IODP Proposal Cover Sheet

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Title:	**The Guaymas Basin Transect: Feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial activity and diversity**
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Permission to post abstract on IODP Web site: X Yes ☐ No

Abstract: *(400 words or less)*

Guaymas Basin, a tectonically complex, active spreading center overlain with thick organic-rich sediments in the central Gulf of California, is characterized by hydrothermal alterations of buried sedimentary organic matter and formation of petroleum and light hydrocarbons. Hot magmatic intrusions (sills) emplaced into these sediments produce organically derived thermogenic alteration products (hydrothermal petroleum) that migrate to the sediment surface, where they fuel extensive and complex microbial ecosystems, The tectonic setting, spatial patterns of hydrothermal activity, organic carbon alteration processes, and attendant microbial activities and community structure at Guaymas Basin are clearly linked, and motivate this proposal that integrates geological, geochemical and microbiological approaches and expertise. We are proposing a drilling transect from ca. 53 km northwest of the spreading center (ca. 2.2 ma. spreading age) , towards the central Guaymas Trough north of DSDP 481, and then 30 km southeast (ca. 1.2 ma). In addition, redrilling DSDP 477 will access high heatflow sites and hydrothermally altered sediments at the active Southern Guaymas spreading center. Selected holes will penetrate into basement basalt. Thus, the Guaymas transect captures the full hydrothermal spectrum from hot spreading center towards cold, mature off-axis sites. The drilling strategy of mixed APC and XCB drilling, according to the varied sediment/rock substrate, and the selection of sites along a transect across Guaymas Basin, pursue two general goals: A) Ground-truthing new seismic data indicating that magmatic sills are emplaced into layered sediment sequences and extending tens of miles from the active spreading center, with profound implications for the geological evolution of Guaymas Basin, and for much more extensive hydrothermal sediment alteration and carbon release than previously thought. B) Tracking the chemical and microbial modifications of buried organic matter along its migration path from deep source to the sediment surface, and linking these processes to microbial in-situ activity and diversity. The integrated structural geology, geochemistry and microbiology of Guaymas Basin provides a model for active sedimented spreading centers, such as the Red Sea, Gulf of Aden, South China Sea, East Sea/Sea of Japan, Aegean Sea, Algero-Balearic Basin in the Mediterranean, and the Northeast Pacific. The Guaymas drilling transect will also inform on the consequences of past rifting episodes affecting organic-rich, heavily sedimented marine regions for hydrocarbon release and climate change.

Scientific Objectives: (*250 words or less*)

A) Determine the spatial and temporal distribution of magmatic sill emplacement.
B) Assess the affects of sediment thickness and type on hydrologic properties, magmatic emplacement, sill properties, and the degree and spatial extent of hydrothermal alteration.
C) Estimate the budget of sequestered versus thermogenically released sedimentary carbon
D) Fully document the in-situ reactions, chemical pathways and consequences of hydrothermal alteration of sediment surrounding a sill prior to the onset of microbial alteration
E) Relate temperature and temperature gradients to the extent and activity of geothermally driven vs microbially catalyzed hydrocarbon transformation
F) Document microbial diversity and activity and the relationships between microbial life and chemical and thermal gradients

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

We will use microbiological and geochemical approaches that are mostly shorebased: Gene sequencing, environmental genomics, nucleic-acid based quantifications, cultivations for microbiology: advanced analytical organic chemistry, biomarker analysis, radiotracer rate measurements, stable C- or S-isotope analysis. However, samples can be adequately prepared and/or conserved in the shipboard microbiology and chemistry labs, and are then shipped to the investigators home institutions. This approach worked well on ODP Leg 201 and IODP Leg 1301.

Proposed Sites:

Site Name	Position	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
GUAYM-01A	27° 38.106’N 111° 53.172’W	1604	400	250	650	Off-axis old sedimentary sequence, no sills
GUAYM-02A	27°.37.788’N 111° 52.668’W	1595	300	1000	1300	Recover off-axis old sediment & sills, and go into basement
GUAYM-03A	27°. 30.246’N 111°. 40.878’W	1749	100	355	455	Recover basement high, sills, & thicker sediment sequence
GUAYM-04A	27°. 28.818’N 111°. 38.664’W	1776	400	300	700	Recover deep sediment pond sequence, to basement
GUAYM-05A	27°. 27.078’N 111°.35.952’W	1763	150	900	1050	Recover basement high & sills under thin sediment
GUAYM-06A	27°. 21.690’N 111°.27.594’W	2043	100	400	500	Hydroth. mounds and sills of spreading center endmember
GUAYM-07A	27°. 18.390’N 111°. 22.500W	1891	500	100	600	Recover conspicuous multiple deep sill/sediment sequences
GUAYM-08A	27°. 12.486’N 111°. 13.374’W	1852	600	400	1000	Recover off-axis endmember with old, compacted sills
GUAYM-09A	27°.01.850’N 111°. 24.030’W	2003	400	0	400	Redo DSDP 477 with modern Microbiol. & Geochem
GUAYM-10A	27°. 50.000’N 111°. 23.00’W	1998	400	0	400	Redo DSDP 477 vicinity with modern Microbio & Geochem

IODP Drilling Pre-proposal: The Guaymas Basin Transect -
Feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial activity and diversity

Guaymas Basin, in the Gulf of California, is a young spreading center where new igneous crust is forming beneath a 1-2 km thick layer of sediment. New seismic data indicate that active, shallow magmatic emplacement, in the form of sills intruding into organic-rich sediment, takes place over a wide region, extending more than 40 km away from the axis of spreading. This observation has a number of important implications that bear directly on the three main scientific themes of IODP, *solid earth cycles*, *environmental change*, and *the deep biosphere*. Rifting promotes sediment accumulation and terrestrial-to-marine chemical exchange, sedimentation affects magmatic emplacement – broadening it relative to unsedimented ridges, broad magmatic emplacement chemically alters a large volume of organic rich sediments, and geochemical and thermal gradients associated with this alteration promote sub-seafloor microbial activity and diversity. Thus, the thematically diverse processes operating in Guaymas Basin are intimately linked. Moreover, these processes should be common to many young spreading centers, which are often thickly sedimented due to their proximity to terrigenous sediment sources and the influence of coastal oceanographic upwelling. Modern examples include the Red Sea, the Gulf of Aden, the South China Sea, the East Sea/Sea of Japan, and the Aegean Sea.

We propose a drilling survey of the Guaymas Basin to examine the links and feedbacks between sediment accumulation, magmatism, rift evolution, carbon sequestration and liberation, hydrothermal carbon maturation, and microbial diversity within this young, sedimented spreading system.

Introduction

The Gulf of California is a narrow sea formed through continental rifting, with the Baja California Peninsula rifting away from North America beginning 12-15 Ma B.P. [*Stock and Lee*, 1994]. Today the gulf is comprised of a number of short spreading segments separated by transform faults. Most of these segments have rifted to completion, including the two segments of the Guaymas Basin, where continental rupture was complete by ~6 Ma [*Lizarralde et al.*, 2007] (Fig. 1). Thick (1-2 km), organic-rich sediments overlie the spreading centers of Guaymas Basin. Magmatic emplacement within Guaymas Basin is thus primarily intrusive, involving shallow intrusion of doleritic sills into unconsolidated sediments [*Saunders et al.*, 1982].

