 2003).

While not a primary goal for this initiative, an additional regional outcome may be identification of new areas of low snow accumulation, slow horizontal ice velocity, and low geothermal heat flux, which are thought most likely to overlie ancient ice that would be suitable for long-term paleoclimate records (ice >1.5 Ma). Finding ancient ice is one of the most important priorities within the ice core and paleoclimate communities because the Early Pleistocene climate pattern of 41 kyr obliquity signals captured in marine sediments is not represented by proxy ice records (Lüthi et al., 2008; Lisiecki and Raymo, 2005). The latter would contain atmospheric gas and temperature information needed to fully explain the transition from 41 kyr to 100 kyr G-I cycles between 1.2 and 0.7 Ma (the mid-Pleistocene Transition, see for example McClymont et al., 2013) and is a major driver for research by the International Partnership in Ice Core Sciences (IPICS) community. Old ice targets principally overlie subglacial highlands between the Wilkes and Aurora subglacial basins, particularly beneath Dome C and areas downstream (Fischer et al., 2013). Thick, slow-moving ice overlying subglacial bedrock highs provides the best opportunity for simultaneous exploration for ancient ice and subglacial bedrock geology.

What evidence from within or beneath the ice sheet is needed to advance knowledge?

Recovery of Late Neogene marine sediments would provide direct evidence of EAIS sensitivity to past warming, documenting past episodes of ice-margin retreat and marine incursions into the WSB and/or ASB. A stratigraphic sequence that includes deposits from the Miocene Climatic Optimum and mid-Pliocene Warm Period would provide optimal targets. However recovery or earlier Miocene, Oligocene or even Eocene sediments would similarly be a success as there is evidence for episodic shelf glaciations and protracted periods of open marine conditions on the Sabrina Coast shelf (Gulick et al., 2017). Therefore such successions would have a strong likelihood of recording some warmer intervals that experienced significant glacial retreat. A transect or grid of sediment samples would help constrain the extent of Pliocene or earlier retreat into deep EAIS basins, providing important spatial constraints for numerical paleo-ice-sheet models. Subglacial rock samples for surface exposure dating would provide further constraints on ice dynamics along the flanks of the basin. In order to leverage this paleo-perspective on WSB and ASB sensitivity for prognostic projections of ice sheet mass balance, we also need to collect observations of modern boundary conditions in these sectors, including ice geometry, basal conditions, crustal uplift and geothermal heat flux.

