Title: **Drilling a site on the Portuguese Margin as a Pleistocene Marine Reference Section for Terrestrial-Marine-Ice core correlation**

Proponent(s): David Hodell, Fatima Abrantes, Gabriela Carrara, Luke Skinner, Chronis Tzedakis

Keywords: Portuguese Margin, Pleistocene, millennial climate variability

Area: Iberian Margin

Contact Information:

- **Contact Person:** David Hodell
- **Department:** Earth Sciences
- **Organization:** University of Cambridge
- **Address:** Downing Street, Cambridge CB2 3EQ
- **Tel.:** +44 (0) 1223 330270
- **Fax:** +44 (0) 1223 333450
- **E-mail:** dah73@cam.ac.uk

Permission to post abstract on IODP Web site: Yes

Abstract: *(400 words or less)*

Few marine sediment cores have played such a pivotal role in paleoclimate research as MD95-2042 from the Portuguese margin (hereafter referred to as the “Shackleton site”). This core preserves a high-fidelity record of millennial–scale climate variability for the last glacial cycles and has been correlated to Greenland ice cores. Here we request 4 days of ship time to extend this remarkable sediment archive to the base of the Pleistocene by drilling four holes to a depth of 150 m. The record will serve as a marine reference section of Pleistocene climate variability.
Scientific Objectives: (250 words or less)

Recovery of a complete Pleistocene record at Shack-04 will provide the material needed to:
1. Document millennial-scale climate variability for older glacial periods of the Pleistocene, including changes in surface and deep-water circulation. 2. Derive a marine sediment proxy record for the Greenland Ice Core beyond the last glacial cycle. 3. Determine interhemispheric phase relationships (leads/lags) by comparing planktic and benthic signals in the same core, thereby overcoming problems of age determination on millennial time scales. 4. Study how millennial and orbital scale variability interact to produce the observed patterns of Pleistocene glacial cycles. 5. Study the stability of climate during past interglacial periods. 6. Link terrestrial, marine and ice core records by analyzing pollen and terrestrial biomarkers that are rapidly delivered to the deep-sea environment off Portugal by rivers.

Please describe below any non-standard measurements technology needed to achieve the proposed scientific objectives.

<p>| Proposed Sites: |</p>
<table>
<thead>
<tr>
<th>Site Name</th>
<th>Position</th>
<th>Water Depth (m)</th>
<th>Penetration (m)</th>
<th>Brief Site-specific Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shack-04</td>
<td>37° 34.29’N, 10° 7.57’W</td>
<td>2578</td>
<td>150 m</td>
<td>150 m</td>
</tr>
</tbody>
</table>
1. Introduction

The impetus for this proposal is Nick Shackleton’s pioneering work on Core MD95-2042 from the Iberian Margin (Fig. 1), which has played a central role in our understanding of millennial-scale climate variability over the last glacial cycle. The unique strength of the sediment record from the Portuguese margin is the promise of correlating millennial-scale variability from the marine environment with ice cores from Greenland and Antarctica (Fig. 2) and with European terrestrial sequences (e.g., Shackleton et al., 2002, 2003; Tzedakis et al., 2004, 2009). Many important scientific contributions were made through the study of the Portuguese Margin cores, some of which include:

1.) timescale development including calibration of the Greenland time scale (e.g., SFCP04 ice-core chronology; Shackleton et al., 2004).
2.) inter-hemispheric phasing (lead/lag) of the climate system during the last glaciation (Shackleton et al., 2000)
3.) millennial-scale variability over the last glacial cycle (Cayre et al., 1999; de Abreu et al., 2003, 2005; Martrat et al., 2007; Moreno et al., 2002; Pailler and Bard, 2002; Schonfeld et al., 2003; Skinner et al., 2003)
4.) study of the last interglacial period (MIS 5e) (Shackleton et al., 2002, 2003; deAbreu et al., 2005; Desprat et al., 2006, 2009; Eynaud et al., 2000)
5.) marine-terrestrial linkages by studying pollen that is transported to the deep-sea environment off Portugal (Shackleton et al., 2002, 2003; Desprat et al., 2006; Sanchez Goni et al., 1999, 2002; Roucoux et al., 2001, 2006; Tzedakis et al., 2004, 2009).