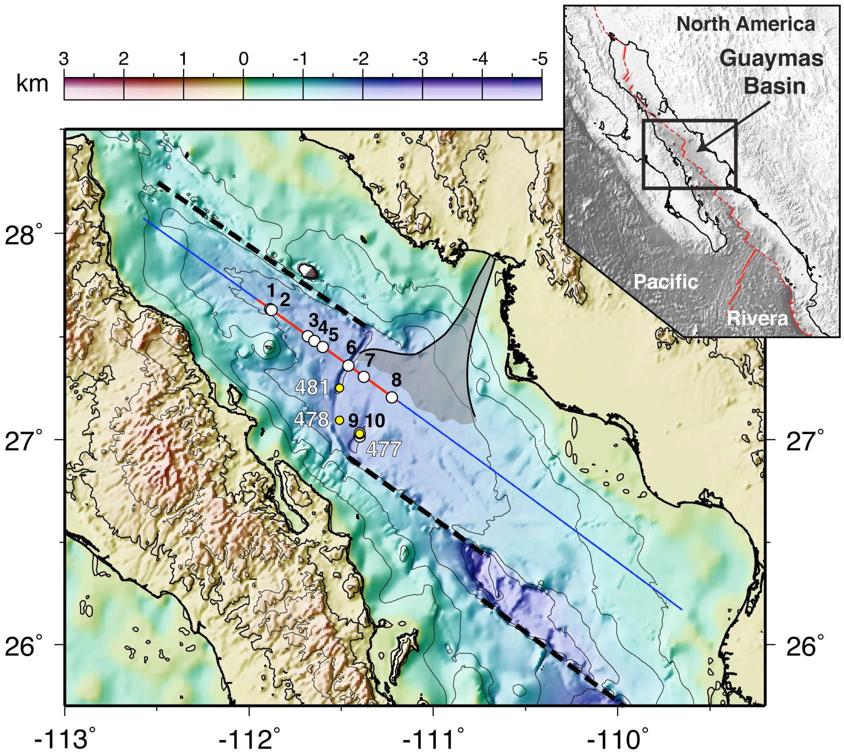

Fig. 1. Bathymetry of Guaymas Basin. Overlapping grabens are bathymetric deeps. Red line indicates portion of MCS transect (blue line) shown in Fig. 2 and site location document. White dots are locations of proposed drill sites 1 – 8. Drill sites 9 and 10 correspond to redrilling the active, hot spreading center near DSDP Leg 64 Site 477 (DSDP sites indicated in yellow)

New seismic data across the rift suggest that the region of active sill emplacement is quite wide, ~90 km, relative to unsedimented spreading systems, where shallow crustal accretion is focused toward the spreading-center axis by hydrothermal cooling [*Maclennan et al.*, 2004]. It is likely that the blanket of sediments in Guaymas Basin inhibits deep crustal hydrothermal circulation [*Hutnak and Fisher*, 2007], thereby limiting crustal-level magmatic focusing and enabling a broad region of shallow magmatic emplacement. A primary consequence of a broad region of shallow magmatic intrusion is that a large volume of organic rich sediment is susceptible to thermogenic alteration.

Field programs conducted at the spreading axis in Guaymas Basin, including DSDP Leg 64, and laboratory experiments have provided the foundation for understanding the thermal alteration of sedimentary organic matter [*Curray and Moore*, 1982; *Von Damm* et al., 1985; *Campbell et al.*, 1988; *Von Damm*, 1991; *Seewald et al.*, 1990, 1994; *Kawka and Simoneit*, 1994; *Simoneit et al.*, 1988; 1996; *de la Lanza-Espino and Soto*, 1999]. Magmatic intrusions into sediments produce organically derived thermogenic alteration products dominated by methane [*Welhan et al.*, 1988], CO_2, low-molecular weight organic acids [*Martens*, 1990], and a wide spectrum of hydrocarbons [*Simoneit and Lonsdale*, 1982; *Simoneit*, 1985; *Bazylinski et al.*, 1988, *Whelan et al.*, 1988] that are released into sedimentary pore fluid and the ocean. Organic-rich fluids transported to the upper sediment column provide fossil carbon substrates to highly active, benthic microbial communities where they are oxidized and assimilated [*Pearson et al.*, 2005; *Amend and Teske*, 2005; *Kniemeyer et al.*, 2007]. Molecular surveys of the surficial Guaymas sediments indicate significant, unexplored microbial diversity, and high potential for novel and unusual hyperthermophiles, hydrocarbon degraders, and sulfur-and methane-cycling microorganisms [*Teske et al.*, 2002, 2003; *Edgcomb et al.*, 2002; *Dhillon et al.*, 2003, 2005; *Kysela et al.*, 2005; *Lever*, 2008; *Teske et al.*, 2009].

Relevance to the IODP Initial Science Plan

The Guaymas Basin hosts a range of fascinating, poorly understood geological, physical and biogeochemical processes that are intimately linked. The geologic processes must be understood in order to understand the hydrologic and geochemical processes, and these in turn must be known in order to understand the biological processes. The processes encompass the entire suite of scientific themes outlined in the IODP initial science plan:

<u>Solid earth cycles and geodynamics.</u> The thick overlying sediments directly influence the distribution of crustal melt and, as a result, the geodynamic evolution of continental rifting.

<u>*Evironmental change, processes and effects.*</u> The extensive inter-layered sill/sediment complex provides an efficient engine for the thermogenic release of carbon stored in the sediments, potentially canceling much of the carbon sink commonly attributed to rifting. A more complete understanding of these systems is thus important to our understanding of the global carbon cycle.

<u>*The deep biosphere and the subseafloor ocean.*</u> The diverse range of thermal and chemical gradients resulting from widespread sill intrusion produces a variety of habitats that support the development of structurally diverse microbial communities in the subseafloor.

Scientific Objectives

The scientific objectives of the proposed drilling effort are aimed at testing the following specific hypothesis related to shallow magmatic emplacement, sedimentary controls on emplacement processes, and their implications for hydrologic, geochemical, and biological processes in the Guaymas Basin subsurface.

• Active magmatic sills emplacement occurs over a broad region, extending more than 40 km away from the kinematic center of spreading.

• Thick sediments promote a wide region of active sill emplacement by limiting deep crustal hydrothermal cooling that focuses shallow magmatism at unsedimented mid-ocean ridges.

• The variation in sediment type across the basin accentuates an asymmetry in melt delivery that controls the evolution of rifting over long timescales.

• The layered, spatially extensive sills are a crucial reaction interface and heat source for the extensive reservoir of organic-rich sediments and hydrothermal fluids in Guaymas.

• Magmatically triggered methane release from organic-rich sediments can influence carbon budgets.

• The thermal regime of the layered sediments and sills controls the extent and activity of geothermally driven versus microbially catalyzed hydrocarbon transformation.

• Microbial life colonizing Guaymas Basin sediments occurs as distinctly stratified, differentially active communities that respond to spatially and temporally varying thermal and chemical gradients in the sediment/sill column across the basin.

• Active microbial communities are key players in transformations of hydrocarbons and buried organic matter, and for metal and sulfur cycling in the Guaymas Basin subsurface.

• Guaymas Basin and other sedimented rifts are sources for novel microbial life, novel microbial pathways and biomarkers in the hydrothermal subsurface.

Tests of these hypothesis require scientific drilling. Accordingly, we propose a series of ten drill holes designed to achieve the following scientific objectives.

1) Determine the spatial and temporal distribution of magmatic sill emplacement.

Overlapping seafloor grabens, ~200 m deep, define the axes of spreading of the two Guaymas Basin segments. The discovery of hydrothermal systems within these grabens [*Lonsdale and Lawver*, 1980], analogies to unsedimented mid-ocean ridges, and early geophysical work within Guymas Basin [*Lawver et al.*, 1975] led to the view that shallow magmatic emplacement occurs in the form of sill intrusion primarily beneath the seafloor grabens. However, new seismic data strongly suggest that active sill emplacement takes place well away from the axial grabens [*Lizarralde et al.*, submitted]. This interpretation implies that crustal melt distribution is fundamentally different at Guaymas Basin than at unsedimented systems and that the region of active magmatic/sedimentary interaction is substantially broader than previously believed.

