IODP Proposal Cover Sheet

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Kane Megamullion Deep Drilling

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Title	KANE OCC, DRILLING LOWER CRUST AND MANTLE AT THE SLOW SPREADING MAR
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Keywords	Oceanic-Core-Complex, serpentinization, biogeochemistry, seismic
Area	Mid Atlantic Ridge

Proponent Information

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Abstract

This proposal is for two 500-m deep holes on the long-lived detachment fault footwall at the Kane Megamullion, an oceanic core complex (OCC) located at 23°N on the Mid Atlantic Ridge (MAR). The site of the first hole, KNA-01A, is on peridotite, which based on seismic structure and geologic reconnaissance represents exhumed mantle directly exposed on the seafloor. The second site, KNC-01A, is on talc-serpentine schist, which is believed to mask a 264 km2 gabbro body close to the same lithospheric flow line. There are 4 principal objectives: (1) Test the seismic and geologic interpretations of the Kane OCC sub-surface structure. (2) Test the variability of crustal architecture with decreasing melt flux in 3D. (3) Examine hydrothermal alteration processes in lower crustal and mantle lithologies as a function of depth and temperature. (4) Explore heterotrophic and chemolithoautotrophic lifestyles in the lower oceanic crust and upper mantle at the Kane OCC. The drilling strategy calls for both sites to be drilled to 500-m using a drill-in hard-rock guide base, and then to deepen whichever hole is in the best shape. Based on the tectonic setting, and past drilling history at Atlantis Bank, and Atlantis Massif, JRSO calculates these holes can be drilled in 33.6 days, assuming an 8.8 days Barbados-Bermuda transit. Based on a standard leg, this leaves 5 days contingency, or sufficient for an additional ~130 m of drilling.

Scientific Objectives

(1) Test the seismic and geologic interpretations of the Kane OCC sub-surface structure
We will drill to test the interpretation based on seismic velocities derived from travel time and full waveform tomography of multichannel seismic data.
(2) Test the variability of crustal architecture with decreasing melt flux in 3D
We will compare the petrological and structural characteristics of gabbros from a 500-m-thick lower crustal section with the inferred mantle section.
(3) Examine hydrothermal alteration processes in lower crustal and mantle lithologies as a function of depth and temperature
We will examine major aqueous alteration processes affecting mafic and ultramafic rocks as a function of depth.
(4) Explore heterotrophic and chemolithoautotrophic lifestyles in the lower oceanic crust and upper mantle at the Kane OCC
We will examine how lithology shapes subsurface microbiology and biogeochemical cycling independent of variations in spreading rate and tectonic setting.

Drilling complementary holes in massifs similar in size, emplaced on the same mantle-flow line at the same spreading rate would eliminate those variables when comparing them structurally, biologically, and geochemically, thus enhancing the global significance of our objectives.

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

No

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 proposal builds upon Proposal 950-Full, which was deactivated and resubmitted as Proposal 971-Full (2019). We have now developed this new proposal, which has been revised following all the encouraging inputs from SEP.

The SEP considered the science to be exciting, impactful and of global significance, but found significant flaws to be considered before sending for external review: (1) the significance of the proposed work; (2) testable hypotheses for each objective; (3) methodologies used to test hypotheses; (4) results and deliverables; (5) risk mitigation strategy.
Following these recommendations we:
(1) Revised the Introduction highlighting the significance of our work (see also section 2)
(2) Formulated 9 hypotheses within 4 objectives (sections 2 and 4)
(3) Explained how each hypothesis will be tested in each objective (section 4), also including methodology (e.g., sections 4.3.1&4.4.1).
(4) Indicated the outcomes and links to IODP Science Plan (section 5)
(5) Articulated a new drilling plan (section 6), indicating operations strategy, depth justification, prioritization of sites, and a new alternate site moving to younger crust on the fault plane (KNC-04A).