MD95-2042 has become a marine reference section for the last glacial period and linking the marine sediment record to polar ice cores and terrestrial archives. Here we request three days of ship time to extend this remarkable record through the Pleistocene by drilling with the JOIDES Resolution (JR).

2. Site Location and relation to other IODP drilling proposals

MD95-2042 was recovered using the CALYPSO Kullenburg corer aboard the Marion Dufresne during a 1995 IMAGES Cruise to the Iberian Margin in a water depth of 3146 m. The core is 32-m long but only the upper 27 m is useable because the lower 5 m is disturbed by flow-in. Sedimentation rates are high, averaging 22 cm kyr\(^{-1}\), providing a detailed record of millennial-scale climate variability that can be confidently correlated to Greenland ice cores (Fig. 2). Nearby cores were collected during IMAGES cruises in 1999 (MD99-2334) and 2001, including MD01-2444 at the location as the proposed site Shack-04.
Fig. 1. The west Iberian Margin (top right) showing location of existing DSDP and ODP sites and piston cores (top left) and detailed bathymetry, core locations and seismic lines in the proposed drilling area (bottom).

Fig. 1. Shack-04 is located at the same position as core MD01-2444.
We propose to drill four holes at Site Shack-04 (37° 34.29′ N, 10° 7.57′ W, 2578 m) located at MD01-2444 and removed from areas showing evidence of downslope transport. Using the IODP Coring Time Estimator Program, quadruple APC to 150 mbsf at Shack-04 will require exactly 4 days, including trip in, pull to mud line between holes, and trip to completion upon last hole but no logging.

The most closely related IODP proposal is #644 (Mediterranean Overflows/GUCADRILL) Environmental Significance of the Mediterranean Outflow Water and its Global Implications. This proposal has been forwarded to OTF for scheduling. Proposal #644 included a site (WI-02A) at the location of piston core MD95-2042 but the site has been relegated to secondary priority and will not be drilled unless dedicated time is allotted through an APL. The main objective of GUCADRILL is to study the history of Mediterranean Outflow Water (MOW) by drilling contourite deposits in the Gulf of Cadiz and West Iberia. Site WI-02A is considered to be complementary to the primary objective of GUCADRILL as it provides a link to study how variations in MOW may affect Atlantic Meridional Overturning Circulation (AMOC). Rather than dilute the main objectives of GUCADRILL, we request 4 days of ship time to be added to the Mediterranean Overflows expedition or another geographically-compatible mission (e.g., Existing proposals in the vicinity include #673, 689, 740).

The European Science Foundation has funded a planning workshop on drilling the...
“Shackleton sites” on the Portuguese Margin as part of the Magellan Workshop Series to be held in November 2009 in Lisbon, Portugal. The product of the workshop will be a full IODP proposal to be submitted April 1, 2010. The full drilling proposal will include multiple sites to provide a greater range of water depths, target sections with the greatest possible sedimentation rates for each time period of interest, and maximize the opportunities to obtain continuous sequences that are undisturbed by downslope transport. Given the late submission date of this proposal, we are uncertain whether the full proposal will make it through the review process and be scheduled for drilling during this phase of IODP which ends in 2013. Furthermore, it is unclear what will become of proposals currently in the system during the transition phase to a new program. We believe it is vital to drill at least one of the “Shackleton sites” on the Portuguese Margin during the current phase of IODP. With advice from SASEC panel members, we have adopted a two-prong strategy of submitting an APL to be followed by a full proposal in April.

