

# IODP Proposal Cover Sheet

937 - Add

Deepening Hole U1309D

Received for:

Title	Accessing the Building Blocks of Life: Deepening Hole U1309D, Atlantis Massif, Mid-Atlantic Ridge		
Proponents	Andrew McCaig, Donna Blackman, Beth Orcutt, Benedicte Menez, Marvin Lilley, Geoffery Wheat, Johan Lissenberg, Benoit Ildefonse, Frieder Klein, Susan Lang, William Seyfried, Muriel Andreani, Barbara John, Marguerite Godard, Antony Morris, Esther Schwarzenbach, Christopher MacLeod, Ivan Savov, Natsue Abe, Yasukiko Ohara		
Keywords	serpentinization, hydrogen, methane, gabbro, fluid	Area	Mid-Atlantic Ridge

## Proponent Information

Proponent	Andrew McCaig
Affiliation	University of Leeds
Country	United Kingdom

Permission is granted to post the coversheet/site table on [www.iodp.org](http://www.iodp.org)

## Abstract

The Atlantis Massif Oceanic Core Complex (OCC) is one of the best studied locations in the ocean crust, the site of four IODP expeditions so far (304, 305, 340T and 357). It is the site of the Lost City Hydrothermal Field (LCHF), venting alkaline fluids rich in hydrogen and methane at 40-90 centigrade. IODP Hole U1309D, located 5km north of the LCHF, is the deepest (1415m) hole so far drilled in young (<2 Ma) ocean crust, sampling a primitive series of gabbroic rocks interpreted in part to be metasomatised peridotite. Gabbroic lithologies in Hole U1309D contrast with serpentinized peridotites sampled near the LCHF by seafloor coring in Exp. 357 and sampling on the south wall of the Massif. The hydrologic regime is also very different at the two locations, with deep permeability required beneath the LCHF, and a low permeability conductive regime evidenced by a linear thermal gradient deeper than 750 mbsf in Hole U1309D.

The principle aim of this proposal is to sample fluids and rocks in a stable regime with temperatures higher than ever sampled before by IODP. We hope to access temperatures above 200 centigrade, where active serpentinization is occurring in olivine-rich rocks, and where the building blocks for life (H<sub>2</sub>, CH<sub>4</sub>, and more complex organic compounds) may be created abiotically.

In addition we will drill a short Hole close to the Lost City Hydrothermal Field in order to gain a complete section through a detachment fault zone and address biosphere, structural and alteration objectives not completed in IODP Expedition 357 due to failure to penetrate to depths envisaged.

We will sample fluids in the existing Hole 1309D using newly developed temperature-sensitive sampling tools and leave a clean legacy hole reaching 2100 mbsf and temperatures of 220 C for future logging and fluid sampling once thermal equilibrium has returned. H<sub>2</sub>, CH<sub>4</sub>, other organic molecules and cations will be sampled in fluid inclusions to compare with ambient fluids. We hypothesise that concentration gradients in volatile species may exist in the Massif.

We will also study the magmatic evolution of oceanic core complexes including melt-rock reaction processes critical to the assembly and geochemistry of oceanic gabbro bodies and the relationship between plutonic rocks and MORB. Drilling to temperature regimes not previously accessed by IODP will allow the limitations of current technology to be evaluated in preparation for future deep drilling.

## Scientific Objectives

Our proposed drilling strategy will address a number of objectives in the Earth in Motion, Earth Connection and Biosphere Frontiers themes of the IODP Science Plan.

Objective 1: The life cycle of an oceanic core complex: Links between igneous, metamorphic, structural and fluid flow processes, and testing of geophysical and hydrothermal models. This objective addresses Science Plan Challenge 9: "How are seafloor spreading and mantle melting linked to ocean crustal architecture?" Challenge 10: "What are the mechanisms, magnitude and history of chemical exchanges between the ocean crust and seawater" and Challenge 14: "How do fluids link subseafloor tectonic, thermal, and biogeochemical processes?"

Objective 2: Accessing the chemical kitchen preceding the appearance of life on Earth: formation of organic molecules of prebiotic interest at high and low temperatures in the Atlantis Massif. This objective addresses Science Plan challenge 10 "What are the mechanisms, magnitude, and history of chemical exchanges between the oceanic crust and seawater?", Challenge 13 "What properties and processes govern the flow and storage of carbon in the subseafloor"; and Challenge 14 "How do fluids link subseafloor tectonic, thermal, and biogeochemical processes?" It will also be of great interest to the Astrobiology Community studying hydrothermal processes on Icy Worlds and Mars

Objective 3: Deep biosphere and limits for life in the Atlantis Massif: controls of lithological substrate, porosity and permeability, temperature, fluid chemistry and reactive gradients on microbiology. This objective concerns Science Plan Challenge 5 "What are the origin, composition, and global significance of deep subseafloor communities?" and Challenge 6 "What are the limits of life in the subseafloor realm?"

### Non-standard measurements technology needed to achieve the proposed scientific objectives

Sampling of fluids using downhole logging tools at selected intervals, in particular using shape metal alloy sampling systems currently under development  
Preserving selected samples away from atmospheric alteration and potentially at near-ambient temperature above the temperature limits of life

Have you contacted the appropriate IODP Science Operator about this proposal to discuss drilling platform capabilities, the feasibility of your proposed drilling plan and strategies, and the required overall timetable for transiting, drilling, coring, logging, and other downhole measurements?

yes

## Proposal History

Submission Type Resubmission from previously submitted proposal

### Review Response

This addendum establishes a new alternate site AMDH5A, which consists of one or more single-bit holes within a polygon defined on the site form (vertices of the polygon are listed in a table in the addendum text)  
This was part of the operations plan of Proposal 937, (see Fig. 11 decision tree)

there are no changes to the Science or Operations proposed in Proposal 937FULL2, and clarified in the PRL

## Proposed Sites (Total proposed sites: 4; pri: 2; alt: 2; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
<u>AMDH-01A</u> (Primary)	30.1687 -42.1186	1656	0	660	660	(i) Sample fluids and measure temperature in existing Hole 1309D down to 1414 mbsf (expected temperature 225 centigrade). (ii) Deepen existing Hole U1309D by ~650 m and collect samples for petrology and geochemistry of abiotic organic compounds and H <sub>2</sub> ; (iii) log Hole with flaked tools. (iv) Drill new 80m Hole 20-30 m north of Hole U1309D, for microbiology sampling of porous rocks, fault zones, and correlation with Holes U1309B and D. This Hole is designated "U1309-J" in the text and site form. Note that Hole 1309C with protruding casing needs to be avoided.
<u>AMDH-02A</u> (Primary)	30.1317 -42.1202	825	3	200	203	200mHole with re-entry. Complete section through detachment fault zone in serpentized peridotite. Sample for deformation, alteration, igneous petrology, microbiology and organic/inorganic geochemistry. Log for temperature and other properties. Legacy Hole for sampling fluids and gases, establishing temperature profile, potential instrumentation
<u>AMDH-03A</u> (Alternate)	30.1389 -42.1455	1275	5	200	205	Drill through detachment fault shear zone; igneous petrology, alteration, deformation fabrics, microbiology, organic geochemistry. potential for post-detachment volcanic rocks. Temperature profile, fluid sampling, potential to provide re-entry system for legacy
<u>AMDH-05A</u> (Alternate)	30.13333 -42.17000	1000	3	100	103	Series of single bit holes. Near complete section through detachment fault zone in serpentized peridotite. Sample for deformation, alteration, igneous petrology, microbiology and organic/inorganic geochemistry. Log for temperature and other properties. Alternate site if operations fail at main sites

## Contact Information

Contact Person:	Andrew McCaig
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Organization:	University of Leeds
Address:	Woodhouse Lane Leeds West Yorkshire LS2 9JT United Kingdom
E-mail/Phone:	a.m.mccaig@leeds.ac.uk; Phone: +44 113 3435219

## Proponent List

First Name	Last Name	Affiliation	Country	Role	Expertise
Andrew	McCaig	University of Leeds	United Kingdom	Principal Lead	Alteration, tectonics, structural geology
Donna	Blackman	UC Santa Cruz	United States	Data Lead	geophysics, heatflow
Beth	Orcutt	Bigelow Laboratory for Ocean Sciences	United States	Other Lead	Microbiology; biogeochemistry;
Benedicte	Menez	IPGP Paris	France	Other Lead	geomicrobiology; geochemistry
Marvin	Lilley	University of Washington	United States	Other Lead	fluid geochemistry; hydrocarbons
Geoffery	Wheat	University of Alaska, Fairbanks	United States	Other Lead	geochemistry; downhole sampling; hydrogeology
Johan	Lissenberg	Cardiff University	United Kingdom	Other Lead	igneous petrology
Benoit	Ildefonse	University of Montpellier	France	Other Lead	igneous petrology; tectonics; physical properties
Frieder	Klein	Woods Hole Oceanographic Institute	United States	Other Lead	fluid geochemistry; fluid-rock interaction
Susan	Lang	University of South Carolina	United States	Other Lead	biogeochemistry; geochemistry
William	Seyfried	University of Minnesota	United States	Other Proponent	fluid geochemistry; fluid-rock interaction
Muriel	Andreani	University of Lyon	France	Other Proponent	metamorphic petrology; geochemistry
Barbara	John	University of Wyoming	United States	Other Proponent	tectonics; petrology; geochronology
Marguerite	Godard	University of Montpellier	France	Other Proponent	petrology; geochemistry
Antony	Morris	University of Plymouth	United Kingdom	Other Proponent	Palaeomagnetism; rock magnetism; tectonics
Esther	Schwarzenbach	Free University Berlin	Germany	Other Proponent	metamorphic petrology; geochemistry
Christopher	MacLeod	Cardiff University	United Kingdom	Other Proponent	tectonics, petrology
Ivan	Savov	University of Leeds	United Kingdom	Other Proponent	geochemistry, volcanology, petrology
Natsue	Abe	Jamstec	Japan	Other Proponent	Igneous petrology
Yasukiko	Ohara	Hydrographic and Oceanographic Department of Japan	Japan	Other Proponent	Marine geology and tectonics

## IODP Proposal 937 Addendum

This addendum adds a new site, AMDH-05A, which consists of a polygon, within which we request permission drill one or more single bit Holes, as requested already in Proposal 937Full2. The decision tree (Fig. 11 in the above proposal document) shows that this is the final contingency if other operations fail.

