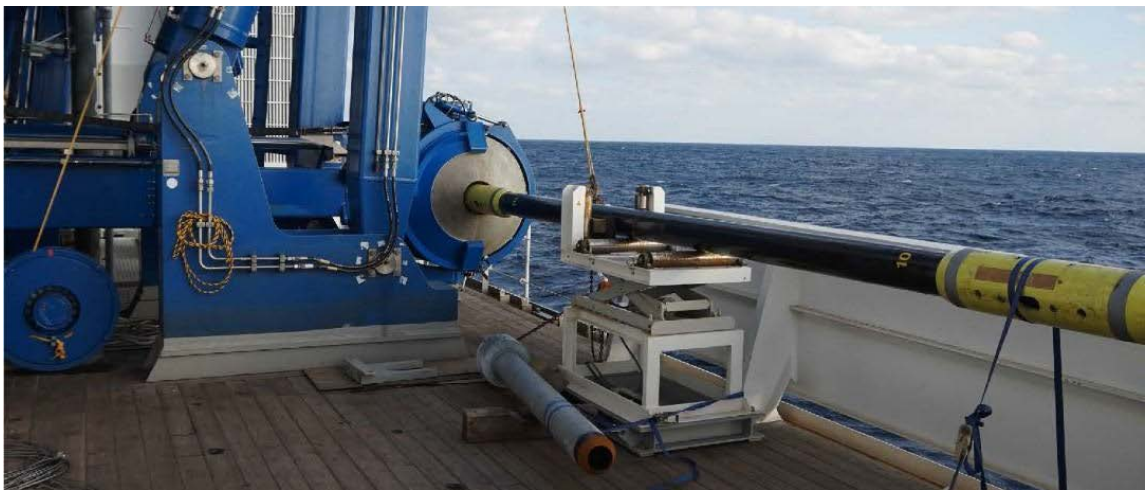

Report on giant piston coring (GPC) capability aboard RRS *Sir David Attenborough*: a UK science community workshop

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Executive summary

During the planning stages for the new UK polar research vessel, the UK community of marine geoscientists had emphasized the need for giant piston coring (GPC) capability on board of a Natural Environment Research Council (NERC) vessel. Only the availability of such a coring system would allow the recovery of sedimentary sequences more than 30 metres long, providing palaeoenvironmental records spanning ten thousand to one million years at high temporal resolution. As a result, NERC acquired a GPC as an associated project for the RRS *Sir David Attenborough* (*SDA*) to ensure the UK develops a leadership role in the field of seabed sampling. Due to pandemic-related delays and high pressure on *SDA* ship time, however, the GPC has not been taken to sea and trialled, yet. To address this issue, the UK science community held

a workshop at the British Antarctic Survey (BAS) in Cambridge on the 27th of March 2024. The hybrid workshop, which was attended by 56 researchers from across the UK and several international partner countries, had the goals to (i) raise awareness amongst the community of the GPC availability aboard *SDA*, (ii) identify scientific priorities for GPC deployments for answering globally significant science questions about our changing oceans and climate, and (iii) develop a strategy of utilizing this new and unique piece of research equipment. Through a series of oral presentations, breakout group discussions and plenary discussions, five unifying themes for progressing use of the UK's GPC were identified, and two priority actions summarised: (1) a 5-8 year coordinated, "NERC Big Idea" programme of GPC expeditions to answer a single key science question, and (2) a "Stepwise Approach" with multiple GPC cruises over an 8-10 year period addressing a range of science topics.

Introduction

During the 2023/24 season the *SDA* completed successfully her first scientific expeditions to the Southern Ocean after having previously undertaken various polar and science equipment trials. The state-of-the-art polar research vessel, which is owned by NERC and operated by BAS, and her new scientific equipment can now be fully utilized by the UK research community and international collaborators. One of the unique, novel capabilities that *SDA* provides is a GPC system manufactured by Ocean Scientific International Ltd. (OSIL). The GPC gives geoscientists the option to recover marine sedimentary sequences of up to 40.6 m length from shallow to deep sea settings in high, middle and low latitude regions. SDA's GPC capability advances the available "arsenal" of conventional coring gear aboard the NERC research vessel fleet, which, apart from the *SDA*, includes the RRS *James Cook* and RRS *Discovery* operated by the National Oceanography Centre (NOC) Southampton. Furthermore, *SDA*'s GPC offers UK researchers the only alternative to recover relatively long marine sediment cores, which otherwise can exclusively be retrieved by large multi-national science programmes, such as the International Ocean Discovery Program (IODP) and its successor IODP^3, or very few specialised ships owned by other nations, such as France's R/V *Marion Dufresne*.