3. Objectives

3.1. A Marine Sediment Analog to the Polar Ice Cores

The polar ice cores have provided superb records of climate change and have become the benchmarks of Pleistocene climate variability. An important challenge for IODP is to identify complementary marine sections with sufficiently high sedimentation rates and climate signals that are suitable for comparison with the ice core records. Only by integrating marine and ice core stratigraphies can we begin to address mechanisms of the coupled ocean-atmosphere system, including the causes of Dansgaard-Oeschger variability, glacial-interglacial cycles and atmospheric CO₂ variation. The oldest ice recovered in Greenland and Antarctica is 124 ka and 900 ka, respectively, and these records are unlikely to be extended beyond 200 ka (Greenland) and 1.5 Ma (Antarctica). We currently must rely on the atmospheric methane record from Antarctic ice cores to serve as a Greenland proxy for rapid North Atlantic changes beyond the last glacial cycle (e.g., Wolff et al., 2009). Temperature proxies (planktic δ¹⁸O and UK’37) at Core MD95-2042 bear a remarkable resemblance to the δ¹⁸O record of the Greenland Ice Core whereas benthic δ¹⁸O resembles Antarctic ice cores for the last glacial period (Fig. 2). A long millennially-resolved record from PORT-1A could serve as a marine sediment proxy record for the Greenland Ice Core beyond 125 ka.

3.2 Interaction of Orbital and Millennial Bands
An important focus of paleoclimate research over the past 15 years has been to understand the origin of millennial-scale climate oscillations that are expressed in records of Greenland and Antarctic ice cores. With few exceptions, deep-sea sedimentary records generally lack the resolution needed to delineate such variability; however, exceptions do exist such as those from the Portuguese Margin (Fig. 2). Millennial-scale climate variability has been well documented for the last glacial cycle in the North Atlantic, but relatively little is known about such variability during older glacial periods of the Pleistocene. Drilling Site PORT-1A will yield long, continuous time series of millennial-scale variation to address questions such as:

1. How do millennial and orbital bands of climate variability interact? What role do millennial-scale events play in triggering glacial terminations (Wolff et al., 2009)?
2. How did millennial-scale variability “evolve” as glacial and orbital boundary conditions changed during the Pleistocene? Did millennial-scale climate variability change in frequency or amplitude across the mid-Pleistocene transition (~920 and 640 ka) when the average climate state evolved toward generally colder conditions with larger ice sheets, and the spectral character of climate variability shifted from dominantly 41 to 100 kyrs?

3.4 Overcoming The Problem with Age Models on Millennial Timescales
Determining the correlation and phase relationships of millennial-scale variability in the ocean-climate system is difficult because absolute dating is too imprecise to resolve the exact timing of events on these time scales. Correlation is often based on “wiggle matching” of climate records that pre-supposes synchronicity for which there is no independent evidence (Wunsch, 2006). An alternative approach is to determine the relative phasing of changes in proxy variables that monitor different components of the ocean-climate system in the same core. Shackleton et al. (2000, 2004) successfully applied this approach to Portuguese Margin Core MD95-2042 by correlating the planktic δ¹⁸O to Greenland and then determining the phase relationships between Greenland and Antarctica by comparing the timing of planktic and benthic δ¹⁸O changes. This same approach of comparing surface and deep proxies can be applied to PORT-1A and extend the study of interhemispheric phase relationships to older glacial periods.

3.4 Marine-Terrestrial Linkages
Marine archives recovered adjacent to the continents have the potential to link continental and marine climate records. The Portuguese Margin has emerged as a critical area for continent-ocean connections because of the combined effects of major river systems and a narrow
continental shelf that lead to the rapid delivery of terrestrial material (e.g., pollen, organic biomarkers) to the deep-sea environment (Tzedakis et al., 2004, 2009). The western Iberian margin not only provides a rare opportunity to link terrestrial and marine records, but also offers the possibility of tying them to polar ice-cores.

4. Community Support
There is wide interest and support within the paleoceanographic community in seeing the Portuguese Margin drilled. At a recent IODP-ICDP workshop on “Acquiring High to Ultra-high Resolution Geological Records of Past Climate Change by Scientific Drilling” (29th Sept-1st Oct 2008, GFZ, Potsdam), the Shackleton sites were identified as a key target for future IODP drilling to obtain marine sediment analogs to the polar ice cores (Thurow et al., 2009). The European Science Foundation has funded a workshop on drilling the Iberian Margin as part of the Magellan Workshop Series to be held in November 2009 in Lisbon, Portugal. A white paper to drill the “Shackleton sites” was submitted and favorably discussed in working groups at the recent IODP INVEST meeting in Bremen (23-25 Sept 2009).