(Note that AMDH-04 was used for an alternate Hole in proposal 937Full, which was removed in proposal 937FullL2)

There is no change in the science or operations plan requested in 937 Full2 and in the PRL.

The polygon is shown in the Site form and has been chosen to include most of the shallow Holes drilled in IODP Expedition 357, and suitable areas of relatively flat seafloor. Experience in Expeditions 304 and 357 suggests that steeper slopes may be covered by large boulders and relatively flat areas away from the base of slopes offer the best chance to entering the seafloor successfully. Therefore the polygon includes a number of such areas. Hole locations would be chosen to complement the shallow holes of Expedition 357 where possible, and precise locations would be selected during the expedition.

We have included logging in the single bit Holes, as was done in IODP U1309B

Table 1: P937 polygon vertices (11 March 2021, minor adjustment to easternmost pts relative to EPSP/SRR) for site AMDH-05A (note that the site form lists the latitude and longitude of the first vertex, and an average seafloor depth)

#	LATdeg	min	LONdeg	min	LATdecDeg	LONdecDeg
1	30	7.80	-42	11.28	30.13000	-42.18800
2	30	8.00	-42	10.20	30.13333	-42.17000
3	30	7.42	-42	9.50	30.12367	-42.15833
4	30	7.60	-42	7.20	30.12667	-42.12000
5	30	7.74	-42	6.75	30.12900	-42.11250
6	30	7.35	-42	5.65	30.12250	-42.09417
7	30	7.80	-42	5.72	30.13000	-42.09533
8	30	8.02	-42	6.90	30.13367	-42.11500
9	30	8.15	-42	7.35	30.13583	-42.12250
10	30	8.70	-42	7.30	30.14500	-42.12167
11	30	9.00	-42	8.50	30.15000	-42.14167
12	30	8.70	-42	11.00	30.14500	-42.18333
1	30	7.80	-42	11.28	30.13000	-42.18800

# IODP Site Forms

## Form 1 – General Site Information

937 - Add

### Section A: Proposal Information

Proposal Title	Accessing the Building Blocks of Life: Deepening Hole U1309D, Atlantis Massif, Mid-Atlantic Ridge
Date Form Submitted	2021-05-30 10:29:11
Site-Specific Objectives with Priority (Must include general objectives in proposal)	(i) Sample fluids and measure temperature in existing Hole 1309D down to 1414 mbsf (expected temperature 225 centigrade). (ii) Deepen existing Hole U1309D by ~650 m and collect samples for petrology and geochemistry of abiotic organic compounds and H <sub>2</sub> ; (iii) log Hole with flaked tools. (iv) Drill new 80m Hole 20-30 m north of Hole U1309D, for microbiology sampling of porous rocks, fault zones, and correlation with Holes U1309B and D. This Hole is designated "U1309-J" in the text and site form. Note that Hole 1309C with protruding casing needs to be avoided.
List Previous Drilling in Area	Expeditions IODP 304, 305 and 357

### Section B: General Site Information

Site Name:	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="text-align: center;">AMDH-01A</td></tr> <tr><td style="text-align: center;">U1309D</td></tr> </table>	AMDH-01A	U1309D	Area or Location:	Atlantis Massif, Mid-Atlantic Ridge
AMDH-01A					
U1309D					
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#		Jurisdiction:	none		
Latitude:	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 10%;">Deg:</td> <td style="text-align: center;">30.1687</td> </tr> </table>	Deg:	30.1687	Distance to Land: (km)	
Deg:	30.1687				
Longitude:	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 10%;">Deg:</td> <td style="text-align: center;">-42.1186</td> </tr> </table>	Deg:	-42.1186	Water Depth (m):	1656
Deg:	-42.1186				
Coordinate System:	WGS 84				
Priority of Site:	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;">Primary: <input checked="" type="checkbox"/></td> <td style="width: 50%;">Alternate: <input type="checkbox"/></td> </tr> </table>	Primary: <input checked="" type="checkbox"/>	Alternate: <input type="checkbox"/>		
Primary: <input checked="" type="checkbox"/>	Alternate: <input type="checkbox"/>				

## Section C: Operational Information

	Sediments	Basement	
Proposed Penetration (m):	0	660	
Total Sediment Thickness (m)	2		
Total Penetration (m):		660	
General Lithologies:	unconsolidated	gabbro, serpentinite	
<b>Coring Plan:</b> (Specify or check)	Continuation of Expedition 305 coring. Multiple re-entry Additional single bit Hole West of U1309D, termed "U1309-J"		
	APC <input type="checkbox"/> XCB <input type="checkbox"/> RCB <input checked="" type="checkbox"/> Re-entry <input checked="" type="checkbox"/> PCS <input type="checkbox"/>		
Wireline Logging Plan:	Standard Measurements	Special Tools	
	WL <input checked="" type="checkbox"/> Porosity <input checked="" type="checkbox"/> Density <input checked="" type="checkbox"/> Gamma Ray <input checked="" type="checkbox"/> Resistivity <input checked="" type="checkbox"/> Sonic ( $\Delta t$ ) <input checked="" type="checkbox"/> Formation Image (Res) <input checked="" type="checkbox"/> VSP (zero offset) <input type="checkbox"/> Formation Temperature & Pressure <input type="checkbox"/>	Magnetic Susceptibility <input type="checkbox"/> Borehole Temperature <input checked="" type="checkbox"/> Formation Image (Acoustic) <input type="checkbox"/> VSP (walkaway) <input type="checkbox"/> LWD <input type="checkbox"/>	
	Other tools: Fluid sampling hopefully using new MTFS tool. Also the 3rd party Kuster tool. For temperature the ETBS tool is requested.		
	Other Measurements: Fluid sampling		
Estimated Days:	Drilling/Coring: 38	Logging: 2	
	Total On-site: 40		
Observatory Plan:	Longterm Borehole Observation Plan/Re-entry Plan Casing with re-entry cone already in place. Hole has been re-entered many times. Hole should be left clear for future logging and fluid sampling.		
Potential Hazards/ Weather:	Shallow Gas <input type="checkbox"/> Hydrocarbon <input type="checkbox"/> Shallow Water Flow <input type="checkbox"/> Abnormal Pressure <input type="checkbox"/> Man-made Objects (e.g., sea-floor cables, dump sites) <input type="checkbox"/> H <sub>2</sub> S <input type="checkbox"/> CO <sub>2</sub> <input type="checkbox"/> Sensitive marine habitat (e.g., reefs, vents) none	Complicated Seabed Condition <input type="checkbox"/> Soft Seabed <input type="checkbox"/> Currents <input type="checkbox"/> Fracture Zone <input type="checkbox"/> Fault <input type="checkbox"/> High Dip Angle <input type="checkbox"/>	Hydrothermal Activity <input type="checkbox"/> Landslide and Turbidity Current <input type="checkbox"/> Gas Hydrate <input type="checkbox"/> Diapir and Mud Volcano <input type="checkbox"/> High Temperature <input checked="" type="checkbox"/> Ice Conditions <input type="checkbox"/>
	Preferred weather window December to May, avoiding Atlantic hurricane season		
	Other: maximum predicted temperature is 225 C at 2100 mbsf, based on gradient in the lower 750 m of Hole U1309D		