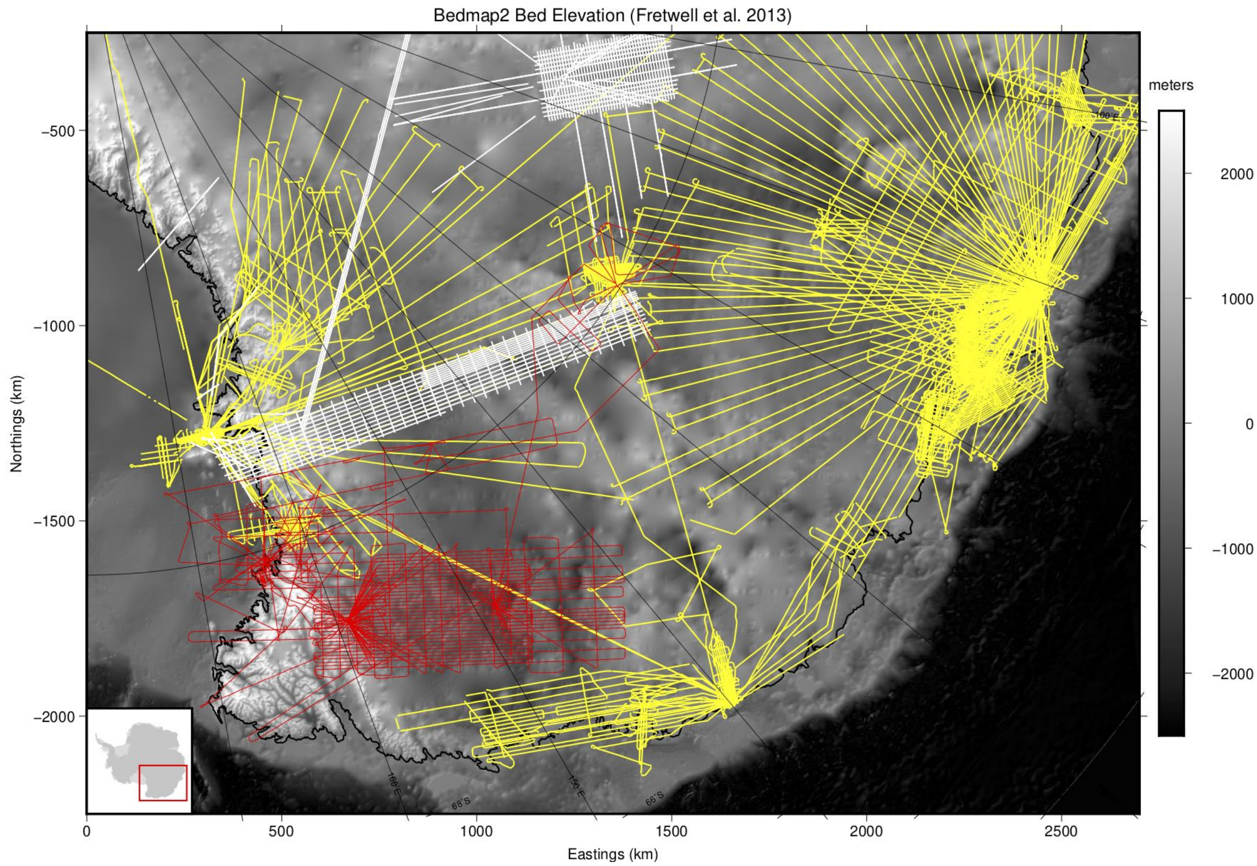

Figure 4: Existing aerogeophysical coverage of Wilkes and Aurora subglacial basins (SOAR in white, ISODYN-WISE in red, and ICECAP in yellow) over Bedmap2 (Fretwell et al., 2013). While some regions of the WSB have excellent coverage, significant gaps remain along the length of the WSB. Much of the ASB has been has been surveyed at low spatial resolution, with varying radiometric quality.

Aerogeophysical surveys provide regional characterization of ice geometry, basal conditions, and subglacial geology. Existing aerogeophysics in this region (Figure 4) include focused 90s-vintage SOAR corridors, the 2005-6 ISODYN-WISE survey by British Antarctic Survey over the central WSB, and regional ICECAP reconnaissance over the Wilkes and Aurora subglacial basins. Focused surveys exist over the major outlet glaciers from ICECAP (Totten, Denman and Mertz), KOPRI (David Glacier) and CReSIS (Byrd Glacier), and at the ‘old ice’ coring site at Dome C. Major gaps in coverage exist inland of David Glacier, between the coastal region and the ISODYN survey and is sparse in the interior of the ASB and along the ranges separating the Wilkes and Aurora subglacial basins. Additional aerogeophysical surveys will enhance regional geologic understanding and provide context needed for choosing more focused, ground-based surveys and ultimate site selection for subglacial access.

Drilling into the subglacial beds in both spot-coring and longer stratigraphic drilling/coring modes is necessary in order to observe the glacial bed and to obtain samples of subglacial material suitable for investigating East Antarctic sensitivity during the Pliocene. **Two principal domains likely exist within the subglacial bedrock realm that are the most important drilling**

targets — sedimentary basins and crystalline bedrock highs. The main basins likely harbor multi-stage depositional records that can be used to interpret long-term tectonic, climatic, marine, and ice-sheet histories. The highlands are likely underlain by crystalline Precambrian bedrock, which can be used to document both surface exposure histories and crustal evolution. Exposure histories will elucidate the timing and magnitude of ice retreat and thinning during the Miocene and Pliocene, and may provide further insight into the timing of EAIS inception. Together, these domains allow the opportunity to compare what the geologic record provides about ice-sheet and marine history and how underlying geology both affects the current glacial regime. Placement of boreholes into the subglacial system will also allow for *in-situ* geophysical instrumentation.