In March 2024 an open community workshop (hybrid format) about GPC capability aboard the *SDA* was held at BAS Cambridge and online. The aims of the workshop, which was attended by 33 participants in person and another 23 participants online, were to raise awareness among the UK marine geoscience community of the new GPC availability aboard *SDA* and scientific targets achievable with this new kit, inform on the reasons why the GPC has not been utilised, yet, initiate the development of strategies to enable GPC use, and highlight the necessity of maximising the use of limited and therefore highly precious science time aboard *SDA*.

Workshop programme

Session 1: Context and framework

The first session provided the framework for researchers interested in writing proposals that will make use of *SDA*'s GPC capability. Presentations focussed on:

- The scientific and technical capabilities of *SDA*. It was pointed out that new scientific equipment, such as the GPC, will only be trialled according to scientific demand, i.e., when

funding for an *SDA* expedition intending to use this equipment has already been secured (*presenter: Dr Sophie Fielding, BAS*).

- The *SDA* itinerary over the coming years. It was highlighted that (i) a new Antarctic/Southern Hemisphere cruise could be scheduled at the earliest during the 2027/28 season (more likely 2029/30 season), whereas Northern Hemisphere GPC trials (requiring 24 days of mobilisation/demobilisation time in total) may be feasible in summer 2026, and a Northern Hemisphere GPC expedition may be possible as early as summer 2027, and (ii) GPC expeditions in the Atlantic Ocean on *SDA* transits between the UK and the Falkland Islands could only be accommodated, if Antarctic logistics cargo was shipped via an alternative route, e.g., on a chartered commercial cargo vessel (*presenter: Randolph Sliester, BAS*).
- Operational details and technical performance of the OSIL GPC. A report about GPC operations and performance on the highly successful mission-specific platform IODP Expedition 386 (Japan Trench) aboard the dedicated Japanese vessel R/V *Kaimei,* including the scientific achievements of this cruise, was presented (*presenter: Dr Jeremy Everest, British Geological Survey*).
- NERC funding opportunities which could support a science project using the GPC. Opportunities include 'Strategic Research and Innovation' streams (*Strategic Research and Innovation Priorities, Partnership and Opportunities, Highlight Topics* – new submissions for the latter are currently paused) and 'Discovery Science' streams (*Pushing the Frontiers, Large Grants*) (*presenter: Jessica Surma, UKRI-NERC*).

<u>Session 2: Scientific objectives</u>

The second session of the workshop comprised solicited presentations on scientific objectives achievable with *SDA*'s GPC and potential coring targets:

- High-resolution records of ice-ocean interactions during the last deglaciation and the Holocene can be obtained from fjords and palaeo-ice stream troughs on the NE Greenland shelf. Such records would improve our understanding of the driving mechanisms of current polar ice-sheet loss and resulting global sea-level rise (*presenter: Prof Jeremy Lloyd, Durham University*).
- Sediment drifts deposited by bottom currents under very high accumulation rates in the North Atlantic provide unique archives of oceanographic and climate changes in a key region of the Atlantic Meridional Overturning Circulation (AMOC). Records obtainable with a GPC, especially along selected depth transects, would allow to investigate circulation changes in the surface and deep North Atlantic on (sub-)decadal timescales from the pre-industrial period back to the last interglacial period (*presenter: Dr Paola Moffa-Sánchez, Durham University*).
- Within the middle to low latitude Atlantic Ocean basin, GPC recovery of sediment records accumulated under high depositional rates from the NW African continental margin would enable the simultaneous study of ocean and climate changes in this region, which is of high societal relevance. Dust and other proxy records (e.g., pollen) archived in these sediments at timescales down to decades would not only help to reconstruct and better understand

past droughts affecting Northern Africa as well as Holocene green periods in the Sahara, whose simulation still presents a major challenge for climate models, but also resolve the rapidity of such dramatic environmental shifts and identify potential climate tipping point (*presenter: Dr Anya Crocker, University of Southampton*).