IODP Site Forms

Form 2 - Site Survey Detail

Proposal #:	937 - Add	Site #:	AMDH-01A	Date Form Submitted:	2021-05-30 10:29:11
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Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: Meg4 Position: Meg4 , CMP 4145 closest, ~400 m to east; RP#3378 closest in meg4_stack_2400_5280.segy
2b Deep penetration seismic reflection (crossing)	yes	Line: Meg10 Position: Meg10, ~1.8 km north, CMP 2405 close perpendicular projection
3 Seismic Velocity	yes	Harding et al. 2016- Meg4 waveform inversion & updated checkshot data from borehole; Blackman et al. 2014- complete sonic log to ~1400 mbsf. (older versions Canales et al. (2008) and Henig et al. (2012) Meg4 downward continued streamer tomography, former to datum above seafloor and latter to seafloor)
4 Seismic Grid	yes	Meg4, Meg5, Meg6, Meg9, Meg10- Canales et al., 2004 (Meg8 outside corner)
5a Refraction (surface)	yes	OBS refraction- Blackman and Collins 2010; Line 9a crosses Site; Line 8 is 1.8 km to N
5b Refraction (bottom)	yes	NOBEL- Harding et al. 2016 waveform inversion for Line 10, just north of hole Collins et al. 2009 shows older tomography for Lines 9 & 10.
6 3.5 kHz	no	
7 Swath bathymetry	yes	CD100 EM12, MARVEL2000 SeaBeam2000, 100-m regional grid Blackman et al., 2008. EM120 20-50m grid Früh-Green et al., 2017.
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	yes	CD100 Tobi MARVEL2000 DSL120
9 Photography or video	yes	MARVEL 2000 Alvin and Argo images
10 Heat Flow	yes	Temperature throughout borehole; from deep section heat flow prediction is 257 mW/m2, Blackman et al., 2014
11a Magnetics	yes	Pariso et al., 1996; MARVEL2000 deep-tow
11b Gravity	yes	Blackman et al . 2008
12 Sediment cores	yes	Holes U1309A, U1309E, U1309F, U1309G
13 Rock sampling	yes	CD100 Dredge, MARVEL2000 Alvin; Hole U1309D core to 1415mbsf
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	1 yr study, Collins et al. 2012
16 Navigation	yes	MCS, OBS & NOBEL refraction, DSL120, Alvin rock sample & dredge locations
17 Other	no	

IODP Site Forms

Form 4 - Environmental Protection

Proposal #:	937 - Add	Site #:	AMDH-01A	Date Form Submitted:	2021-05-30 10:29:11
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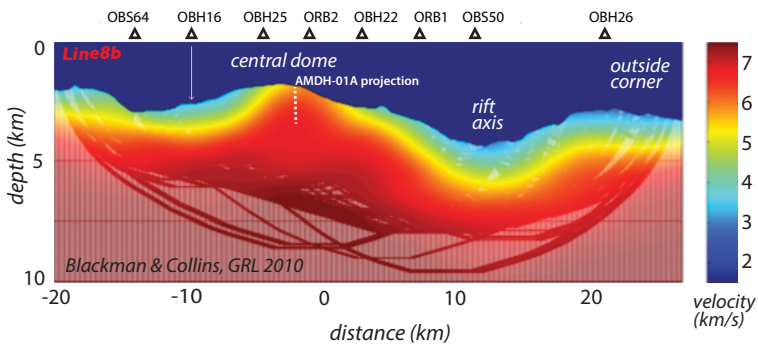
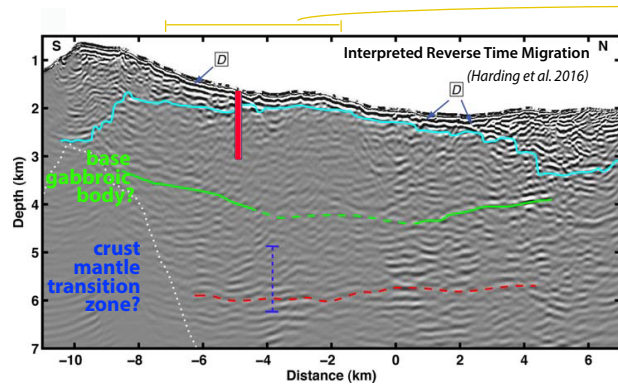
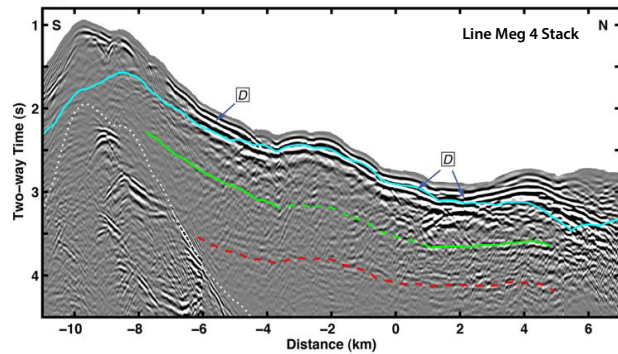
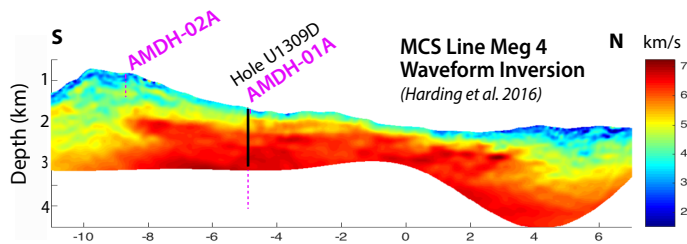
Pollution & Safety Hazard	Comment
1. Summary of operations at site	visual check for flow; re-enter; slow down-run for minimally-perturbed T measure; up run for caliper & (initial) borehole fluid sampling; additional fluid sampling to cover desired intervals (if dont have multi-sample capability); RCB coring; logging of at least newly-penetrated section, full section if time.
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	none
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	none
5. Are there reasons to expect hydrocarbon accumulations at this site?	none
6. What "special" precautions will be taken during drilling?	minimal disturbance in hole until initial T measurement & fluid sampling are complete. During final logging temperature needs to be monitored to avoid damage to temperature-limited logging tools
7. What abandonment procedures need to be followed?	standard for tool stuck in hole, if that were to occur
8. Natural or manmade hazards which may affect ship's operations	~20m casing was left protruding from seafloor at Hole U1309C in 2004
9. Summary: What do you consider the major risks in drilling at this site?	moderately high temperature as hole deepens (~150-250 °C expected)

IODP Site Forms

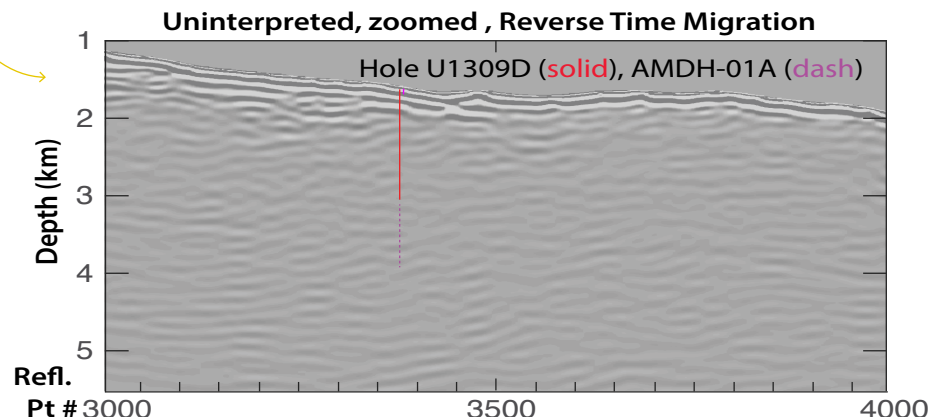
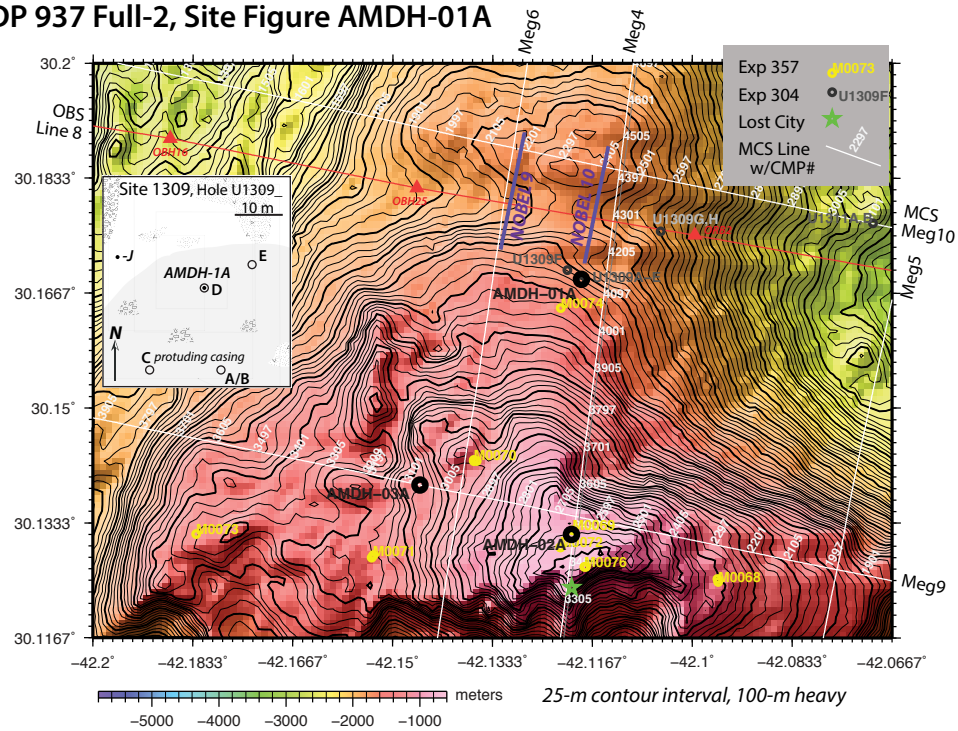
Form 5 - Lithologies