Remote and ground-based geophysical observations are required both for core-site reconnaissance and to provide the boundary conditions for ice-sheet models required to estimate future sensitivity of the marine-based sectors of East Antarctica. In particular, radar, active seismic, and electromagnetic methods can be used to determine internal and basal ice-sheet conditions important for characterizing ice-sheet flow. Passive seismic and electromagnetic data can help characterize lower crustal and mantle conditions for understanding regional tectonics and geothermal flux. Geodetic observations of the glacial isostatic adjustment (GIA) from within the basin can provide constraints on regional glacial evolution. We currently measure GIA with subaerial GNSS observations, which are limited to areas with outcropping bedrock. New techniques using instrumented boreholes can be developed for estimating vertical motion of the crust beneath ice (i.e., sub-ice geodesy).

Where will you gather the field evidence?

This interdisciplinary program will focus on the Aurora and Wilkes subglacial basins and their associated highlands. Fundamentally, a sustained program of subglacial access drilling represents first-order scientific exploration of a part of the EAIS about which little is known yet is showing initial evidence of ice-mass loss.

How will you gather the evidence? A decadal scale sequenced program:

This program will be conducted as a multi-year campaign involving regional-scale aerogeophysical surveys, detailed site characterization, on-site drilling and coring, sample recovery and analysis, and legacy borehole occupation for long-term instrumentation. Subglacial access will be required via multiple boreholes across subglacial basins and flanking highlands. A proposed general sequence of activities will include:

- Regional aerogeophysics (magnetics, gravity, radar)
- Detailed geophysical site surveys (active & passive seismic, radar, MT/CSEM, GPS)
- Geothermal heat flux survey (by melt probe/DTS)
- Upgrade & development of clean-access drilling/coring systems (WISSARD, RAID, etc.)
- Drill site selection
- Drilling activities (spot coring & stratigraphic coring), coordination through IDP
- Core acquisition

- Core characterization and sample descriptions (off-site)
- Subsampling of cores for study
- Borehole access and instrumentation (for long-term observation)
- Sample analysis and data-numerical modeling integration

Aerial and ground based geophysical site characterization

Drilling is a large logistical and financial undertaking that requires thoughtful evidence-based decision making. Using regional and local geophysical surveys enables more control on the determination of specific drilling locations and increased knowledge that these locations will successfully test the desired hypotheses. Site characterization will also affect stewardship requirements by confirming the existence of a thawed or frozen bed. This environmental knowledge will determine the suitability of different drill systems and the level of effort required to meet environmental stewardship thresholds.

Prior to drilling, multiple campaigns of site characterization should occur over the area(s) of interest. This should include both aerogeophysical surveying with radar and potential fields, as well as ground based radar and seismic surveys. A regional campaign of aerogeophysical survey with grid spacing of 5-10 km can be used to describe the variability of bed topography, ice thickness, hydrology, thermal state, and make inferences about geological variability. A denser radar aerogeophysical survey with line spacing of 1 to 2 km will refine the characterization of the region to be sampled and assure that local topography and environmental conditions are considered when a specific drilling target is determined. The region is ringed by major air hubs for the US, Australia, France, Korea, and Italy, and hosts in the interior the traverse supported joint French-Italian Concordia Station, so while significant gaps remain over this vast region, it can be accessible through international collaboration.

Ground based site characterization is necessary to either, or both, describe local topography in finer detail, which is essential for regions with high relief, and to describe the geological and structural context that exists below the ice/bed interface. This sequence of observations has been recently demonstrated in the region at Little Dome C, on behalf of the European Beyond EPICA Oldest Ice project. Reconnaissance surveys allow planning of a high resolution survey of a promising site (Young et al., 2017), at down to 1 km line spacing, which in turn allowed for much finer ground based surveys and rapid access drilling efforts for heat flow, allowing for site selection for this ice coring effort.

These surveys will create the justification for a chosen drill systems and for the location(s) in which the systems will be deployed. Understanding the regional characterization of the drill site will enable generalization of the subglacial observations increasing the impact of discoveries. Additionally, these surveys can be used to minimize risk to the project by understanding the environmental conditions that will be sampled, that the chosen site is suitable for the hypotheses to be tested, and that the logistical plan meets SCAR standards for environmental stewardship.