- Sub-Antarctic sediment records targeted by a GPC in the Atlantic sector of the Southern Ocean would offer the possibility to analyse circulation changes within the Southern Ocean and along the AMOC throughout glacial-interglacial cycles on (sub-)millennial timescales, especially the timing and phasing of such changes in comparison to changes in the high-latitude Northern Hemisphere (e.g., bipolar seesaw). Furthermore, such records would shed light on the conundrum of potential carbon storage in the deep Southern Ocean during glacial times and its release back into the atmosphere during glacial terminations (*presenter: Prof Steve Barker, Cardiff University*).
- Similar to the records from the NE Greenland shelf, high resolution Holocene and last deglacial records from the continental shelves around the Antarctic Peninsula and on sub-Antarctic islands (such as the South Orkney Islands) are suitable GPC targets that would improve our understanding of ice-ocean interactions and rates of polar ice-sheet loss. Sediments deposited over glacial-interglacial cycles under high accumulation rates in the Scotia Sea and on the Falkland Plateau provide an opportunity to reconstruct changes in sea-ice extent and Antarctic Circumpolar Current circulation as well feedback mechanisms between ice, ocean and atmosphere (*presenter: Dr Claire Allen, BAS*).
- A systematic collection of carefully selected high-resolution sediment records spanning the time from the last glacial period to today along bathymetric and meridional transects in both the eastern and western Atlantic Ocean has the potential to resolve crucial unanswered questions about the timing and magnitude of changes in ocean circulation (current strength and direction), water column stratification and water mass distribution along the entire path of the AMOC. The combination of such a GPC coring strategy with a highly coordinated analytical multi-proxy approach for the recovered sediment samples would help to resolve discrepancies amongst both traditional and novel proxies. Data from such proxies are often available from just a few individual core sites, not only resulting in geographical and bathymetric data gaps but also introducing spatial bias. A synoptic mapping of the AMOC by GPC coring during *SDA* transits between the UK and the Southern Ocean would take time but provide invaluable insights of AMOC changes and related climate-ocean interactions on timescales spanning from decades to glacial-interglacial cycles. This knowledge would serve to assess the risk of abrupt AMOC collapse into reduced flow in response to current and future global warming (*presenter: Prof Alex Piotrowski, University of Cambridge*).

<u>Session 3: Breakout group and plenary discussions</u>

Workshop participants were divided into those online and those in-person, and then sub-divided into Northern Hemisphere and Southern Hemisphere groups. The results of the breakout group conversations were summarized and reported back to all participants. Breakout groups had identified five cross-cutting themes which are listed below. The first three themes summarise community scientific goals and the last two are perceived challenges for the GPC.

Unifying Themes

- *Theme #1: Value of GPC science and key research topics*

There was widespread enthusiasm for the new UK capability to recover sediment cores up to ~40 m long. Participants identified a broad range of science applications for GPC coring both in Northern Hemisphere areas (around Greenland, North Atlantic, around the UK) and in the Southern Ocean. These included but are not limited to: palaeoceanographic and palaeoenvironmental reconstructions (e.g., ocean overturning circulation; ice-sheet histories; CO_2 cycling and carbon sequestration; submarine mega-landslides, tsunami and other natural hazards; contourite and bottom current reconstructions; palaeoseismicity). The diversity of these interests illustrates how long piston cores will advance multiple different science areas.

- *Theme #2: A coordinated and integrated research programme for GPC expeditions*

There was a strong desire to maximise efficiency of future GPC coring campaigns via a series of coordinated proposals within a large, integrated research programme. The GEOTRACES programme (https://www.geotraces.org/) was mentioned several times as a successful example of large-scale, targeted marine data collection. However, it was also recognised that such an approach needs to be carefully focussed given that science time on the *SDA* is limited, and high-quality site survey data are needed for most GPC locations. Such a programme must also have a broad reach within the UK marine science community given the level of resource and ship time needed. A community-level coordinated approach minimises risks associated with individual projects or proxies, whilst at the same time fostering a more supportive and collaborative research environment. Such a programme could be centred around specific science themes e.g., high-resolution Holocene/deglacial records, or target specific past "time slices" identified by the community.

- *Theme #3: Potential GPC coring sites and linkages identified*

It was recognised that a "scattergun approach", where multiple proposals are submitted to NERC/UKRI, may be the way to initiate GPC trials and use of this capability. Several participants stated their intention to submit GPC proposals in the July 2024 or January 2025 *Pushing the Frontiers* rounds. A wide range of optimal GPC sites was identified based on participant expertise and scientific topics in *Theme #1*. Named examples were mostly from the Northern Hemisphere: Eirik Drift, Feni Drift, Donegal-Barra Fan, sites south of Iceland and in the northern part of the AMOC, sites on the NE and West Greenland continental margin, west coast of Africa, and mega-landslides within the Nordic seas that may create far travelling and highly dangerous tsunamis. Sites in the Southern Hemisphere had already been described in the talks by C. Allen and S. Barker but sub-Antarctic fjords (for carbon sequestration) and sites north of the Polar Front (best carbonate preservation) were also specifically mentioned.