Proposal #:	937 - Add	Site #:	AMDH-01A	Date Form Submitted:	2021-05-30 10:29:11
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Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 150	detachment zone	~1.2 Ma rocks	3.5	few m of fault zone, metadiabase, metagabbro		n/a	upper 20 m cased. Age from Grimes et al (2008) applies to whole section
350 - 380	highly altered rock, likley reflector source		5.3	olivine-rich troctolite, troctolite, gabbro			reflectivity modeling by Collins et al., 2009 velocity control by waveform inversion, 304/305/340T checkshots, sonic log (Harding et al. 2016)
750 - 750	(paleo) fault		5	fault gouge, diabase			
1080 - 1200	portions highly altered, possible reflectors		5.8	olivine-rich troctolite (serpentinized) interfingered gabbro			
4000 - 4000	green reflector Meg4		6.9	base gabbro?			Harding et al 2016



### IODP 937 Full-2, Site Figure AMDH-01A



**MCS:** meg4\_stack\_2400\_5280.segy (correct nav), meg4migrated.segy (needs nav), meg4.cdp\_nav\_bt\_twt

**Refraction:** obs64ch\*n08.segy, obh16n8r.segy, obh25n8r.segy, orb2n08.segy, obh22n8r.segy, orb1n08.segy, obs50ch\*n08cor.segy, obh26n8r.segy

# IODP Site Forms

## Form 1 – General Site Information

937 - Add

### Section A: Proposal Information

Proposal Title	Accessing the Building Blocks of Life: Deepening Hole U1309D, Atlantis Massif, Mid-Atlantic Ridge
Date Form Submitted	2021-05-30 10:29:11
Site-Specific Objectives with Priority (Must include general objectives in proposal)	200mHole with re-entry. Complete section through detachment fault zone in serpentinized peridotite. Sample for deformation, alteration, igneous petrology, microbiology and organic/inorganic geochemistry. Log for temperature and other properties. Legacy Hole for sampling fluids and gases, establishing temperature profile, potential instrumentation
List Previous Drilling in Area	IODP Expedition 357, IODP Expedition 304/305

### Section B: General Site Information

Site Name:	AMDH-02A	Area or Location:	Mid Atlantic Ridge, Atlantis Massif
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#	50m from MOO69A	Jurisdiction:	common
Latitude:	Deg: 30.1317	Distance to Land: (km)	
Longitude:	Deg: -42.1202	Water Depth (m):	825
Coordinate System:	WGS 84		
Priority of Site:	Primary: <input checked="" type="checkbox"/>	Alternate: <input type="checkbox"/>	

## Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	3	200
Total Sediment Thickness (m)	3	
Total Penetration (m):		203
General Lithologies:	loose foram sand	serpentite, talc-tremolite chlorite schist, metadiabase, metagabbro, breccia, fault rock
<b>Coring Plan:</b> (Specify or check)	Pilot Hole 50m; hard rock re-entry system with ~15m casing; 2-bit Hole to 200m	
	APC <input type="checkbox"/>	XCB <input type="checkbox"/> RCB <input checked="" type="checkbox"/> Re-entry <input checked="" type="checkbox"/> PCS <input type="checkbox"/>
Wireline Logging Plan:	Standard Measurements	Special Tools
	WL <input checked="" type="checkbox"/> Porosity <input checked="" type="checkbox"/> Density <input checked="" type="checkbox"/> Gamma Ray <input checked="" type="checkbox"/> Resistivity <input checked="" type="checkbox"/> Sonic ( $\Delta t$ ) <input checked="" type="checkbox"/> Formation Image (Res) <input checked="" type="checkbox"/> VSP (zero offset) <input type="checkbox"/> Formation Temperature & Pressure <input type="checkbox"/>	Magnetic Susceptibility <input type="checkbox"/> Borehole Temperature <input checked="" type="checkbox"/> Formation Image (Acoustic) <input type="checkbox"/> VSP (walkaway) <input type="checkbox"/> LWD <input type="checkbox"/>
	Other tools: MTT tool, ETBS tool, WSTP tool, potentially Kuster tool (exact choice of tools may be an operational choice)	
	Other Measurements:	
Estimated Days:	Drilling/Coring: 5.1	Logging: 0.5 Total On-site: 5.6
Observatory Plan:	Longterm Borehole Observation Plan/Re-entry Plan Hard rock re-entry system. Potential for observatory	
Potential Hazards/Weather:	Shallow Gas <input type="checkbox"/> Complicated Seabed Condition <input checked="" type="checkbox"/> Hydrothermal Activity <input type="checkbox"/> Hydrocarbon <input type="checkbox"/> Soft Seabed <input type="checkbox"/> Landslide and Turbidity Current <input type="checkbox"/> Shallow Water Flow <input type="checkbox"/> Currents <input type="checkbox"/> Gas Hydrate <input type="checkbox"/> Abnormal Pressure <input type="checkbox"/> Fracture Zone <input checked="" type="checkbox"/> Diapir and Mud Volcano <input type="checkbox"/> Man-made Objects (e.g., sea-floor cables, dump sites) <input checked="" type="checkbox"/> Fault <input checked="" type="checkbox"/> High Temperature <input type="checkbox"/> H <sub>2</sub> S <input type="checkbox"/> High Dip Angle <input type="checkbox"/> Ice Conditions <input type="checkbox"/> CO <sub>2</sub> <input type="checkbox"/>	Preferred weather window December to May (avoiding Atlantic hurricane season)
	Sensitive marine habitat (e.g., reefs, vents) Lost City Hydrothermal Field is ~0.5 km away	
Other:	Pieces of RD2 drill string left in MOO69A may not be visible. Hardrock seabed with rubble and small sediment ponds	

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #:	937 - Add	Site #:	AMDH-02A	Date Form Submitted:	2021-05-30 10:29:11
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Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: Meg4 , Position: CMP# 3480 closest, 190 m to east; ~RP# 2726 in meg4_stack_2400_5280.segy
2b Deep penetration seismic reflection (crossing)	yes	Line: Meg9 Position: CMP 2750, 375 m north
3 Seismic Velocity	yes	Harding et al. 2016 & in prep- Meg4 & Meg9 waveform inversion (older version Henig et al. 2012 Meg4 & 9 downward continued to seafloor streamer tomography)
4 Seismic Grid	yes	Meg4, Meg5, Meg6, Meg9, Meg10- Canales et al., 2004 (Meg8 outside corner)
5a Refraction (surface)	yes	OBS refraction- Blackman and Collins 2010; Line 9a near site
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	CD100 EM12, MARVEL2000 SeaBeam2000, 100-m regional grid Blackman et al., 2008. EM120 20-50m grid Früh-Green et al., 2017.
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	yes	CD100 Tobi MARVEL2000 DSL120
9 Photography or video	yes	MARVEL 2000 Alvin and Argo images
10 Heat Flow	no	
11a Magnetics	yes	Pariso et al., 1996; MARVEL2000 deep-tow
11b Gravity	yes	Blackman et al., 2008
12 Sediment cores	no	
13 Rock sampling	yes	CD100 Dredge, MARVEL2000 Alvin; Exp357 Holes M0069A; M0072A,B; M0076A,B
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	1 yr study, Collins et al. 2012
16 Navigation	yes	MCS, OBS refraction, DSL120, Alvin rock sample & dredge locations
17 Other	no	

IODP Site Forms

Form 4 - Environmental Protection

Proposal #:	937 - Add	Site #:	AMDH-02A	Date Form Submitted:	2021-05-30 10:29:11
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Pollution & Safety Hazard	Comment
1. Summary of operations at site	RCB pilot Hole 50m; Hard rock re-entry system with ~17 m casing; RCB to 100mbsf; temperature log at end of drilling and logging, temperature, and fluid sampling at end of expedition
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	none
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	none
5. Are there reasons to expect hydrocarbon accumulations at this site?	none
6. What "special" precautions will be taken during drilling?	none
7. What abandonment procedures need to be followed?	standard
8. Natural or manmade hazards which may affect ship's operations	junk in Hole M0069A
9. Summary: What do you consider the major risks in drilling at this site?	serpentinite fault zone so drilling conditions may be difficult