Specific changes for each objective are:
[Objective 1]
• We made testing the geological interpretation of the seismic models a primary objective, and formulated an alternate hypothesis (H1.2) in case the seismic models have been incorrectly interpreted (section 4.1). In such scenario, we discussed the implications for Objectives 3 and 4 (Section 5), and mitigation strategies (Section 6).
• We included Full Waveform Inversion Vp vertical profiles (Fig. 5), compared with laboratory measurements (IODP Expedition 357). Resolution of the FWI models is discussed in Sections 6.2, 6.4. Models are included in the survey data package and in Xu et al. (2020).
[Objective 2]
• We formulated two distinct hypotheses (H2&3) to be tested by drilling (new Fig.3), also recalled in the Introduction.
• We indicated the methods (petrological, structural and geochemical investigations) used to test hypothesis H2 (section 4.2)
• We justified drilling depths (section 6.2) and added an alternated site as operational mitigation risk (KNC-04A).
[Objective 3 (former-4)]
• We stated 3 hypotheses (H4,5,6) that focus on the alteration of mafic and ultramafic rocks,
• We added a new section explaining an array of well-established and cutting-edge methods (section 4.3.1)
• We indicated mitigation strategy if drilling did not yield the lithologies expected and underlined the values of the returned data (section 4.3), i.e., we considered a range of lithologies and alteration intensities, and implications for the composition of fluids and habitability (new Figs.8, 9).
[Objective 4 (former-5)]
• We stated 3 closely related hypotheses (H7,8,9) focusing on the possibility that heterotrophs dominate the microbial community and the possible links between microbial activities, carbon source, and host rocks.
• We expanded our discussion of prior studies of ocean crust and links between different alteration processes/lithologies and microbial biomass and activity. We also explained why we are poised to address our objectives/ questions regardless of whether one or two sites are drilled.
• We expanded our description of proposed methods in the new section 4.4.1.

Finally, we provided high-resolution images and implemented site forms as requested.

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Proposed Sites (Total proposed sites: 6; pri: 2; alt: 4; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
KNA-01A (Primary)	23.49047 -45.38105	2315	0	500	500	Drill with coring to 500-m minimum, with option to go deeper if time permits to 1000 meters in mantle exposed on the seafloor. The Site will recover the first long section of the abyssal mantle for the purpose of determining: (i) the seismic character of the shallow mantle, (ii) the nature of the basement below a 'orphan crust', (iii) the alteration processes and carbon (bio-)geochemistry, (iv) the biochemistry and deep biosphere in the oceanic mantle.
KNA-02A (Alternate)	23.51191 -45.37665	2473	0	500	500	Drill with coring to 500-m minimum, with option to go deeper if time permits to 1000 meters in mantle exposed on the seafloor. The Site will recover the first long section of the abyssal mantle for the purpose of determining: (i) the seismic character of the shallow mantle, (ii) the nature of the basement below a 'orphan crust', (iii) the alteration processes and carbon (bio-)geochemistry, (iv) the biochemistry and deep biosphere in the oceanic mantle.
KNA-03A (Alternate)	23.48768 -45.36771	2413	0	500	500	Drill with coring to 500-m minimum, with option to go deeper if time permits to 1000 meters in mantle exposed on the seafloor. The Site will recover the first long section of the abyssal mantle for the purpose of determining: (i) the seismic character of the shallow mantle, (ii) the nature of the basement below a 'orphan crust', (iii) the alteration processes and carbon (bio-)geochemistry, (iv) the biochemistry and deep biosphere in the oceanic mantle.
KNC-01A (Primary)	23.49278 -45.28650	2080	0	500	500	Drill and core a long section of the lower ocean crust in the Mid-Atlantic Ridge segment. The Site is covered by talc and serpentine schist on a detachment footwall, but based on seismic results, the schist is little more than a meter thick, and is underlain by lower crustal gabbro. This Site will (i) test the seismic interpretation of Kane MM (ii) collect a gabbro section formed at a moderate melt supply, (ii) evaluate hydrothermal and (iv) biological processes in the lower crust to be compared with other holes at slow spreading ridges.
KNC-02A (Alternate)	23.47182 -45.29118	2080	0	500	500	Drill and core a long section of the lower ocean crust in the Mid-Atlantic Ridge segment. The Site is covered by talc and serpentine schist on a detachment footwall, but based on seismic results, the schist is little more than a meter thick, and is underlain by lower crustal gabbro. This Site will (i) test the seismic interpretation of Kane MM (ii) collect a gabbro section formed at a moderate melt supply, (ii) evaluate hydrothermal and (iv) biological processes in the lower crust to be compared with other holes at slow spreading ridges.
KNC-04A (Alternate)	23.49067 -45.27670	2183	0	500	500	Drill and core a long section of the lower ocean crust in the Mid-Atlantic Ridge segment. The Site is covered by talc and serpentine schist on a detachment footwall, but based on seismic results, the schist is little more than a meter thick, and is underlain by lower crustal gabbro. This Site will (i) test the seismic interpretation of Kane MM (ii) collect a gabbro section formed at a moderate melt supply, (ii) evaluate hydrothermal and (iv) biological processes in the lower crust to be compared with other holes at slow spreading ridges.