- *Theme #4: Timing and location of GPC cruises*

There was significant concern that the SDA's schedule excludes her availability for GPC coring cruises for a considerable time (Southern Hemisphere earliest GPC cruise probably not before 2029/30; Northern Hemisphere earliest possibility in 2027). There were multiple requests for clarity on ship/GPC availability. Two further notes: (i) If the SDA with her GPC capability is potentially being offered for IODP[3] mission-specific platform cruises at one point in the future

(which is understood to be under consideration by UKRI/NERC), this will open up a new way for GPC proposals on one hand but limit the time for GPC cruises proposed by the UK community on the other hand, and (ii) there is also strong desire for GPC capability on transit legs and even outside traditional *SDA* operating area in the longer term (e.g., Pacific Ocean).

- *Theme #5: Funding, international collaboration and GPC core storage*

The community questioned the best method to secure funding for GPC cruises in the future and requested clarification from NERC/UKRI. There is desire for a large-scale strategic programme (*Theme #2*) but how should this be fed up to NERC? The community wants increased collaboration with international partners (e.g., Denmark, Germany) beyond existing partnerships (NERC-NSF, UK-Norway), particularly because partners often hold important site survey information (seismic data, short sediment cores) that is required before GPC coring can take place. A final point was raised that the UK core storage facility, i.e., the *British Ocean Sediment Core Research Facility* (*BOSCORF*) at NOC in Southampton, is completely full. So, the question arises where long GPC cores will be stored for the long term after their collection, given that BAS core storage capability is limited, even though it has recently been extended. Other core storage facilities at higher education institutions in the UK are also near capacity.

"Setting the scene" for GPC capability on RRS *Sir David Attenborough*

During a plenary discussion following the breakout group reports, the community identified a list of priority actions (see below) for future use of the GPC. However, several potential restrictions were noted, and these are stated here to "set the scene" ahead of the list.

- The *SDA* is unlikely to sail outside of the Atlantic Ocean and adjacent polar regions.
- The GPC system cannot be easily transferred to another ship via barter systems.
- GPC use in the Southern Ocean can probably only begin in the 2029/30 season (vs. 2027 for the Arctic); this represents a significant delay for the Antarctic community.
- There needs to be a dedicated trials cruise prior to any *bona fide* GPC science cruise with technical and ship expertise preserved.
- Additional marine engineering resource at BAS is required to support GPC coring (e.g., support from NOC's National Marine Facilities).
- The community desire for GPC coring during *SDA* transit legs (i.e., from the UK to the Southern Ocean) comes with a significant knock-on to BAS operations; it is likely that a second (i.e., charter) vessel would be required to fulfil BAS logistical needs.

Priority actions for GPC capability

1. **"BIG IDEA" programme (5-8 years):** The UK community is strongly supportive of a systematic, coordinated programme of GPC coring with common and broad scientific goals. A "Big Idea" programme would be based on a key scientific objective for global ocean and environmental change and could pave the way for a funding opportunity for GPC expeditions, e.g., via *Strategic Research and Innovation priorities* funding. One idea is to identify critical new sites for GPC coring as well as known "treasure" sites where new material is needed to carry out state-of-the-art proxy work, along the pathway

of the AMOC from the North Atlantic to the Southern Ocean. AMOC is a key part of the global ocean conveyor that regulates heat, carbon, and nutrient transfer in the Atlantic Ocean, including towards the UK. This coordinated approach would involve deriving the same proxy records for each site to ensure comparability and would be designed to fill crucial spatial and bathymetric knowledge gaps. GPC cores could also be used to determine the wider relationship between AMOC circulation, ocean warming, polar ice-sheet melting, related sea-level rise, and tsunamigenic mega-landslides in the Nordic seas.

2. **Stepwise approach (8-10 years):** An alternative to the above includes a series of GPC coring expeditions, for example, on average one per year over an 8-10 year period based on individual proposals addressing a range of science topics. However, it was recognized that back-to-back GPC cruises are required to preserve GPC capability in terms of technical and ship-based expertise. Within the total timeframe, GPC expeditions could be scheduled by science theme (e.g., resolving ice-sheet histories for 2 years and then natural hazards for 2 years etc.), or by geographic location, addressing diverse scientific topics (e.g., Greenland and North Atlantic for 2 years, then equatorial Atlantic for 2 years).

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