5. Summary
Four days of drilling are requested at Site Shack-04 to quadruple-APC to a depth of ~150 m. Drilling even one site on the Portuguese Margin would be a very wise investment for IODP as the science is low risk and is likely to have very high scientific impact. Alley (2003) suggested that paleoceanographers should consider following the ice core community’s lead and organize a research effort to “generate a few internationally coordinated, multiply replicated, multiparameter, high time resolution-type sections of oceanic change.” We support such an approach and propose that Shack-04 could constitute one such marine reference section. The site could serve as a proof of concept for adopting a new strategy for sampling and analyzing IODP cores that emphasizes a truly muti-proxy approach with attention to resolution, replication and time control.

6. References
de Abreu, Lucia; Shackleton, Nicholas J; Schönfeld, Joachim; Hall, Melinda; Chapman, Mark R., 2003. Millenial-scale oceanic climate variability off the Western Iberian margin during the last two glacial periods, Marine Geology, 196(1-2), 1-20, doi:10.1016/S0025-3227(03)0046-X


Shackleton, N. J., M. A. Hall, and E. Vincent (2000), Phase relationships between millennial-scale events 64,000–24,000 years ago, Paleoclimatology, 15, 565–569.


List of Proponents and Expertise:

David A. Hodell (Godwin Laboratory for Paleoclimate Research, University of Cambridge, Cambridge, UK CB2 3EQ, E-mail: dah73@cam.ac.uk)
Expertise: Paleoceanography, stable isotope geochemistry, marine stratigraphy, nature and origin of suborbital climate variability in the polar oceans, developing marine sediment analogs to the polar ice cores, ocean-atmosphere linkages and the relative timing, phasing, and interhemispheric coupling mechanisms of climate change, role of the Southern Ocean in global carbon cycling and climate change, causes of glacial-to-interglacial cycles.

Fatima Abrantes (Marine Geology Unit., LNEG, Estrada da Portela, Zambujal, Apartado 7586, PT-2721-866 Amadora, Portugal, E-mail: fatima.abrantes@ineti.pt)
Expertise: Paleoceanography, oceanic paleoproductivity Cenozoic marine diatoms (taxonomy, evolution, biostratigraphy), general sedimentology and geochemistry of marine sediments.

Gabriela Carrara (Marine Geology Unit., LNEG, Estrada da Portela, Zambujal, Apartado 7586, PT-2721-866 Amadora, Portugal, E-mail: gabriela.carrara@ineti.pt)
Expertise: Acquisition, processing and interpretation of marine seismic single and multichannel profiles, bathymetric and reflectivity data, morphotectonic and structural analysis in marine areas of mid ocean ridges, transform faults and back-arc settings, management of multidisciplinary data by relational databases.

Luke Skinner (Godwin Laboratory for Paleoclimate Research, University of Cambridge, Cambridge, UK CB2 3EQ, E-mail: lcs32@cam.ac.uk)
Expertise: Paleoceanography-paleoclimate, marine sediments and millennial climate change, millennial variability of surface- and deep-water Temperature, deep-water radiocarbon variability and millennial climate change, marine isotope stage stratigraphy

Chronis Tsedakis (UCL Department of Geography, Room 107, Pearson Building,, University College London, Gower Street, London, WC1E 6BT, E-Mail: p.tzedakis@ucl.ac.uk)
Expertise: Quaternary palaeoecology and stratigraphy. palynology, linking marine-terrestrial chronologies, response of vegetation to variations in climatic forcing on orbital and millennial/centennial timescales.
IODP Site Summary Forms:  
Form 1 - General Site Information  
Please fill out information in all gray boxes  
Revised 7 March 2002