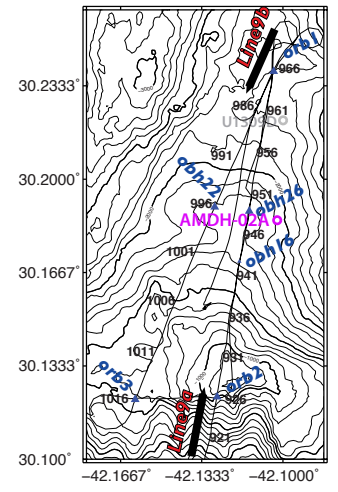
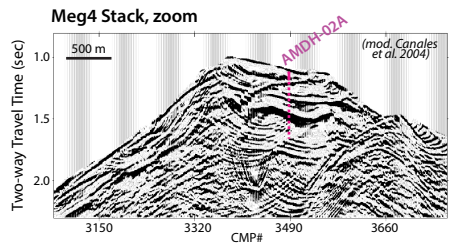
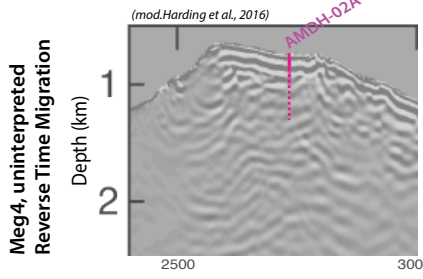
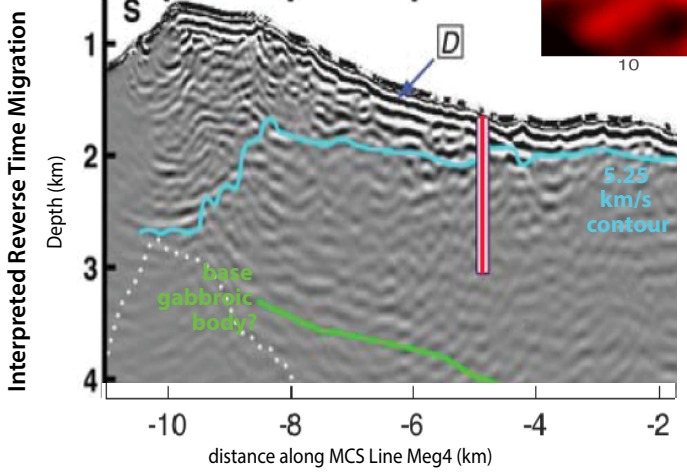
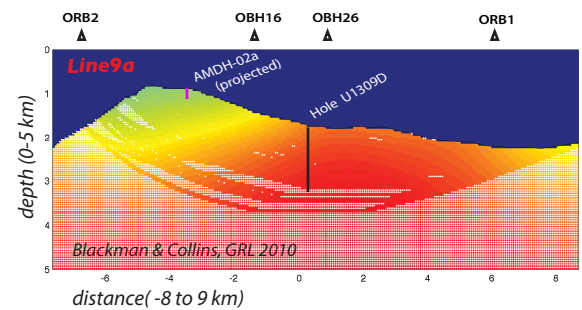
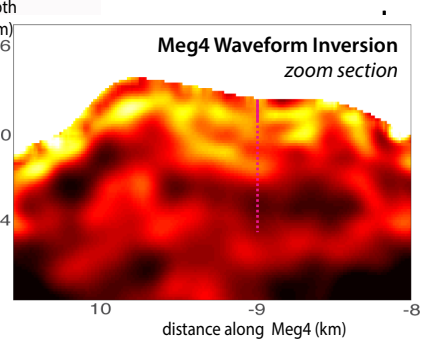
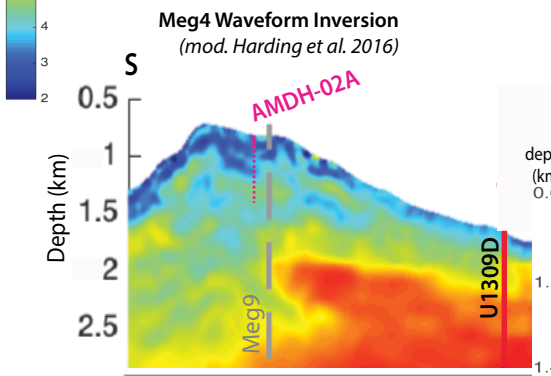
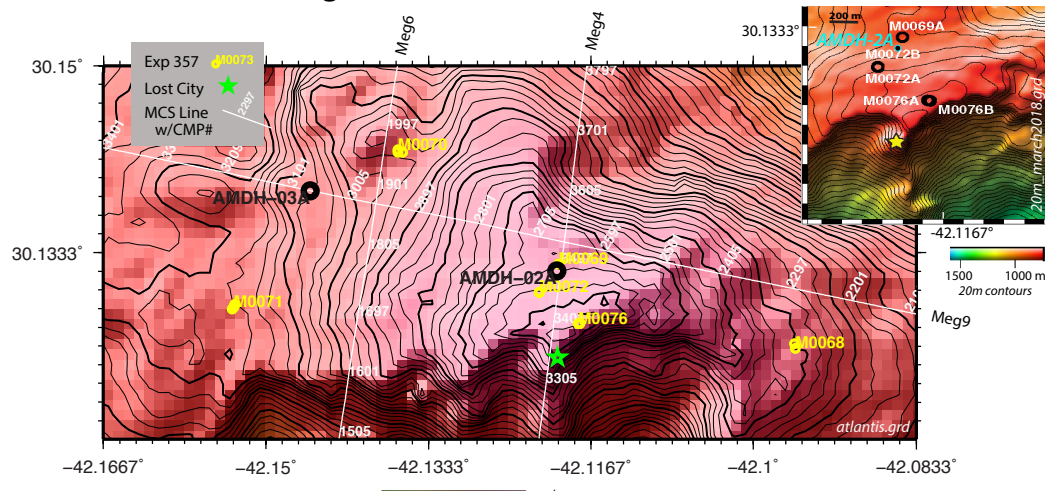
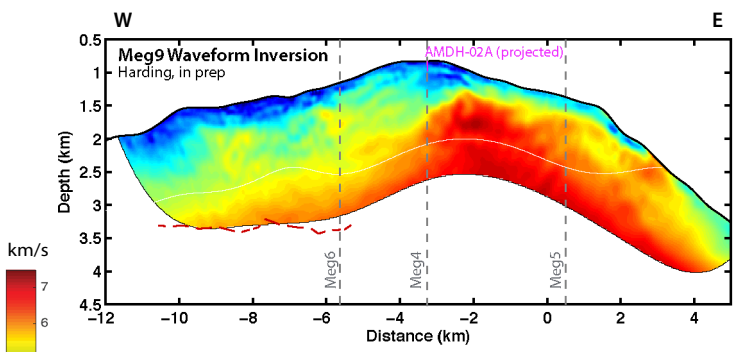
IODP Site Forms

Form 5 - Lithologies

Proposal #:	937 - Add	Site #:	AMDH-02A	Date Form Submitted:	2021-05-30 10:29:11
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Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 6.5		0		loose carbonate sand in pockets. rubble possible			Based on M0069A, 50 m away, but sediment pockets very variable
6.5 - 12		1		metadiabase			based on M0069A. Good recovery in this section, but may not occur based on moderately dipping contact
12.5 - 13.2		1		sub-horizontal fault zone and breccia			based on M0069A. Similar fault zones likely throughout section
13.2 - 100				heterogeneous fault/shear zone dominated by serpentinite			13-16.5 mbsf section in M0069A was massive serpentinite with good recovery

# IODP 937 Full-2, Site Figure AMDH-02A



**MCS:** meg9migrated.segy, meg9stack.segy, meg9.cdp\_nav\_bat\_twtt, meg4\_stack\_2400\_5280.segy (correct nav), meg4migrated.segy (needs nav), meg4.cdp\_nav\_bt\_twtt

**Refraction:** orb1n09.segy, obh16n9.segy, obh26n9.segy, orb2n09.segy

# IODP Site Forms

## Form 1 – General Site Information

937 - Add

### Section A: Proposal Information

Proposal Title	Accessing the Building Blocks of Life: Deepening Hole U1309D, Atlantis Massif, Mid-Atlantic Ridge
Date Form Submitted	2021-05-30 10:29:11
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Drill through detachment fault shear zone; igneous petrology, alteration, deformation fabrics, microbiology, organic geochemistry. potential for post-detachment volcanic rocks. Temperature profile, fluid sampling, potential to provide re-entry system for legacy
List Previous Drilling in Area	IODP Exp 357; IODP Exp 304/305

### Section B: General Site Information

Site Name:	AMDH-03A	Area or Location:	Mid Atlantic Ridge, Atlantis Massif
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#		Jurisdiction:	common
Latitude:	Deg: 30.1389	Distance to Land: (km)	
Longitude:	Deg: -42.1455	Water Depth (m):	1275
Coordinate System:	WGS 84		
Priority of Site:	Primary: <input type="checkbox"/>	Alternate: <input checked="" type="checkbox"/>	