Our seismic interpretation is based on a number of factors, including the distinct seismic character of the interpreted sill horizon and it's similarity to other known sills [*Davies et al.*, 2002; *Thomson and Hutton*, 2004] and to the reflective feature beneath the seafloor mound within the northern graben, which is most likely a sill. The interpretation needs to be verified, however, and its implications explored. . Sediment thickness above a sill provides a maximum intrusion age, and the thickness of undisrupted sediments overlying sediments disrupted by the intrusion event provides tighter age constraints, but these proxies (which suggest, for example, that sills at 2 Ma spreading age were emplaced 120 ky ago) need to be verified. Verifying the age of intrusions, defining the distribution of sill age with distance from the axis, and understanding the causes of overlying sedimentary disruption (e.g. the intrusion event and subsequent hydrologic and chemical processes) are all required in order to fully understand how sedimented spreading systems operate. These goals can only be achieved through drilling.

2) Assess the affects of sediment thickness and type on hydrologic properties, magmatic emplacement, sill properties, and the degree and spatial extent of hydrothermal alteration.

We hypothesize that thick sediments enable a broad region of shallow sill emplacement. Understanding this sedimentary effect will be aided by the observed asymmetry in the depth distribution and character of the sills on either side of the axial graben. This asymmetry correlates with a change in sediment type on either side of the basin, with primarily biogenic sediments to the northwest and more terrigenous input to the southeast due to the wetter climate of mainland Mexico relative to the Baja Peninsula. Density contrasts within the sediments, depression of geotherms in the southeast due to greater sedimentary flux [*Hansen and Nielsen*, 2002], and thermal refraction due to the lower permeability of the turbiditic sediments [*Spinelli et al.*, 2004] may create a tendency for melt to migrate westward during its vertical ascent through the crust. Crustal strength would also be affected, as heat advected with migrating melt enhances the lateral temperatures differences, resulting in asymmetric crustal tectonics, which is observed in the crustal scale seismic velocity structure [*Lizarralde et al.*, 2007]. Such a scenario is speculative, but, if true, it could alter our view of the role of sediments in early rift evolution, as asymmetric regional climatic conditions commonly result during early rifting. The differences in sedimentary properties across the basin can be utilized to probe the sensitivity of magmatic emplacement to sediment type. The proposed drilling will enable us to measure geothermal gradients within the sedimentary column across the entire basin and to relate these gradients to sedimentary physical properties, providing both the input parameters and the observables needed to constrain thermal models of basin evolution.

3) Estimate the budget of sequestered versus thermogenically released sedimentary carbon.

The narrow seas created by continental rifting are sites of terrigenous and biogenic sediment deposition. The carbon sequestration associated with such sedimentation [*Lerman et al.*, 2007] has led to suggestions that rifting may cool the atmosphere, leading to glaciation [*Eyles*, 2008] and even a "snowball-Earth" [*Donnadieu, et al.*, 2004]. Carbon sequestration within young spreading systems such as Guaymas Basin, however, may be an inefficient process despite high sedimentation rates, since the sediments promote a broadly distributed heat source that can efficiently release carbon back into the ocean. This hypothesis only holds, however, if alteration processes surrounding off-axis sills are as efficient as those known to occur within the axial grabens at Guaymas Basin. These processes require both heat and fluid flux, and tectonism within the grabens may accentuate fluid flux relative to off-axis sites. Drilling data are required to determine the extent of thermal alteration of sediments around sills intruded at various depths below the seafloor and various distances from the axial graben. These data will enable us to understand the influence of overburden, tectonism, and thermal regime on thermogenic alteration in the vicinity of an intruded sill and thus better estimate the carbon flux associated with sill intrusion into organic rich sediment.

4) Fully document the in-situ reactions, chemical pathways and consequences of hydrothermal alteration of sediment surrounding a sill prior to the onset of microbial alteration.

Guaymas Basin sediments are organic-rich, containing 2-4 wt. % organic carbon [*Simoneit and Bode*, 1982]. Accordingly, the geochemistry of thermally influenced sediments is dominated by the degradation of organic matter. Focused venting of hydrothermal fluids at temperatures as high as 317°C and diffusive flow through the sediments releases organic alteration products that include short- and long-chain hydrocarbons, aromatic compounds, ammonia short-chain fatty acids, and increases levels of porewater DOC [*Von Damm et al.*, 1985; *Welhan*, 1988; *Whelan et al.*, 1988; *Kawka and Simoneit*, 1990; *Martens*, 1990, *Rushdi and Simoneit*, 2002; *Simoneit and Sparrow*, 2002]. Based on ^{14}C dating, most of the hydrothermal petroleum has a recent (3-6 ka) origin in the upper 30 m of the sediment column, whereas DIC (precipitating as carbonates in surficial sediments) originates in deeper, older sediments [*Peter et al.*, 1991; *Simoneit and Kvenvolden*, 1994]. Although the chemical composition of hydrothermal petroleum has been well characterized, reaction pathways that regulate the formation and stability of organic alteration products remain poorly constrained. Large spatial and temporal variations in the composition of organic degradation products are expected in subsurface environments influenced by sill intrusion owing to steep temperature gradients that include the near critical region of seawater. Moreover, chemical gradients that characterize subsurface environments involve redox active inorganic species that participate directly in organic reactions (*Seewald*, 2003). Many of these organic-inorganic interactions have been studied during laboratory experiments (*Leif and Simoneit* 2000; *McCollom et al*, 2001; *Seewald* 2001), but their significance in natural systems is unknown due to a lack of quantitative *in situ* observations. Knowledge of these fluids, their chemical gradients and circulation is central to understanding the distribution of subseafloor microbial life, the fate of carbon, and sediment/basalt alteration processes that influence the transport and deposition of metals.

The mechanisms and extent of metal sulfide precipitation, maturation, metal remobilization and microbial metal cycling in hydrothermally altered sediments require detailed study; earlier models had suggested that subsurface precipitation of metal sulfides reduces the metal content of the Guaymas vent fluids by several orders of magnitude [*Von Damm*, 1990; *Von Damm et al.*, 1985]. These questions will be addressed with recently developed metal stable isotope systematics (*Rouxel et al.*, 2008a,b, 2004; *Anbar and Rouxel* 2007). The microbiological implications are significant; for example, many vent archaea do not survive exposure to toxic metal-rich hydrothermal fluids without metal complexation [*Edgcomb et al.*, 2004].

5) <u>Relate temperature and temperature gradients to the extent and activity of geothermally driven vs microbially catalyzed hydrocarbon transformation.</u>

Our current knowledge of Guaymas Basin microbiology is primarily based on pushcore sampling surficial sediments within the seafloor grabens. Here, upward substrate and temperature fluxes create a spatially compressed habitat for anaerobic, sulfate-reducing or methanogenic microbial communities, often with methane- or hydrocarbon-oxidizing activities [*Rueter et al.*, 1994; *Teske et al.*, 2002; *Dhillon et al.*, 2005; *Kniemeyer et al.*, 2007; reviewed *Teske*, 2009]. These microbial communities in the upper sediment column and near the sediment surface intercept and oxidize hydrocarbons and inorganic electron donors that originate in the deep, hydrothermally heated sediment column [*Pearson et al.*, 2005].

Guaymas Basin provides a model system to explore the full range of biotic and abiotic hydrocarbon transformations under different temperature and pressure regimes, from active spreading center to cool flanking regions, and to correlate these microbial processes - such as microbial hydrocarbon cracking. oxidation and remineralization [*Parkes*, 1999] - with their in-situ temperature controls. The temperature for abiotic petroleum degradation is generally limited to temperatures >120°C [*Machel*, 1998], but the upper limit for microbial life is ca. 120°C – 130°C [*Jørgensen et al.*, 1992; *Kashefi and Loveley*, 2003; *Takai et al.*, 2008]. Low temperature abiotic maturation of organic matter generating a different spectrum of organics (LMW org. acids, acetate) [*Wellsbury et al.*, 1997] may coexist with low-temperature alkane cracking mediated by methanogens [*Zengler et al.*, 1999].