Section A: Proposal Information

Title of Proposal: Correlation of Marine, Ice-core and Terrestrial Records by IODP Drilling of the “Shackleton sites” on the Iberian Margin

Date Form Submitted: 1 April 2010

Site Specific Objectives with Priority (Must include general objectives in proposal)
1. Recover millennial-scale marine reference section for the Quaternary
2. Provide marine sediment analog to the polar ice cores
3. Reconstruct deep water circulation changes (i.e., mixing ratio of southern and northern component water.
4. Facilitate marine-terrestrial correlations.
5. Construct an integrated stratigraphy (geomagnetic paleointensity, oxygen isotopes, etc)

List Previous Drilling in Area: No drilling sites are available in the immediate area. Many long piston cores have been collected through the years, both as part of the IMAGES programme as of the POP project (see Figure 1).

Section B: General Site Information

Site Name: (e.g. SWPAC-01A) 4A
Area or Location: Southwest Portugal
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #

Latitude: Deg: 37 Min: 34.29 N
Jurisdiction: Portugal
Longitude: Deg: 10 Min: 07.57 W
Distance to Land: 115 km
Coordinates System: WGS 84, Other ( )
Water Depth: 2578 m
Priority of Site: Primary: XX Alt:
## Section C: Operational Information

### Proposed Penetration: (m)
- Sediments: 500 m
- Basement: 150 m

What is the total sed. thickness? >1500 m

### General Lithologies:
- Clay, silt and sand

### Coring Plan:
- (Specify or check)
- 1-2-3-APC  PC*  XD  MD*  PCS  CB  Rddy  GB  GB*  Systems Currently Under Development

### Wireline Logging Plan:
- Standard Tools
  - Neutron-Porosity
  - Litho-Density
  - Gamma Ray
  - Resistivity
  - Acoustic
  - Formation Image
- Special Tools
  - Borehole Televiwer
  - Nuclear Magnetic Resonance
  - Geochemical
  - Side-Wall Core Sampling
  - Borehole Seismic
  - Borehole Temperature & Pressure
  - Formation Fluid Sampling
- LWD
  - Density-Neutron
  - Resistivity-Gamma Ray
  - Acoustic
- Expected value (For Riser Drilling) °C

### Max. Borehole Temp.:
- Expected value (For Riser Drilling)

### Mud Logging:
- (Riser Holes Only)
- Basic Sampling Intervals: 5m

### Estimated days:
- Drilling/Coring: 4
- Logging: 1.1
- Total On-Site: 4

### Future Plan:
- Please check following List of Potential Hazards

<table>
<thead>
<tr>
<th>Potential Hazards</th>
<th>Weather Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow Gas</td>
<td>November</td>
</tr>
<tr>
<td>Complicated Seabed Condition</td>
<td>November</td>
</tr>
<tr>
<td>Hydrothermal Activity</td>
<td>November</td>
</tr>
<tr>
<td>Hydrocarbon</td>
<td>November</td>
</tr>
<tr>
<td>Soft Seabed</td>
<td>November</td>
</tr>
<tr>
<td>Landslide and Turbidity Current</td>
<td>November</td>
</tr>
<tr>
<td>Shallow Water Flow</td>
<td>November</td>
</tr>
<tr>
<td>Currents</td>
<td>November</td>
</tr>
<tr>
<td>Methane Hydrate</td>
<td>November</td>
</tr>
<tr>
<td>Abnormal Pressure</td>
<td>November</td>
</tr>
<tr>
<td>Fractured Zone</td>
<td>November</td>
</tr>
<tr>
<td>Diapir and Mud Volcano</td>
<td>November</td>
</tr>
<tr>
<td>Man-made Objects</td>
<td>November</td>
</tr>
<tr>
<td>Fault</td>
<td>November</td>
</tr>
<tr>
<td>High Temperature</td>
<td>November</td>
</tr>
<tr>
<td>H2S</td>
<td>November</td>
</tr>
<tr>
<td>High Dip Angle</td>
<td>November</td>
</tr>
<tr>
<td>Ice Conditions</td>
<td>November</td>
</tr>
<tr>
<td>CO2</td>
<td>November</td>
</tr>
</tbody>
</table>