## Section C: Operational Information

	Sediments	Basement	
Proposed Penetration (m):	5	200	
Total Sediment Thickness (m)	5		
Total Penetration (m):			205
General Lithologies:	loose foram sand; carbonate cemented breccia	serpentinite, talc-tremolite chlorite schist, metadiabase, metagabbro, breccia, fault rock	
<b>Coring Plan:</b> (Specify or check)	single bit to destruction, but if AMDH-01A fails completely, deeper Hole with re-entry. Sediment thickness is likely maximum based on previous Holes (M0070; M0071, Site U1309)		
	APC <input type="checkbox"/>	XCB <input type="checkbox"/>	RCB <input checked="" type="checkbox"/> Re-entry <input type="checkbox"/> PCS <input type="checkbox"/>
Wireline Logging Plan:	Standard Measurements	Special Tools	
WL	<input checked="" type="checkbox"/>	Magnetic Susceptibility	<input type="checkbox"/>
Porosity	<input checked="" type="checkbox"/>	Borehole Temperature	<input checked="" type="checkbox"/>
Density	<input checked="" type="checkbox"/>	Formation Image (Acoustic)	<input type="checkbox"/>
Gamma Ray	<input checked="" type="checkbox"/>	VSP (walkaway)	<input type="checkbox"/>
Resistivity	<input checked="" type="checkbox"/>	LWD	<input type="checkbox"/>
Sonic ( $\Delta t$ )	<input checked="" type="checkbox"/>		
Formation Image (Res)	<input checked="" type="checkbox"/>		
VSP (zero offset)	<input type="checkbox"/>		
Formation Temperature & Pressure	<input type="checkbox"/>		
	Other tools: MTT, ETBS for temperature. Kuster and/or WSTP tool for fluid sampling (temperature probably too low to use new SMA tool)		
	Other Measurements:		
Estimated Days:	Drilling/Coring: 4	Logging: 1	Total On-site: 5
Observatory Plan:	Longterm Borehole Observation Plan/Re-entry Plan depending on time, a re-entry system may be installed with potential for future instrumentation		
Potential Hazards/Weather:	Shallow Gas <input type="checkbox"/>	Complicated Seabed Condition <input type="checkbox"/>	Hydrothermal Activity <input type="checkbox"/>
	Hydrocarbon <input type="checkbox"/>	Soft Seabed <input type="checkbox"/>	Landslide and Turbidity Current <input type="checkbox"/>
	Shallow Water Flow <input type="checkbox"/>	Currents <input type="checkbox"/>	Gas Hydrate <input type="checkbox"/>
	Abnormal Pressure <input type="checkbox"/>	Fracture Zone <input checked="" type="checkbox"/>	Diapir and Mud Volcano <input type="checkbox"/>
	Man-made Objects (e.g., sea-floor cables, dump sites) <input type="checkbox"/>	Fault <input checked="" type="checkbox"/>	High Temperature <input type="checkbox"/>
	H <sub>2</sub> S <input type="checkbox"/>	High Dip Angle <input type="checkbox"/>	Ice Conditions <input type="checkbox"/>
	CO <sub>2</sub> <input type="checkbox"/>		
	Sensitive marine habitat (e.g., reefs, vents)		Preferred weather window December to May (avoiding Atlantic hurricane season)
	Other:		

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #:	937 - Add	Site #:	AMDH-03A	Date Form Submitted:	2021-05-30 10:29:11
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Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: Meg9 Position: ~CMP 3125
2b Deep penetration seismic reflection (crossing)	yes	Line: Meg6 Position: ~600m to east
3 Seismic Velocity	yes	Harding et al. 2016 & in prep- Meg9 waveform inversion (older version) Henig et al. 2012 Meg9 downward continued to seafloor streamer tomography)
4 Seismic Grid	yes	Meg4, Meg5, Meg6, Meg9, Meg10- Canales et al., 2004 (Meg8 outside corner)
5a Refraction (surface)	yes	OBS refraction- Blackman and Collins 2010; Line 9b closest to site
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	CD100 EM12, MARVEL2000 SeaBeam2000, 100-m regional grid Blackman et al., 2008. EM120 20-50m grid Früh-Green et al., 2017.
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	yes	CD100 Tobi MARVEL2000 DSL120
9 Photography or video	yes	MARVEL 2000 Alvin and Argo images
10 Heat Flow	no	
11a Magnetics	yes	Pariso et al., 1996; MARVEL2000 deep-tow
11b Gravity	yes	Blackman et al 2008
12 Sediment cores	no	
13 Rock sampling	yes	CD100 Dredge, MARVEL2000 Alvin; Exp 357 cores, M0070A-c and M0071A to C most relevant
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	1 yr study, Collins et al. 2012
16 Navigation	yes	MCS, OBS refraction, DSL120, Alvin rock sample & dredge locations
17 Other	no	

IODP Site Forms

Form 4 - Environmental Protection

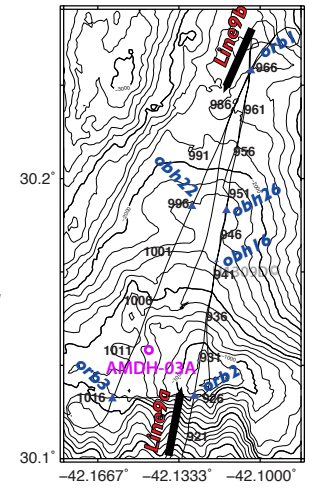
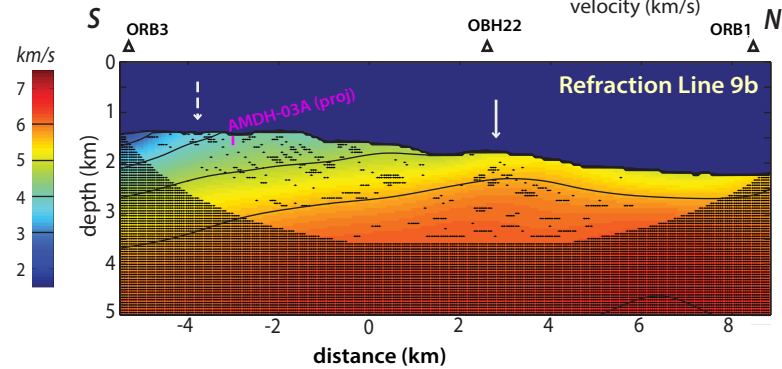
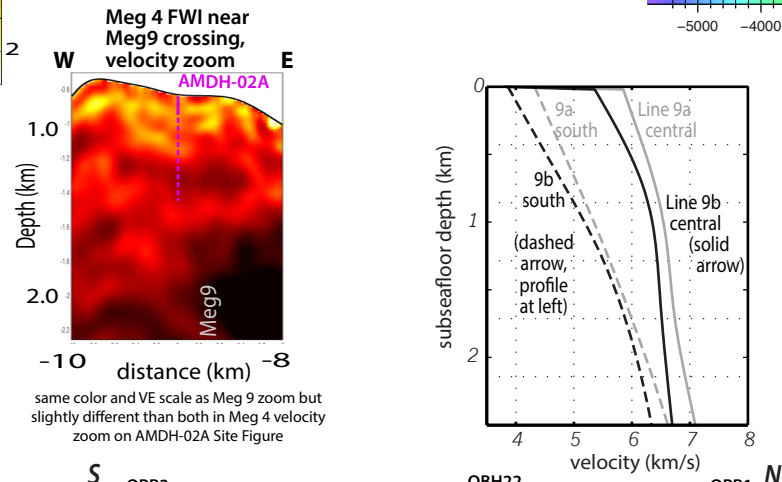
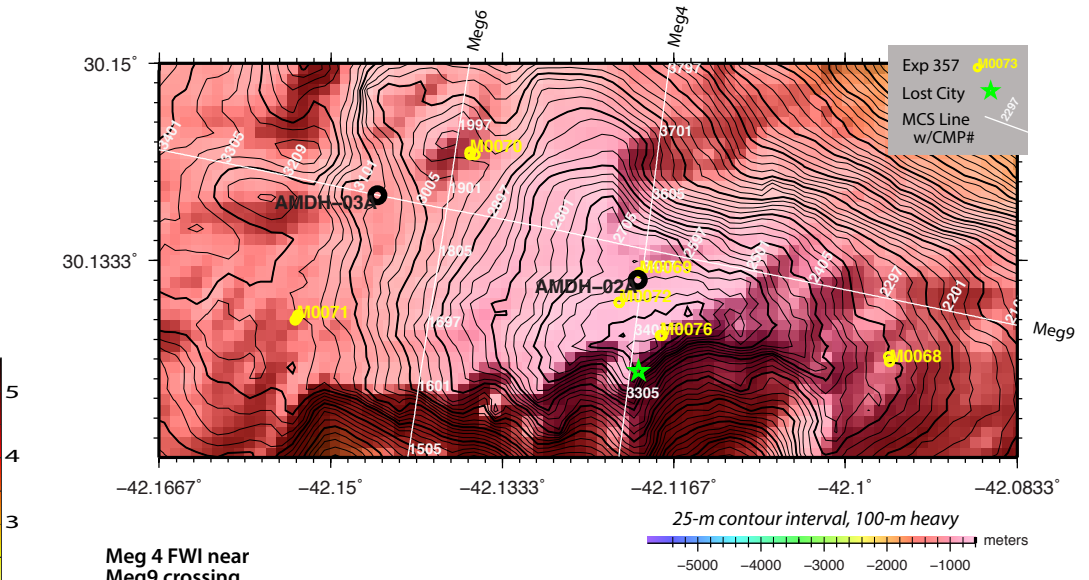
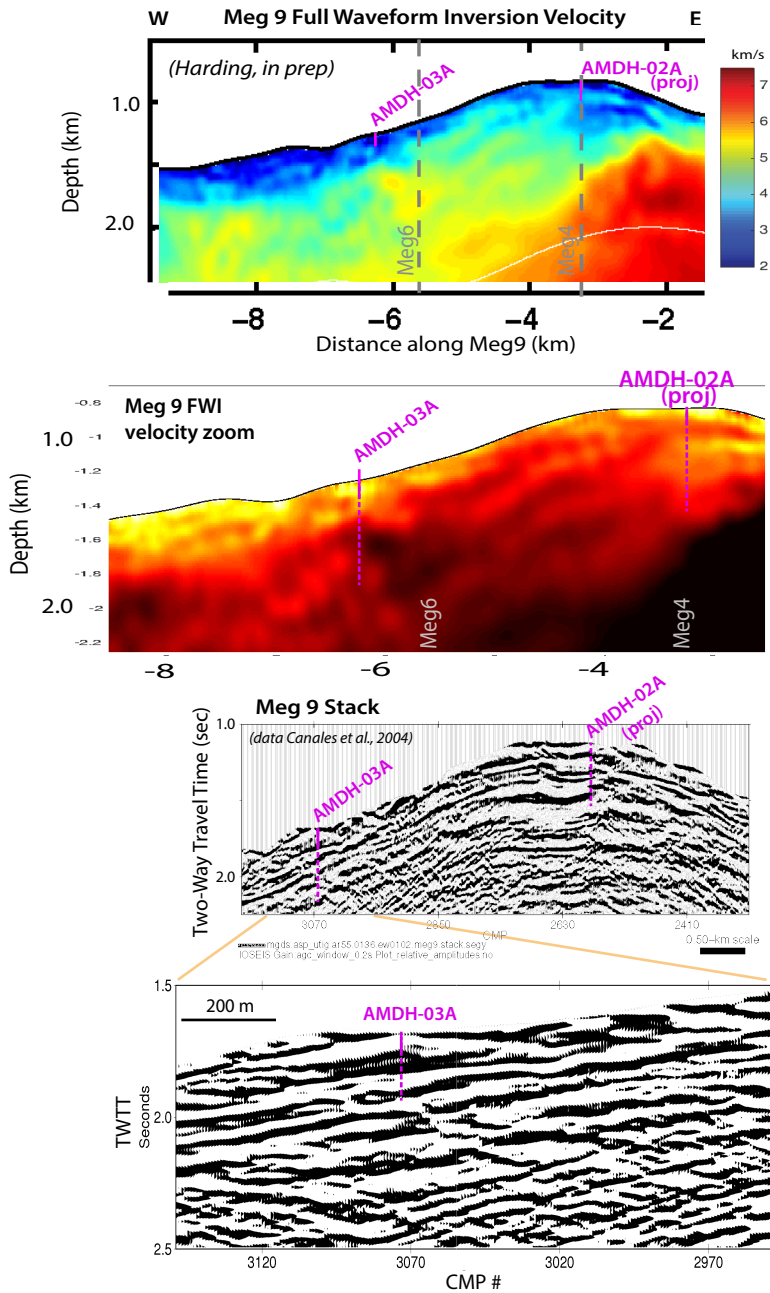
Proposal #:	937 - Add	Site #:	AMDH-03A	Date Form Submitted:	2021-05-30 10:29:11
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Pollution & Safety Hazard	Comment
1. Summary of operations at site	
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	
4. Indications of gas hydrates at this location	
5. Are there reasons to expect hydrocarbon accumulations at this site?	
6. What "special" precautions will be taken during drilling?	
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	
9. Summary: What do you consider the major risks in drilling at this site?	