6) <u>Document microbial diversity and activity and the relationships between microbial life and chemical and thermal gradients.</u>

Multiple studies have explored microbial diversity and processes at the surface of Guaymas Basin sediments, such as methanogenesis and anaerobic methane oxidation [*Teske et al.*, 2002; *Kallmeyer and Boetius*, 2004; *Dhillon et al.*, 2005], sulfate reduction [*Elsgaard et al.*, 1994; *Jørgensen et al.*, 1990; 1992; *Weber and Jørgensen*, 2002; *Kallmeyer et al.*, 2003; *Weber and Jørgensen*, 2002; *Dhillon et al.*, 2003], aerobic degradation of aromatic hydrocarbons [*Götz and Jannasch*, 1993], diverse heterotrophic bacteria and protists [*Guezennec et al.*, 1996, *Edgcomb et al.*, 2002], and oxygen- or nitrate-dependent sulfide oxidation [*Jannasch et al.*, 1989; *Nelson et al.*, 1989; *Gunderson et al.*, 1992]. However, we know next to nothing about the depth extent of microbial life and microbial activities in the Guaymas system, except for preliminary evidence for deep biogenic methane sources [*Whelan et al.*, 1988], and phospholipid fatty acid (PLFA) profiles of deep Guaymas sediment cores [*Summit et al.*, 2000]. Microbial process rate measurements and molecular genetic surveys have demonstrated geochemically controlled stratification of microbial life and microbial activity over spatial scales of tens and hundreds of meters for the subseafloor biosphere in non-hydrothermal sediments [*Coolen et al.*, 2002; *Inagaki et al.*, 2003; 2006; *Parkes et al.*, 2005; *Sørensen and Teske*, 2006]. Temperature permitting, novel and active microbial communities are likely to permeate the deep subsurface across Guaymas Basin.

Analyses of microbial community structure, functional genes and genomics, state-of-the-art enrichments and pure culture isolations, high-throughput metagenomic surveys, and biomarker studies will significantly extend our knowledge of subsurface microbial diversity and activity along chemical and thermal gradients. We recognize this investigation of novel deep subsurface microbial life, its habitat range, genetic repertoire and environmental tolerances, as a strongly exploratory project component, but one with impressive precedents and potential for high returns [*Biddle et al.* 2008].

Drilling Site Selection

A series of eight holes (01-08) are planned along a NW-SE transect across the northern Guaymas Basin spreading segment. The locations of these holes along a MCS transect (Fig. 1), were chosen to sample sill/sediment sequences of similar age but increasing distance from the spreading axis. Two holes (09 and 10) are proposed within the Southern Trough near Site 477 (Fig. 1). These holes will drill the same sequence of sills and sediments as during DSDP Leg 64, providing a detailed biogeochemical and microbiological examination of sediments and sill/sediment interfaces using modern culturing techniques. We are open to further development and adjustment of our site selection and proposed drilling depths, as our pre-proposal evolves.

GUAYM-01A, 02A: These holes are located at the northwestern extent of recent sill emplacement. G-01 will penetrate ~600 m of unintruded sediment, bottoming at a deep sill. G-02 will drill through the same sequence of sediment that has been intruded by a recent sill at ~400 m depth. Comparison of the sediments in these two holes will provide data on the effects of sill emplacement above and below a recently intruded sill. G-02 will also extend through the entire pile of interbedded sediment and sills to the fully igneous crust beneath, providing constraints on the frequency of sill intrusion throughout the duration of active emplacement.

GUAYM-03A: This site lies above a peak in the sill horizon and above a very shallow seismic horizon that has the appearance of gas. This shallow sill may be young and hydrothermally active, providing data on the geochemical and microbial processes at an active, off-axis sill intrusion.

GUAYM-04A, 05A: Similar to Sites G-01 and 02, these sites sample the same strata that have experienced different degrees of disruption above the shallowest sill, with the strata at site G-05 being intensely disturbed. Data from these holes will enable us to relate the seismic character of disruption to the physical, chemical and biologic processes responsible for the disruption. Site G-05 will also penetrate fully igneous crust as part of the suite of three holes designed to constrain the spatio-temporal pattern of sill emplacement as well as the regional thermal regime.

GUAYM-06A: This site is located at a large seafloor hydrothermal mound with what is likely an igneous sill beneath. Since no hydrothermal activity has been identified within the northern graben, this mound is probably no longer active, providing an opportunity to examine the full effects of intense hydrothermal and alteration processes on sediments with an axial graben.

GUAYM-07A, 08A: These holes will penetrate the more terrigenous sediments on the southeastern side of the basin, enabling us to relate differences sedimentary processes to sill emplacement alteration processes. Site G-08 will also penetrate to the fully igneous basement. This site lies above the geometric center of spreading and the shallowest point of the Moho, which is likely the site of maximum melt flux from the mantle into the crust. G-08 will complete the regional thermal gradient transect of holes and provide a key test to the hypothesis that sediment type and thickness exerts a primary control on crustal melt distribution.

GUAYM-09A, 10A: These holes will drill the same sequence of sills and sediments as explored in DSDP leg 64, providing a detailed biogeochemical and microbiological examination of sediments and sill/sediment interfaces using modern culturing techniques. Samples from these sites will allow us to examine the length scale of geochemical and microbiological variability with respect to known lateral variability of shallow intrusions within the graben [*Lonsdale and Becker*, 1985]. We plan to extend one of these holes through as complete a sequence of sediment layers and sills as possible, hopefully reaching the deeply buried igneous crust.

Site survey requirements

The detailed position of the lateral drilling sites may be adjusted based on the results of the scheduled Guaymas Basin mapping survey to be conducted this year by Soule, Lizarralde and Seewald (Oct 18 – Nov. 2, 2009; NSF-ODP 0751901).

Interdisciplinary research

Our team combines the geological, geochemical, and microbiological expertise for a successful implementation of this drilling project. For space reasons, we have included details in the list of proponents and their affiliation and expertise.

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Proponents and their affiliation and expertise

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Expertise: The Teske lab at UNC Chapel Hill has long-standing expertise with the microbial diversity, anaerobic microbial processes, and environmental genomics of Guaymas Basin and microbiologically related hydrocarbon seeps In addition, the Teske lab works on microbial diversity and functional gene surveys of the sedimentary deep subsurface since ODP Leg 201 in 2002, and is performing – in collaboration with the Bay Paul Center at MBL – extensive pyrosequencing surveys of the bacterial and archaeal subsurface biosphere in organic-rich deep subsurface sediments.

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Expertise: Organic geochemistry of hydrothermal vents. The Seewald lab at WHOI has outstanding expertise in hydrothermal transformations, sources and sinks of volatile hydrocarbons and organic acids, which are expected to play a major role in the deep, hydrothermally heated sediments of Guaymas Basin.

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Expertise: Chemical cycling and isotopic fractionation of metals in ocean crust and hydrothermal systems. Rouxel's group at WHOI has pioneered the investigations of metal and metalloid isotopes in seafloor hydrothermal systems as biogeochemical tracers of hydrothermal flux and processes, and their importance for metallogenesis and deep

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Expertise: Quantification of microbial populations in deep subsurface sediments. Axel Schippers' group is focusing on molecular quantification of deep subsurface microorganisms using cell staining techniques that target specifically active microbial cells. In addition, the Schippers lab has extensive experience with gene-based quantification techniques.

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Expertise: Deep subsurface biogeochemical cycles and process rates, esp. methane and sulfur. The Jørgensen group is one of the premier research centers for sulfur biogeochemistry, with 20 years of experience in sulfate reduction and sulfur oxidation in Guaymas Basin, plus the methodology for sensitively measuring these microbial process rates at very low activities in deep subsurface sediments.

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Expertise: Geology of magmatic flows and spreading centers; see below

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Expertise: Tectonics, geophysics and seismic surveys of ocean spreading centers. Lizarralde and Soule at WHOI have reported recent seismic results that provide the impetus for exploring the magmatic accretion across the Guaymas Basin, and have expertise in continental rifting and magmatic processes at mid-ocean ridges. Lonsdale has worked extensively in Guaymas Basin and developed the foundational observations guiding our understanding of the tectonic history of the Gulf of California.