Network of rock/sediment sampling in the basin & highlands

Stratigraphic sampling of basin sediments.
As described above, our goal is recovery of marine sediments of Late Neogene age via coring/drilling samples that can provide direct evidence of EAIS sensitivity to past warming, with ice margin retreat and marine incursions into the Wilkes and/or Aurora subglacial basins. A stratigraphic sequence including deposition during the Miocene Climatic Optimum and Pliocene Warm Period would provide optimal target intervals to test ice sheet sensitivity, and provide parallel records to those developed by stratigraphic drilling and data-model integration in the Ross Sea region for the Miocene (Gasson et al., 2016; Levy et al., 2016) and Pliocene (Naish et al., 2009; Pollard and DeConto, 2009).

Bedrock sampling on the flanks of the basins.
Coring of subglacial bedrock will be done in order to provide samples suitable for studies of lithologic composition, exposure history, and crustal history. Given the widely spaced and limited coastal rock exposures, our knowledge of the bedrock geology is poorly constrained. Exposed bedrock consists mostly of Precambrian igneous and metamorphic rock (reviewed above). Coring of bedrock on high-standing flanks of the basins is expected to include similar geology, but coring is expected to recover a wide range of possible rock types, compositions, and ages. Study of igneous rocks recovered as glacial erratics from sediment cores, offshore dredging, and onshore moraines illustrates that rock material derived from the continental interior are not represented in present-day outcrop (Goodge and Fanning, 2010; Goodge et al., 2017). Thus, it is expected that coring of bedrock will likely yield entirely new subglacial geologic materials.

Subsampling of rock cores will provide opportunity for study of rock and mineral materials. Rock material can be used for measurement of physical properties (petrofabrics, density, magnetic susceptibility, thermal conductivity, heat production, seismic velocity & anisotropy) and whole-rock geochemical compositions (major, trace and rare-earth elements). Rock samples will also be used for petrographic study and mineral analysis in order to recover petrogenetic information. Mineral separates can be used for integrated high-temperature geochronology, low-temperature thermochronology, and exposure age dating in order to determine age and thermal histories.

A composite drilling approach would use drilling/coring systems suitable to sample basin stratigraphic records and flanking bedrock highs, as it is unlikely that one system would suit all needs. Selection of sites would consider shared logistical support and multiple year deployments to maximize scientific return.

Occupation of boreholes for geophysical data

It is of great value scientifically to use boreholes to acquire additional data sets, for example, to constrain both ice models (sub-ice geodesy, geothermal heat flux, englacial temperature, modern velocity structure) and for in-situ geophysical measurement (temperature gradient, heat flow, crustal stress, geodetics, seismology). Geothermal heat flux is a critical parameter that should be measured as widely as possible in order to document the distribution and variability of heat flow, and as an input to ice-sheet models. Details are described below.

Geothermal flux survey

Antarctic geothermal flux is presently poorly known except at past drilling sites, but may vary very substantially over distances of only a few tens of kilometers (IDPO, 2016, pg. 24). Geothermal flux is the largest unknown in determining basal conditions (Van Liefferinge and Pattyn, 2013; IDPO, 2016; Fischer et al., 2013). Yet those conditions are key information for modeling ice dynamics and glacial history (IDPO, 2016, pp. 23-24), as well as efforts to find and sample Antarctic ice older than 800 kyr (Fischer et al., 2013), and in support of the U.S. Rapid Access Ice Drill (RAID) project to core Antarctic subglacial bedrock and deep ice in many locations (Goodge and Severinghaus, 2016).

Temperature depth-profiles are the primary data to explore geothermal flux, and are presently measured by logging (IDPO, 2016) in boreholes that have been acquired first for other purposes (e.g., ice coring). Current logistical costs substantially limit drilling to acquire additional temperature profiles, even where such profiles are essential to drill site reconnaissance (IDDO, 2016). Thus, geothermal flux surveys based on current methods are limited to under sampling important spatial variability, and will often occur too late to inform selection of drill site locations.