Proposal #:	937 - Add	Site #:	AMDH-03A	Date Form Submitted:	2021-05-30 10:29:11
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Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

# IODP 937 Full-2, Site Figure AMDH-03A



**MCS:** meg9migrated.segy, meg9stack.segy, meg9.cdp\_nav\_bat\_twtt  
**Refraction:** orb3n09.segy, obh22n9.segy, orb1n09.segy  
**Velocity models (waveform inversion):** Meg9velModel.txt



# IODP Site Forms

937 - Add

## Form 1 – General Site Information

### Section A: Proposal Information

Proposal Title	Accessing the Building Blocks of Life: Deepening Hole U1309D, Atlantis Massif, Mid-Atlantic Ridge
Date Form Submitted	2021-05-30 10:29:11
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Series of single bit holes. Near complete section through detachment fault zone in serpentinized peridotite. Sample for deformation, alteration, igneous petrology, microbiology and organic/inorganic geochemistry. Log for temperature and other properties. Alternate site if operations fail at main sites
List Previous Drilling in Area	IODP Expedition 357, IODP Expedition 304/305

### Section B: General Site Information

Site Name:	AMDH-05A	Area or Location:	Mid Atlantic Ridge, Atlantis Massif
<small>If site is a reoccupation of an old DSDP/ODP Site, please include former Site#</small>	polygon containing various IODP 357 sites	Jurisdiction:	common
Latitude:	Deg: 30.13333	Distance to Land: (km)	
Longitude:	Deg: -42.17000	Water Depth (m):	1000
Coordinate System:	WGS 84		
Priority of Site:	Primary: <input type="checkbox"/> Alternate: <input checked="" type="checkbox"/>		

## Section C: Operational Information

	Sediments	Basement	
Proposed Penetration (m):	3	100	
Total Sediment Thickness (m)	3		
Total Penetration (m):			103
General Lithologies:	loose foram sand	serpentite, talc-tremolite chlorite schist, metadiabase, metagabbro, breccia, fault rock	
<b>Coring Plan:</b> (Specify or check)	several single bit holes selected to complement Exp 357 shallow drilling		
	APC <input type="checkbox"/>	XCB <input type="checkbox"/>	RCB <input checked="" type="checkbox"/>
	Re-entry <input type="checkbox"/>		PCS <input type="checkbox"/>
Wireline Logging Plan:	Standard Measurements	Special Tools	
WL	<input checked="" type="checkbox"/>	Magnetic Susceptibility	<input checked="" type="checkbox"/>
Porosity	<input checked="" type="checkbox"/>	Borehole Temperature	<input checked="" type="checkbox"/>
Density	<input checked="" type="checkbox"/>	Formation Image (Acoustic)	<input type="checkbox"/>
Gamma Ray	<input checked="" type="checkbox"/>	VSP (walkaway)	<input type="checkbox"/>
Resistivity	<input checked="" type="checkbox"/>	LWD	<input type="checkbox"/>
Sonic ( $\Delta t$ )	<input checked="" type="checkbox"/>		
Formation Image (Res)	<input checked="" type="checkbox"/>		
VSP (zero offset)	<input type="checkbox"/>		
Formation Temperature & Pressure	<input type="checkbox"/>		
	Other tools: MTT tool, ETBS tool, WSTP tool,		
Other Measurements:			
Estimated Days:	Drilling/Coring: 20	Logging: 0.5	Total On-site: 20.5
Observatory Plan:	Longterm Borehole Observation Plan/Re-entry Plan		
Potential Hazards/Weather:	Shallow Gas <input type="checkbox"/>	Complicated Seabed Condition <input checked="" type="checkbox"/>	Hydrothermal Activity <input type="checkbox"/>
	Hydrocarbon <input type="checkbox"/>	Soft Seabed <input type="checkbox"/>	Landslide and Turbidity Current <input type="checkbox"/>
	Shallow Water Flow <input type="checkbox"/>	Currents <input type="checkbox"/>	Gas Hydrate <input type="checkbox"/>
	Abnormal Pressure <input type="checkbox"/>	Fracture Zone <input checked="" type="checkbox"/>	Diapir and Mud Volcano <input type="checkbox"/>
	Man-made Objects (e.g., sea-floor cables, dump sites) <input checked="" type="checkbox"/>	Fault <input checked="" type="checkbox"/>	High Temperature <input type="checkbox"/>
	H <sub>2</sub> S <input type="checkbox"/>	High Dip Angle <input type="checkbox"/>	Ice Conditions <input type="checkbox"/>
	CO <sub>2</sub> <input type="checkbox"/>		
	Sensitive marine habitat (e.g., reefs, vents) Lost City Hydrothermal Field is ~0.5 km away from the polygon edge		Preferred weather window December to May (avoiding Atlantic hurricane season)
Other:	Pieces of RD2 drill string left in some Exp 357 holes may not be visible. Hardrock seabed with rubble and small sediment ponds		