IODP Site Summary Forms:
Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New X **Revised**

Section A: Proposal Information

Title of Proposal:	**The Guaymas Basin Transect – feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial activity and diversity**
Date Form Submitted:	April 1, 2009
Site Specific Objectives with Priority (Must include general objectives in proposal)	Site GUAYM-01A is a companion site to GUAYM-02A, at approx. 53 km distance from the spreading center and 2.2 m.a spreading age. In contrast to GUAYM-02A, the strong seismic reflector at ca. 300 mbsf is missing, and allows detection of two additional reflectors (continuous with faint reflectors at GUAYM-02A) that might correspond to very deeply buried sills. We propose drilling to a depth of ca. 400 mbsf, with the objective to recover the full off-axis sediment sequence and also the depth horizon that corresponds to the upper strong reflector at GUAYM-02A.
List Previous Drilling in Area:	DSDP Leg 64

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	GUAYM-01A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Guaymas Basin
Latitude:	Deg: 27°N	Min: 38.106	Jurisdiction:	Mexico
Longitude:	Deg: 111°W	Min: 53.172	Distance to Land:	50 km
Coordinates System:	WGS 84, Other ( )			
Priority of Site:	Primary:	Alt: X	Water Depth:	1604 m

Section C: Operational Information

	Sediments		Basement	
Proposed Penetration: (m)	upper 400 m are sediment layers, the thickest and probably the oldest in our Transect		Basement, identified by a high sill-to-sediment ratio, may be reached at some point below the 400 m sediment layer	
	What is the total sed. thickness? ca. 400 m			
			Total Penetration:	650 m

General Lithologies:	sediments consisting of diatom ooze and mud turbidites,, hydrothermally altered sediments resulted in sandstone and gray claystones; dolerite sills	
Coring Plan: *(Specify or check)*	Sediments are cored with APC, magmatic sills and basement with XCB	
	1-2-3-APC: **X** VPC* ☐ XCB: **X** MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐	
	** Systems Currently Under Development*	

Wireline Logging Plan:	Standard Tools	Special Tools		LWD
	Neutron-Porosity X	Borehole Televiewer ☐	Formation Fluid Sampling ☐	Density-Neutron ☐
	Litho-Density X	Nuclear Magnetic Resonance ☐	Borehole Temperature & Pressure X	Resistivity-Gamma ray ☐
	Gamma Ray X	Geochemical X	Borehole Seismic ☐	Acoustic ☐
	Resistivity X	Side-Wall Core Sampling ☐		
	Acoustic X			
	Formation Image ☐		Others (Microbiology)	Others ( )

Max.Borehole Temp. :	*Expected value (For Riser Drilling)* < 84°C (best analog: 130°C/km mbsf at off-axis DSDP 478°C	

Mud Logging: *(Riser Holes Only)*	Cuttings Sampling Intervals					
	from	m	to	m,	m intervals	
	from	m	to	m,	m intervals	
					Basic Sampling Intervals: 5m	

Estimated days:	Drilling/Coring: 3	Logging: 1	Total On-Site: 4
Future Plan:	*Longterm Borehole Observation Plan/Re-entry Plan*		

Hazards/ Weather:	*Please check following List of Potential Hazards*			*What is your Weather window? (Preferable period with the reasons)*
	Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity X	Year-round due to protected Gulf of California location
	Hydrocarbon X	Soft Seabed ☐	Landslide and Turbidity Current ☐	
	Shallow Water Flow ☐	Currents ☐	Methane Hydrate ☐	
	Abnormal Pressure ☐	Fractured Zone ☐	Diapir & Mud Volcano ☐	
	Man-made Objects ☐	Fault ☐	High Temperature X	
	H_2S X	High Dip Angle ☐	Ice Conditions ☐	
	CO_2 ☐			

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Please fill out information in all gray boxes
Revised 7 March 2002

New: X | Revised:

Section A: Proposal Information

Title of Proposal:	**The Guaymas Basin Transect – feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial activity and diversity**
Date Form Submitted:	April 1, 2009
Site Specific Objectives with Priority (Must include general objectives in proposal)	Site GUAYM-02A has thick sediment cover (ca. 300 mbsf), underlain by a deeply buried strong seismic reflector (sill). We hypothesize that the uppermost sill is underlain by a sequence of intercalated sediment and sills. Down-hole lithology of GUAYM-02A will be compared to GUAYM-01A where sill reflectors seem to abruptly terminate. This site represents a late stage of Guaymas Basin evolution (ca. 2.1 m.a. spreading age), with multiple buried sills under moderately thick sediment cover that indicates much more recent sill emplacement. We anticipate that basement (identified by a high sill-to-sediment ratio) underlies intercalated sediement and sills at unknown depth. The site objective is to recover this complete sequence at our oldest (spreading age) off-axis endmember site, most removed from hydrothermal influence at the Guaymas Basin spreading center, and to document the geochemical and microbiological endmember state of mature, 50 km off-axis Guaymas Basin sediments and sills that have been intruded by sills in the last 50 k.a. We propose to drill this site until basement basalt is reached.
List Previous Drilling in Area:	DSDP Leg 64

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	GUAYM-02A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Guaymas Basin
Latitude:	Deg: 27°N	Min: 37.788	Jurisdiction:	Mexico
Longitude:	Deg: 111°W	Min: 52.668	Distance to Land:	50 km
Coordinates System:	WGS 84			
Priority of Site:	Primary: X	Alt:	Water Depth:	1595 m

Section C: Operational Information

Proposed Penetration: (m)

	Sediments	Basement
Proposed Penetration: (m)	upper 300 m are sediment layers, overlying a strong seismic reflector (magmatic sill) at ca. 300 mbsf. Intercalated, increasingly compactd sediments and sills expected below 300 mbsf.	Basement, identified by a high sill-to-sediment ratio, may be reached at some point below the 300 m upper sediments
	What is the total sed. thickness? Ca. 300 m	
		Total Penetration: 1300 m

General Lithologies: sediments consisting of diatom ooze and mud turbidites,, hydrothermally altered sediments resulted in sandstone and gray claystones; dolerite sills

Coring Plan: *(Specify or check)*

Sediments are cored with APC, magmatic sills and basement with XCB

1-2-3-APC: **X** VPC* ☐ XCB: **X** MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐

** Systems Currently Under Development*

Wireline Logging Plan:

Standard Tools	Special Tools		LWD
Neutron-Porosity X	Borehole Televiewer ☐	Formation Fluid Sampling ☐	Density-Neutron ☐
Litho-Density X	Nuclear Magnetic Resonance ☐	Borehole Temperature & Pressure X	Resistivity-Gamma ray ☐
Gamma Ray X	Geochemical X	Borehole Seismic ☐	Acoustic ☐
Resistivity X	Side-Wall Core Sampling ☐		
Acoustic X			
Formation Image ☐		Others (Microbiology)	Others ( )

Max.Borehole Temp. :

Expected value (For Riser Drilling)

Expected value (For Riser Drilling)

< 84°C (best analog: 130°C/km mbsf at off-axis DSDP 478°C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from m to m, m intervals

from m to m, m intervals

Basic Sampling Intervals: 5m

Estimated days:

Drilling/Coring: 6	Logging: 1	Total On-Site: 7

Future Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity X
Hydrocarbon X	Soft Seabed ☐	Landslide and Turbidity Current ☐
Shallow Water Flow ☐	Currents ☐	Methane Hydrate ☐
Abnormal Pressure ☐	Fractured Zone ☐	Diapir & Mud Volcano ☐
Man-made Objects ☐	Fault ☐	High Temperature X
H_2S X	High Dip Angle ☐	Ice Conditions ☐
CO_2 ☐		

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

Year-round due to protected Gulf of California location

IODP Site Summary Forms:

Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New X **Revised**

Section A: Proposal Information

Title of Proposal:	**The Guaymas Basin Transect – feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial activity and diversity**
Date Form Submitted:	April 1, 2009
Site Specific Objectives with Priority (Must include general objectives in proposal)	Site GUAYM-03A has ca. 100 m of sediments overlying a shallow sill intrusion. A strong reflector interpreted as accumulated gas lies ca. 20 mbsf, below which the sediments are intensely disrupted until the sill is encountered. The seafloor at this site has a spreading age of >1 m.a., but the underlying sill is one of the most shallow in the imaged sill horizon. The site objective is to recover these relatively disrupted sediments and shallow sill to document what appears to be one of the more active off-axis sites. This will provide insight into the geochemistry and microbiological consequences of recent sill intrusions into mature Guaymas Basin sediments.
List Previous Drilling in Area:	DSDP Leg 64

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	GUAYM-03A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Guaymas Basin
Latitude:	Deg: 27°N	Min: 30.246	Jurisdiction:	Mexico
Longitude:	Deg: 111°W	Min: 40.878	Distance to Land:	50 km
Coordinates System:	WGS 84, Other ( )			
Priority of Site:	Primary: X	Alt:	Water Depth:	1749 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	upper ~100 m, overlying strong seismic reflectors (magmatic sills). Intercalated sediments and sills expected below 100 mbsf. What is the total sed. thickness? Ca. 100 m	Basement, identified by a high sill-to-sediment ratio, may be reached at some point below the 100 m sediment layer
		Total Penetration: 455 m
General Lithologies:	sediments consisting of diatom ooze and mud turbidites,, hydrothermally altered sediments resulted in sandstone and gray claystones; dolerite sills	
Coring Plan: *(Specify or check)*	Sediments are cored with APC, magmatic sills and basement with XCB 1-2-3-APC: **X** VPC* ☐ XCB: **X** MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐ ** Systems Currently Under Development*	

Wireline Logging Plan:

Standard Tools	Special Tools		LWD
Neutron-Porosity X	Borehole Televiewer ☐	Formation Fluid Sampling ☐	Density-Neutron ☐
Litho-Density X	Nuclear Magnetic Resonance ☐	Borehole Temperature & Pressure X	Resistivity-Gamma ray ☐
Gamma Ray X	Geochemical X	Borehole Seismic ☐	Acoustic ☐
Resistivity X	Side-Wall Core Sampling ☐		
Acoustic X			
Formation Image ☐		Others (Microbiology)	Others ( )

Max.Borehole Temp. :

Expected value (For Riser Drilling)
Expected value (For Riser Drilling)
< 84°C (best analog: 130°C/km mbsf at off-axis DSDP 478°C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from	m	to	m,		m intervals
from	m	to	m,		m intervals

Basic Sampling Intervals: 5m

Estimated days:	Drilling/Coring: 3	Logging: 1	Total On-Site: 4

Future Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity X
Hydrocarbon X	Soft Seabed ☐	Landslide and Turbidity Current ☐
Shallow Water Flow ☐	Currents ☐	Methane Hydrate ☐
Abnormal Pressure ☐	Fractured Zone ☐	Diapir & Mud Volcano ☐
Man-made Objects ☐	Fault ☐	High Temperature X
H_2S X	High Dip Angle ☐	Ice Conditions ☐
CO_2 ☐		

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

Year-round due to protected Gulf of California location

IODP Site Summary Forms:

Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New X Revised

Section A: Proposal Information

Title of Proposal:	**The Guaymas Basin Transect – feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial activity and diversity**
Date Form Submitted:	April 1, 2009
Site Specific Objectives with Priority (Must include general objectives in proposal)	The first of two neighboring sites (GUAYM-04A and –05A) that follow the intrusion and emplacement of magmatic sills into older, stratified sediments; these sediments reach a depth of 400 m at this site. At GUAYM-05A (ca. 0.8 m.a. spreading age), strong seismic reflectors (presumably magmatic sills) reach a shallow depth of ca. 200 mbsf; they appear to have obliterated deep sediment stratification, and also disturbed overlying sediments. The site objective is to drill through these fresh sills that were emplaced into stratified deep sediments (and are therefore younger than spreading age), and to document the geological evolution, geochemistry and microbiological consequences of this recent phase of Guaymas Basin spreading. This site will be drilled into the hypothesized stack of intercalated sills and sediment to a depth of 700 m.
List Previous Drilling in Area:	DSDP Leg 64

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	GUAYM-04A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Guaymas Basin
Latitude:	Deg: 27°N	Min: 28.818	Jurisdiction:	Mexico
Longitude:	Deg: 111°W	Min: 38.664	Distance to Land:	50 km
Coordinates System:	WGS 84, Other ( )			
Priority of Site:	Primary: X	Alt:	Water Depth:	1776 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	upper 400 m, overlying strong seismic reflectors (magmatic sills). Intercalated sediments and sills below 400 mbsf. What is the total sed. thickness? Ca. 400 m	Basement, identified by a high sill-to-sediment ratio, may be reached at some point below the 400 m sediment layer.
		Total Penetration: 700 m
General Lithologies:	sediments consisting of diatom ooze and mud turbidites,, hydrothermally altered sediments resulted in sandstone and gray claystones; dolorite sills	
Coring Plan: *(Specify or check)*	Sediments are cored with APC, magmatic sills and basement with XCB 1-2-3-APC: **X** VPC* ☐ XCB: **X** MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐ ** Systems Currently Under Development*	

Wireline Logging Plan:

Standard Tools	Special Tools		LWD
Neutron-Porosity X	Borehole Televiewer ☐	Formation Fluid Sampling ☐	Density-Neutron ☐
Litho-Density X	Nuclear Magnetic Resonance ☐	Borehole Temperature & Pressure X	Resistivity-Gamma ray ☐
Gamma Ray X	Geochemical X	Borehole Seismic ☐	Acoustic ☐
Resistivity X	Side-Wall Core Sampling ☐		
Acoustic X			
Formation Image ☐		Others (Microbiology)	Others ( )

Max.Borehole Temp. :

Expected value (For Riser Drilling)
Expected value (For Riser Drilling)
< 84°C (best analog: 130°C/km mbsf at off-axis DSDP 478°C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from	m	to	m,	m intervals
from	m	to	m,	m intervals

Basic Sampling Intervals: 5m

Estimated days:

Drilling/Coring: 4	Logging: 1	Total On-Site:5

Future Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity X
Hydrocarbon X	Soft Seabed ☐	Landslide and Turbidity Current ☐
Shallow Water Flow ☐	Currents ☐	Methane Hydrate ☐
Abnormal Pressure ☐	Fractured Zone ☐	Diapir & Mud Volcano ☐
Man-made Objects ☐	Fault ☐	High Temperature X
H_2S X	High Dip Angle ☐	Ice Conditions ☐
CO_2 ☐		

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

Year-round due to protected Gulf of California location

IODP Site Summary Forms:

Form 1 - General Site Information

Please fill out information in all gray boxes

Revised 7 March 2002

New X **Revised**

Section A: Proposal Information

Title of Proposal:	**The Guaymas Basin Transect – feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial activity and diversity**
Date Form Submitted:	April 1, 2009
Site Specific Objectives with Priority (Must include general objectives in proposal)	This is the second of two neighboring sites (GUAYM-04A and –05A) that follow the intrusion and emplacement of magmatic sills into older, stratified sediments. At GUAYM-05A (ca. 0.7 m.a. spreading age), strong seismic reflectors (presumably magmatic sills) reach a shallow depth of ca. 150 mbsf. They appear to have obliterated deep sediment stratification, and have disturbed overlying sediments with the exception of the surficial 30 – 50 m layer. The site objective is to drill through these fresh sills that were emplaced into stratified deep sediments (and are therefore younger than spreading age), and to document the geological evolution, geochemistry and microbiological consequences of this recent phase of Guaymas Basin spreading. At this site we will attempt to drill into and recover basement (identified by a higher sill-to-sediment ratio), which was a challenge for future work identified after DSDP 64.
List Previous Drilling in Area:	DSDP Leg 64