Recent development supported by the NSF offers a means to address these limitations, in the form of optical fiber emplacement for Raman Distributed Temperature Sensing (DTS) measurement of temperature depth-profiles (Tyler et al., 2013; Kobs et al., 2014; Fisher et al., 2015), together with low-logistical cost melt probes to emplace the fiber. Development and testing of such emplacement is currently progressing through deployments on 10-100 m depth-scales (at realistic ice temperatures), and can be expected to be ready for deployment to depths of thousands of meters in time for the ground based geophysical site characterization surveys described above. Such as technology can be expected to deploy at numerous sites for relatively low cost and minimal logistical footprint.

Thus, the incorporation of melt-probe emplaced DTS in regional characterization of prospective drill sites will contribute strongly, both to maximizing scientific return from those sites, and to broaden understanding of the spatial distribution of heat transfer in the subglacial crust for modeling ice flow dynamics and geologic mapping.

When do you hope to conduct the field season? Infrastructure needed?

We anticipate a multi-year, sequenced program given the limited nature of constraining data needed for strategic selection of borehole sites. Initial aerogeophysical and heat-flux surveys will be done to image ice and subglacial materials. Site selection for drilling will use these data in order to identify suitable science targets, and then require detailed site surveys with both airborne and ground-based instrumentation. We can adapt one or more existing drilling platforms for subglacial access, including RAID, WISSARD, Roving, ASIG, and Winkie drilling systems, or a new drill for deep subglacial sediment coring could be developed. We anticipate a coordinating support role during the development and implementation phases to be provided by the Ice Drilling Program (IDP-Dartmouth). RAID requires traverse support and will be available after completion of an initial science campaign (Phase 1) operating in the South Pole region of central East Antarctica; deployment of RAID for Phase 2 in the Wilkes and Aurora basin area of East Antarctica will require a significant adaptation for ensuring environmental stewardship in regions with a thawed bed as well as operational support from McMurdo station, Dome C facilities, or coastal bases operated by other countries. The WISSARD drilling system in its current design will require traverse support, but could be upgraded to use water pressure to generate electrical power locally in the deep ice-hole to drive an ice and sediment coring system with wire-line recovery. ASIG, Winkie and UNL Roving drills are light-weight systems deployable by small fixed-wing aircraft. However, a notable logistical requirement for all of these drilling systems is fuel, which would require multiple flights to deploy, or accommodate with traverse delivery and pre-staging.

Penetration into subglacial targets where water is present will require clean-access approach, which is available with the WISSARD system (presently at 1500 m, but upgradable to 2500 m depth capability) or Roving Drill (1000 m depth capability). Clean-access capability could be incorporated into the next iteration of a RAID Drill. Technological advances in coring should be explored to allow for improved recovery of basal sediment-rich ice, for examination of those sediments, but also as a means of clearing debris from the bottom of a drill hole, and for the recovery of a sequence of sediment cores (i.e., 10s to 100s of meters). A systematic regimen of filter replacement of hot-water drilling systems would allow for recovery and sampling of englacial and basal sediment debris, including soft sediment clasts that may contain marine microfossils of use in dating past marine incursions. The potential to use water from a hot-water drill to drive an electrical generator at the bottom of a borehole to power a drilling system to recover ice or sediment cores could be explored.

Leveraging international collaborations and operational infrastructure in this region can be an effective and more efficient way to develop a program of this scale in a region relatively distant from US stations. We suggest developing contacts and working toward collaborative efforts with nations that have stations in this region, for example Australia (Casey), France (Dumont d'Urville), France and Italy (Concordia, Zucchelli), Jang Bogo (Korea), and Russia (Mirny, Vostok).

The way forward - workshop proposal

The first step toward advancing this exploration initiative to investigate East Antarctic subglacial marine basins is to write a proposal to NSF to request support for a workshop to develop the science and operational plan, broaden participation to include a wider scientific community, bring together relevant data, consider the appropriate drilling approaches and infrastructure, address upgrades to existing facilities, and the need to develop new capabilities.

Who contributed to this white paper?

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