What is your Weather window? (Preferable period with the reasons)

First weeks of November. Weakest wind season in the area.
## IODP Site Summary Forms:

Please fill out information in all gray boxes

<table>
<thead>
<tr>
<th>Proposal #:</th>
<th>Site #: 4A</th>
<th>Date Form Submitted: 1 April 2010</th>
</tr>
</thead>
</table>

### Details of available data and data that are still to be collected

<table>
<thead>
<tr>
<th>Data Type</th>
<th>SSP Requirements</th>
<th>Exists In DB</th>
<th>Details of available data and data that are still to be collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High resolution seismic reflection</td>
<td>chirp line acquired simultaneously with BIGSETS multichannel survey</td>
<td>Primary Line(s) chirp BS09 (Location of Site on line (SP or Time only))</td>
</tr>
<tr>
<td>2</td>
<td>Deep Penetration seismic reflection</td>
<td>multichannel seismic lines BIGSETS (48 chan) and medium resolution multichannel (12 chan) STEAM 94</td>
<td>Primary Line BIGSETS 09 (Location of Site on line (SP or Time only)): SP 3950</td>
</tr>
<tr>
<td>3</td>
<td>Seismic Velocity†</td>
<td>Derived from multichannel seismic reflection profiles</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Seismic Grid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5a</td>
<td>Refraction (surface)</td>
<td>Regional refraction data exits from several research projects and national institutions: González <em>et al.</em> (1996, 1998, 2001); Dávila (1999); Mendes-Victor <em>et al.</em> (1999); Gutsher <em>et al.</em>, 2001; Medialdea, <em>et al.</em> (2004). Data set in the following institutions: Instituto Jaime Almera, CSIC (Spain); Real Observatorio de la Armada de San Fernando (Spain); Instituto Geológico y Minero de España (Spain); Université de Brest (France); Instituto de Ciencias del Mar, CSIC (Spain); ISMAR-BO Istituto Scienze Marine (Bologna, Italy); Universidade de Lisboa (Portugal), LNEG (Portugal).</td>
<td></td>
</tr>
<tr>
<td>5b</td>
<td>Refraction (near bottom)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3.5 kHz</td>
<td></td>
<td>Location of Site on line (Time)</td>
</tr>
<tr>
<td>7</td>
<td>Swath bathymetry</td>
<td>SWIM swath bathymetry compilation (Zitellini <em>et al.</em> 2009)</td>
<td></td>
</tr>
<tr>
<td>8a</td>
<td>Side-looking sonar (surface)</td>
<td>GLORIA (Discovery cruise 90, Portugal)</td>
<td></td>
</tr>
<tr>
<td>8b</td>
<td>Side-looking sonar (bottom)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Photography or Video</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Heat Flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11a</td>
<td>Magnetics</td>
<td>Regional <em>magnetic &amp; gravimetric</em> data from several research projects and national institutions: Dañobeitia <em>et al.</em> (1999); Srivastava <em>et al.</em> (2000), Galindo-Zaldivar <em>et al.</em> (2003); Roeser <em>et al.</em> (2002); Rovere, <em>et al.</em> (2004); Silva <em>et al.</em>, (2000). Data set in the following institutions: Instituto Jaime Almera, CSIC (Spain); Real</td>
<td></td>
</tr>
</tbody>
</table>
Observatorio de la Armada de San Fernando (Spain); Instituto Geológico y Minero de España (Spain); Universidad de Brest (France); Instituto de Ciencias del Mar, CSIC (Spain); ISMAR-Istituto Scienze Marine (Bologna, Italy); Universidade de Lisboa (Portugal), LNEG (Portugal).