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	GUAYM-05A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Guaymas Basin
Latitude:	Deg: 27°N	Min: 27.078	Jurisdiction:	Mexico
Longitude:	Deg: 111°W	Min: 35.952	Distance to Land:	50 km
Coordinates System:	WGS 84, Other ( )			
Priority of Site:	Primary: X	Alt:	Water Depth:	1763 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	upper 150 m, overlying magmatic sills (inferred based in seismics), followed by >900 m of intercalated sediments and sills, potentially with an increasing sill-to-sediment ratio.	Basement, identified by a high sill-to-sediment ratio, may be reached at some point below the 150 m sediment layer.. Seismic results suggest ~950 mbsf.
	What is the total sed. thickness? 150 m	
		Total Penetration: 1050 m
General Lithologies:	sediments diatom ooze and mud turbidites, hydrothermally altered sediments resulted in sandstone and gray claystones; dolerite sills	

Coring Plan: *(Specify or check)*

Sediments are cored with APC, magmatic sills and basement with XCB

1-2-3-APC: **X** VPC* ☐ XCB: **X** MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐

** Systems Currently Under Development*

Wireline Logging Plan:

Standard Tools	Special Tools		LWD
Neutron-Porosity X	Borehole Televiewer ☐	Formation Fluid Sampling ☐	Density-Neutron ☐
Litho-Density X	Nuclear Magnetic Resonance ☐	Borehole Temperature & Pressure X	Resistivity-Gamma ray ☐
Gamma Ray X	Geochemical X	Borehole Seismic ☐	Acoustic ☐
Resistivity X	Side-Wall Core Sampling ☐		
Acoustic X			
Formation Image ☐		Others (Microbiology)	Others ( )

Max.Borehole Temp. :	*Expected value (For Riser Drilling)* < 84°C (best analog: 130°C/km mbsf at off-axis DSDP 478°C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from	m	to	m,	m intervals
from	m	to	m,	m intervals

Basic Sampling Intervals: 5m

Estimated days:	Drilling/Coring: 6	Logging: 1	Total On-Site: 7

Future Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity X
Hydrocarbon X	Soft Seabed ☐	Landslide and Turbidity Current ☐
Shallow Water Flow ☐	Currents ☐	Methane Hydrate ☐
Abnormal Pressure ☐	Fractured Zone ☐	Diapir & Mud Volcano ☐
Man-made Objects ☐	Fault ☐	High Temperature X
H_2S X	High Dip Angle ☐	Ice Conditions ☐
CO_2 ☐		

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

Year-round due to protected Gulf of California location

IODP Site Summary Forms:
Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New X **Revised**

Section A: Proposal Information

Title of Proposal:	**The Guaymas Basin Transect – feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial activity and diversity**
Date Form Submitted:	April 1, 2009
Site Specific Objectives with Priority (Must include general objectives in proposal)	Site GUAYM-06A sits within the active graben at the Guaymas Basin spreading axis along the multi-channel seismic transect of Lizarralde et al. [2009]. This site, located in zero-spreading-age crust, is analogous to DSDP site 477 and should represent the youngest and hottest site along the transect. GUAYM-06A is located on a seafloor mound (interpreted to be hydrothermal in origin) within the graben and is underlain by <100 m of highly-disturbed sediments. The first prominent reflector (sill) is at ca. 100 mbsf. This site will allow a thorough investigation of a reference site for hydrothermal alteration of sediments by recently emplaced sills, and the resulting gradients of temperature, geochemical regime, and microbial activity & community structure in the sediments. This baseline will be compared to the sediment and sill sequences recovered in older spreading-age crust to evaluate whether similar thermal and geochemical regimes and microbial activity are or are not restricted to the spreading axis grabens.
List Previous Drilling in Area:	DSDP Leg 64

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	GUAYM-06A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Guaymas Basin
Latitude:	Deg: 27°N	Min: 21.69	Jurisdiction:	Mexico
Longitude:	Deg: 111°W	Min: 27.594	Distance to Land:	50 km
Coordinates System:	WGS 84, Other ( )			
Priority of Site:	Primary: X	Alt:	Water Depth:	2043 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	upper 100 mbsf a hydrothermal mound and sediments; ntercalated sediments and sills below100 m.	Basement, identified by a high sill-to-sediment ratio, may be reached at some point below the 100 m sediment layer.
	What is the total sed. thickness? 100 m	
		Total Penetration: 500 m

General Lithologies:	top 100 m sediment diatom ooze and mud turbidites, then dolorite sill, then hydrothermally altered sediments (to sandstone and gray claystones) & hydrothermal mound	

Coring Plan: *(Specify or check)*

Sediments with APC coring, magmatic sills and basement with XCB coring

1-2-3-APC: **X** VPC* ☐ XCB: **X** MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐

** Systems Currently Under Development*

Wireline Logging Plan:

Standard Tools	Special Tools		LWD
Neutron-Porosity X	Borehole Televiewer ☐	Formation Fluid Sampling ☐	Density-Neutron ☐
Litho-Density X	Nuclear Magnetic Resonance ☐	Borehole Temperature & Pressure X	Resistivity-Gamma ray ☐
Gamma Ray X	Geochemical X	Borehole Seismic ☐	Acoustic ☐
Resistivity X	Side-Wall Core Sampling ☐		
Acoustic X			
Formation Image ☐		Others (Microbiology)	Others ( )

Max.Borehole Temp. :

Expected value (For Riser Drilling)
ca. 80°C (nearest analog: 161°C/km mbsf at DSDP 481, ca. 15 km south)

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from	m	to	m,	m intervals
from	m	to	m,	m intervals

Basic Sampling Intervals: 5m

Estimated days:	Drilling/Coring: 3	Logging: 1	Total On-Site: 4

Future Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity X
Hydrocarbon X	Soft Seabed ☐	Landslide and Turbidity Current ☐
Shallow Water Flow ☐	Currents ☐	Methane Hydrate ☐
Abnormal Pressure ☐	Fractured Zone ☐	Diapir & Mud Volcano ☐
Man-made Objects ☐	Fault ☐	High Temperature X
H_2S X	High Dip Angle ☐	Ice Conditions ☐
CO_2 ☐		

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

Year-round due to protected Gulf of California location

IODP Site Summary Forms:
Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New X **Revised**

Section A: Proposal Information

Title of Proposal:	**The Guaymas Basin Transect – feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial activity and diversity**
Date Form Submitted:	April 1, 2009
Site Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of multiple distinct sediment and sill layers (that are indicated by Soule-Lizzaralde multichannel seismic survey) from an intermediate position and age of Guaymas Basin flanks (ca. 0.4 m.a. spreading age), located between the currently active spreading center (GUAYM-06A and and the southeastern flank endmember (>1 m.a, GUAYM-08A). The seismic stratification at GUAYM-07A, only 10 km from the spreading center, extends with little change towards the edge of the active Northern Guaymas trench, and is believed to reflect turbiditic sedimentary layers. Strong seismic reflectors reflecting sill emplacement seem to deepen with distance from the spreading axis and are at ca. 500 mbsf at this location. This site will allow us to evaluate differences in sediment lithology and structure that we believe exist across the Guaymas Basin and drive the asymmetry in sill type and emplacement depth. The sediment permeability may fundamentally change the nature of hydrothermal circulation to the SE, relative to the NW, of the spreading axis.
List Previous Drilling in Area:	DSDP Leg 64

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	GUAYM-07A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Guaymas Basin
Latitude:	Deg: 27°N	Min: 18.39	Jurisdiction:	Mexico
Longitude:	Deg: 111°W	Min: 22.5	Distance to Land:	50 km
Coordinates System:	WGS 84, Other ( )			
Priority of Site:	Primary: X	Alt:	Water Depth:	1891 m

Section C: Operational Information

	Sediments		Basement
Proposed Penetration: (m)	500 m of sediment underlain by intercalated sediments and sills. What is the total sed. thickness? 500 m		Basement, identified by a high sill-to-sediment ratio, may be reached at some point below the 500 m upper sediment/sill layer
		Total Penetration:	600 m
General Lithologies:	sediments consisting of diatom ooze and mud turbidites, hydrothermally altered sediments resulted in sandstone and gray claystones; dolerite sills		
Coring Plan: *(Specify or check)*	Sediments with APC coring, magmatic sills and basement with XCB coring 1-2-3-APC**X** VPC* ☐ XCB **X** MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐ ** Systems Currently Under Development*		