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #:	937 - Add	Site #:	AMDH-05A	Date Form Submitted:	2021-05-30 10:29:11
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Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: Meg4 , Position: CMP# 3480 closest, 190 m to east; ~RP# 2726 in meg4_stack_2400_5280.segy
2b Deep penetration seismic reflection (crossing)	yes	Line: Meg9 Position: CMP 2750, 375 m north
3 Seismic Velocity	yes	Harding et al. 2016 & in prep- Meg4 & Meg9 waveform inversion (older version Henig et al. 2012 Meg4 & 9 downward continued to seafloor streamer tomography)
4 Seismic Grid	yes	Meg4, Meg5, Meg6, Meg9, Meg10- Canales et al., 2004 (Meg8 outside corner)
5a Refraction (surface)	yes	OBS refraction- Blackman and Collins 2010; Line 9a near site
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	CD100 EM12, MARVEL2000 SeaBeam2000, 100-m regional grid Blackman et al., 2008. EM120 20-50m grid Früh-Green et al., 2017.
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	yes	CD100 Tobi MARVEL2000 DSL120
9 Photography or video	yes	MARVEL 2000 Alvin and Argo images
10 Heat Flow	no	
11a Magnetics	yes	Pariso et al., 1996; MARVEL2000 deep-tow
11b Gravity	yes	Blackman et al., 2008
12 Sediment cores	no	
13 Rock sampling	yes	CD100 Dredge, MARVEL2000 Alvin; Exp357 Holes M0069A; M0072A,B; M0076A,B
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	1 yr study, Collins et al. 2012
16 Navigation	yes	MCS, OBS refraction, DSL120, Alvin rock sample & dredge locations
17 Other	no	Because this site is an area rather than a specific point, the data uploaded for AMDH-2A and AMDH-3A is sufficiently representative

IODP Site Forms

Form 4 - Environmental Protection

Proposal #: 937 - Add	Site #: AMDH-05A	Date Form Submitted: 2021-05-30 10:29:11
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Pollution & Safety Hazard	Comment
1. Summary of operations at site	RCB to 100mbsf; logging at end of drilling for each hole with sufficient depth
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	none
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	none
4. Indications of gas hydrates at this location	none
5. Are there reasons to expect hydrocarbon accumulations at this site?	none
6. What "special" precautions will be taken during drilling?	none
7. What abandonment procedures need to be followed?	standard
8. Natural or manmade hazards which may affect ship's operations	junk in some Exp 357 holes
9. Summary: What do you consider the major risks in drilling at this site?	serpentinite fault zone so drilling conditions may be difficult

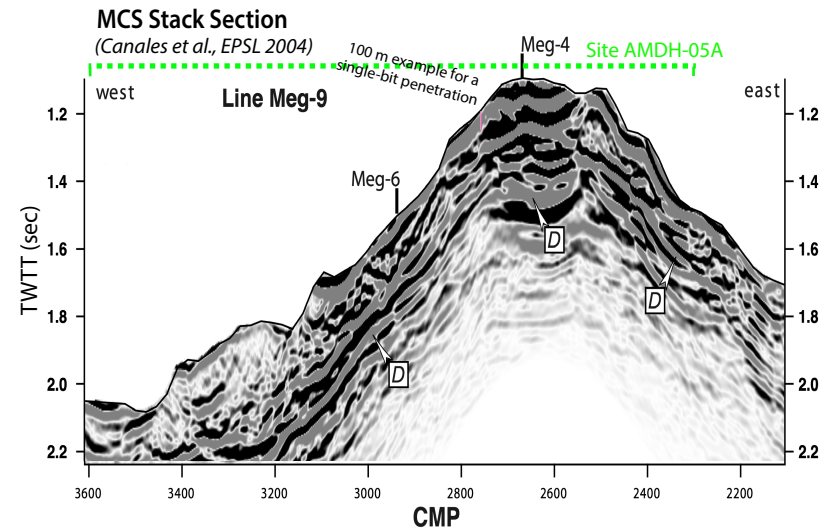
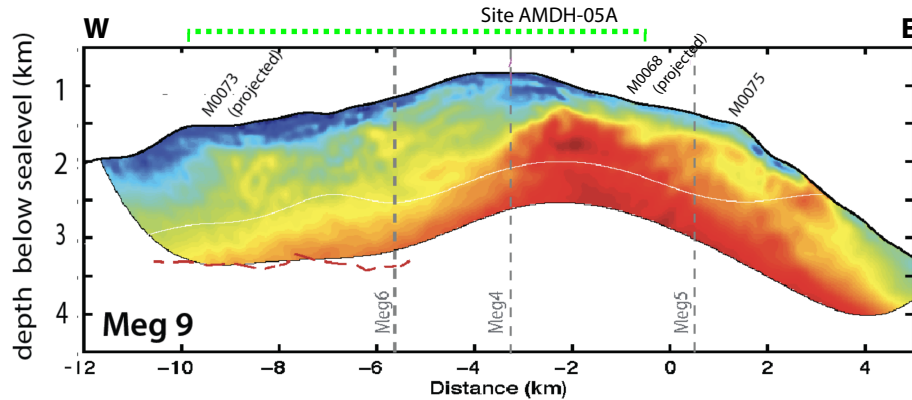
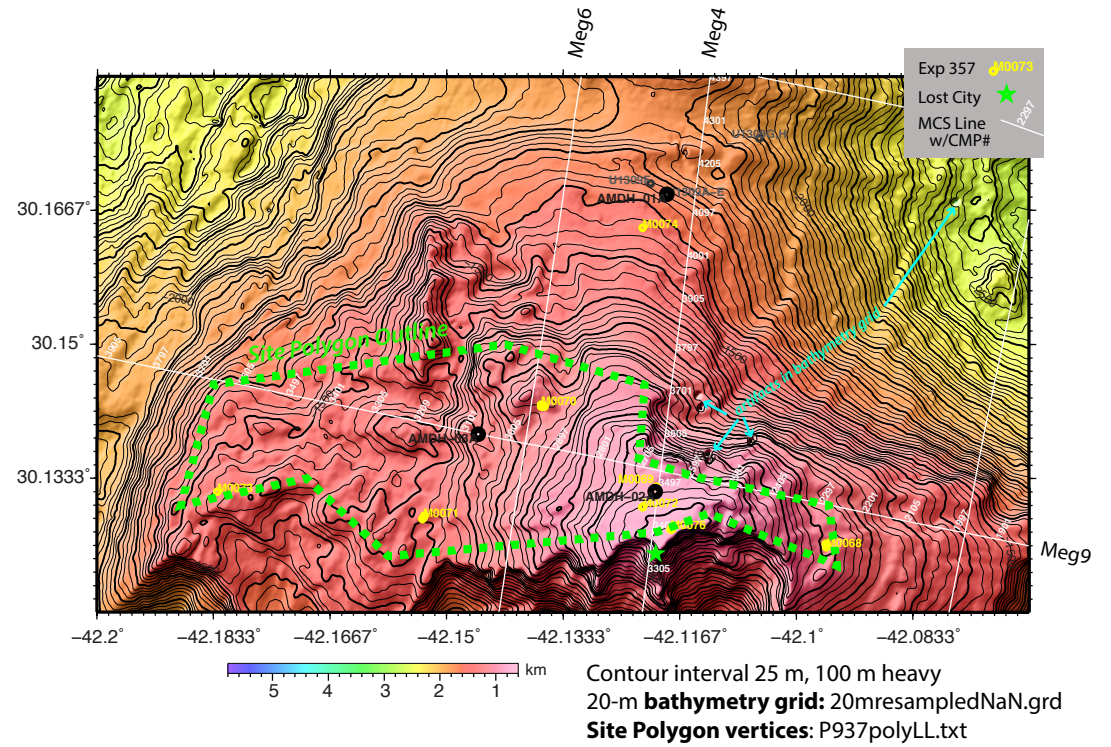
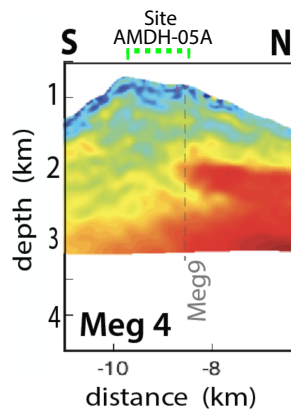
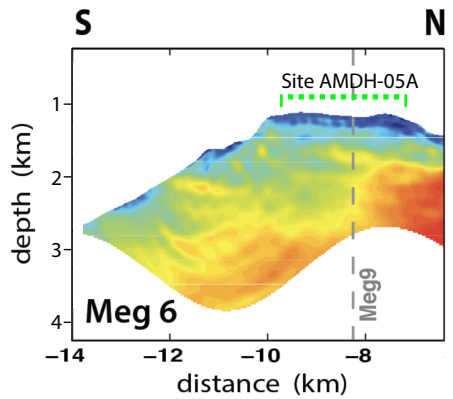
IODP Site Forms

Form 5 - Lithologies

Proposal #:	937 - Add	Site #:	AMDH-05A	Date Form Submitted:	2021-05-30 10:29:11
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Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 6.5		0		loose carbonate sand in pockets. rubble possible			Based on M0069A, 50 m away, but sediment pockets very variable
6.5 - 12		1		metadiabase			based on M0069A. Good recovery in this section, but may not occur based on moderately dipping contact
12.5 - 13.2		1		sub-horizontal fault zone and breccia			based on M0069A. Similar fault zones likely throughout section
13.2 - 100				heterogeneous fault/shear zone dominated by serpentinite			13-16.5 mbsf section in M0069A was massive serpentinite with good recovery

# IODP 937 Addendum-2, Site Figure AMDH-05A



MCS: meg9migrated.segy, meg9stack.segy, meg9.cdp\_nav\_bat\_twtt  
 Velocity models (waveform inversion): Meg9velModel.txt, Meg6velModel.txt, Meg4velModel.txt