11b Gravity

12 Sediment cores MD01-2444.

13 Rock sampling

14a Water current data

14b Ice Conditions

15 OBS microseismicity NEAREST 2007-2008

16 Navigation

17 Other

SSP Classification of Site: SSP Watchdog: Date of Last Review:

SSP Comments:

X=required; X*=may be required for specific sites; Y=recommended; Y*=may be recommended for specific sites; R=required for re-entry sites; T=required for high temperature environments; † Accurate velocity information is required for holes deeper than 400m.
**IODP Site Summary Forms:**

<table>
<thead>
<tr>
<th>Proposal #: 763-APL</th>
<th>Site #: 4A</th>
<th>Date Form Submitted: 1 April 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Depth (m): 2578</td>
<td>Sed. Penetration (m): 150</td>
<td>Basement Penetration (m):</td>
</tr>
</tbody>
</table>

Do you need to use the conical side-entry sub (CSES) at this site? Yes ☐ No ☐

Are there high temperatures expected at this site? Yes ☐ No ☐

Are there any other special requirements for logging at this site? Yes ☐ No ☐

If “Yes” Please describe requirements: ________________________________

What do you estimate the total logging time for this site to be: _______

<table>
<thead>
<tr>
<th>Measurement Type</th>
<th>Scientific Objective</th>
<th>Relevance (1=high, 3=Low)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutron-Porosity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litho-Density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gamma Ray</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistivity-Induction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acoustic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FMS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BHTV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistivity-Laterolog</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnetic/Susceptibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density-Neutron (LWD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistivity-Gamma Ray (LWD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other: Special tools (CORK, PACKER, VSP, PCS, FWS, WSP)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For help in determining logging times, please contact the ODP-LDEO Wireline Logging Services group at:

borehole@ldeo.columbia.edu
http://www.ldeo.columbia.edu/BRG/brg_home.html
Phone/Fax: (914) 365-8674 / (914) 365-3182

Note: Sites with greater than 400 m of penetration or significant basement penetration require deployment of standard toolstrings.
<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Summary of Operations at site: (Example: Triple-APC to refusal, XCB 10 m into basement, log as shown on page 3.)</td>
<td>4x-APC to refusal.</td>
</tr>
<tr>
<td>2</td>
<td>Based on Previous DSDP/ODP drilling, list all hydrocarbon occurrences of greater than background levels. Give nature of show, age and depth of rock:</td>
<td>NO DSDP/ODP drilling in the area</td>
</tr>
<tr>
<td>3</td>
<td>From Available information, list all commercial drilling in this area that produced or yielded significant hydrocarbon shows. Give depths and ages of hydrocarbon-bearing deposits.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Are there any indications of gas hydrates at this location?</td>
<td>NO</td>
</tr>
<tr>
<td>5</td>
<td>Are there reasons to expect hydrocarbon accumulations at this site? Please give details.</td>
<td>NO</td>
</tr>
<tr>
<td>6</td>
<td>What “special” precautions will be taken during drilling?</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>What abandonment procedures do you plan to follow:</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Please list other natural or manmade hazards which may effect ship’s operations: (e.g. ice, currents, cables)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Summary: What do you consider the major risks in drilling at this site?</td>
<td>No major risks expected.</td>
</tr>
<tr>
<td>Sub-bottom depth (m)</td>
<td>Key reflectors, Unconformities, faults, etc</td>
<td>Age</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------------------------------</td>
<td>-----</td>
</tr>
<tr>
<td>86 m (102 ms)</td>
<td>Sea bottom 2578 m</td>
<td>1.8 Ma</td>
</tr>
<tr>
<td>397.8 m (468 ms)</td>
<td>Purple reflector (Discontinuity)</td>
<td>Upper Pliocene (3.6 Ma)</td>
</tr>
<tr>
<td>498.1 m (586 ms)</td>
<td>Green reflector (Unconformity)</td>
<td>Base Pliocene (5.4 Ma)</td>
</tr>
</tbody>
</table>
Correlation of Marine, Ice-core and Terrestrial Records by IODP Drilling of the "Shackleton sites" on the Iberian Margin

Site SHACK-4A

Shot 4500 on Station 9407
Shot 3900 on BS-09
Site SHACK-4A