Wireline Logging Plan:

Standard Tools	Special Tools		LWD
Neutron-Porosity X	Borehole Televiewer ☐	Formation Fluid Sampling ☐	Density-Neutron ☐
Litho-Density X	Nuclear Magnetic Resonance ☐	Borehole Temperature & Pressure X	Resistivity-Gamma ray ☐
Gamma Ray X	Geochemical X	Borehole Seismic ☐	Acoustic ☐
Resistivity X	Side-Wall Core Sampling ☐		
Acoustic X			
Formation Image ☐		Others (Microbiology)	Others ( )

Max.Borehole Temp. :	*Expected value (For Riser Drilling)* < 84°C (best analog: 130°C/km mbsf at off-axis DSDP 478°C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from	m	to	m,		m intervals
from	m	to	m,		m intervals

Basic Sampling Intervals: 5m

Estimated days:	Drilling/Coring: 4	Logging: 1	Total On-Site:5

Future Plan:	*Longterm Borehole Observation Plan/Re-entry Plan*

Hazards/ Weather:

Please check following List of Potential Hazards			*What is your Weather window? (Preferable period with the reasons)*
Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity X	Year-round due to protected Gulf of California location
Hydrocarbon X	Soft Seabed ☐	Landslide and Turbidity Current ☐	
Shallow Water Flow ☐	Currents ☐	Methane Hydrate ☐	
Abnormal Pressure ☐	Fractured Zone ☐	Diapir & Mud Volcano ☐	
Man-made Objects ☐	Fault ☐	High Temperature X	
H_2S X	High Dip Angle ☐	Ice Conditions ☐	
CO_2 ☐			

IODP Site Summary Forms:

Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New X **Revised**

Section A: Proposal Information

Title of Proposal:	**The Guaymas Basin Transect – feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial activity and diversity**
Date Form Submitted:	April 1, 2009
Site Specific Objectives with Priority (Must include general objectives in proposal)	Recovery of sediment/sill sequence representing an off-axis, old endmember site GUAYM-08A (>1 m.a.) without recent hydrothermal activity. The seismic profile at this site (29 km from the spreading center) shows a vertically compressed sequence of seismic reflecting that appears to be continuous with the seismic stratification at drilling site GUAYM-07A, only 10 km from the spreading center. These reflectors are believed to represent a sequence of mud turbidites. At ~200 mbsf the sediment sequence shows severe disruption that continues to a depth of ~600 mbsf. At ~600 mbsf seismic reflectors indicating sill emplacement are encountered. These sills show a classic u-shaped morphology that is not displayed in sills to the NW of the spreading axis. We will drill to ~1000 m in an attempt to recover basement rock (high sill-to-sediment ratio) for comparison to that recovered to the NW of the spreading axis (GUAYM-02A, GUAYM-05A).
List Previous Drilling in Area:	DSDP Leg 64

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	GUAYM-08A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Guaymas Basin
Latitude:	Deg: 27°N	Min: 12.486	Jurisdiction:	Mexico
Longitude:	Deg: 111°W	Min: 13.374	Distance to Land:	50 km
Coordinates System:	WGS 84, Other ( )			
Priority of Site:	Primary: X	Alt:	Water Depth:	1852 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	Ca. 200 m of turbiditic sediments underlain by ca. 400 m of structurally disrupted sediments, some sills may be encountered, but not anticipated What is the total sed. thickness? 600 m	Sills should be encountered at ca. 600 mbsf with increasing sill-to-sediment ratios until basement is reached at ca. 1000 m.
		Total Penetration: 1000 m

General Lithologies:	sediments consisting of diatom ooze and mud turbidites,, hydrothermally altered sediments resulted in sandstone and gray claystones; dolerite sills	

Coring Plan: *(Specify or check)*

Sediments with APC coring, magmatic sills and basement with XCB coring

1-2-3-APC X VPC* ☐ XCB X MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐

** Systems Currently Under Development*

Wireline Logging Plan:

Standard Tools	Special Tools		LWD
Neutron-Porosity X	Borehole Televiewer ☐	Formation Fluid Sampling ☐	Density-Neutron ☐
Litho-Density X	Nuclear Magnetic Resonance ☐	Borehole Temperature & Pressure X	Resistivity-Gamma ray ☐
Gamma Ray X	Geochemical X	Borehole Seismic ☐	Acoustic ☐
Resistivity X	Side-Wall Core Sampling ☐		
Acoustic X			
Formation Image ☐		Others (Microbiology)	Others ( )

Max.Borehole Temp. :

Expected value (For Riser Drilling)
Expected value (For Riser Drilling)
< 84°C (best analog: 130°C/km mbsf at off-axis DSDP 478°C

Mud Logging: *(Riser Holes Only)*

Cuttings Sampling Intervals

from	m	to	m,		m intervals
from	m	to	m,		m intervals

Basic Sampling Intervals: 5m

Estimated days:	Drilling/Coring: 6	Logging: 1	Total On-Site: 7

Future Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity X
Hydrocarbon X	Soft Seabed ☐	Landslide and Turbidity Current ☐
Shallow Water Flow ☐	Currents ☐	Methane Hydrate ☐
Abnormal Pressure ☐	Fractured Zone ☐	Diapir & Mud Volcano ☐
Man-made Objects ☐	Fault ☐	High Temperature X
H_2S X	High Dip Angle ☐	Ice Conditions ☐
CO_2 ☐		

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

Year-round due to protected Gulf of California location

IODP Site Summary Forms:

Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New X **Revised**

Section A: Proposal Information

Title of Proposal:	**The Guaymas Basin Transect – feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial diversity**
Date Form Submitted:	April 1, 2009
Site Specific Objectives with Priority (Must include general objectives in proposal)	Redrilling of young, hydrothermally active sediment and sill layers at DSDP site 477 at the active Southern spreading center of Guaymas Basin, with two objectives. A) Thorough investigation of this reference site for hydrothermal alteration of sediments by recently emplaced sills, and the resulting gradients of temperature, geochemical regime, and microbial activity & community structure in the sediments. B) Re-examining and extending the data and results of DSDP 477 with modern geochemical and microbiological methods. C) Documenting a third spreading center site, in the Southern Guaymas Trench for geological, geochemical and microbiological characterization and comparison, in addition to GUAYM-06A in the Northern Guaymas Trench and GUAYM-10A in the Southern Guaymas Trench. The complex tectonic setting, sill emplacements, and pattern of hydrothermal activity of Guaymas Basin requires a third spreading center site for adequate documentation of the spreading center endmember.
List Previous Drilling in Area:	DSDP site 477

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	GUAYM-09A (DSDP 477)	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Guaymas Basin
Latitude:	Deg: 27°N	Min: 01.85 N	Jurisdiction:	Mexico
Longitude:	Deg: 111°W	Min: 24.03 W	Distance to Land:	25 km
Coordinates System:	WGS 84, Other ( )			
Priority of Site:	Primary: X	Alt:	Water Depth:	2003 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	Sediments form the top 58 m layer, and occur again below the sill at 105 mbsf What is the total sed. thickness? unknown ? m	Basement is probably not reached
		Total Penetration: 400 m
General Lithologies:	top 58 m diatom ooze and mud turbidites, then dolorite sill to 105 m, then hydrothermally altered sediments (to sandstone and gray claystones)	
Coring Plan: *(Specify or check)*	Sediments with APC coring, magmatic sills with XCB coring 1-2-3-APC: **X** VPC* ☐ XCB: **X** MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐ ** Systems Currently Under Development*	

Wireline Logging Plan:

Standard Tools	Special Tools		LWD
Neutron-Porosity X	Borehole Televiewer ☐	Formation Fluid Sampling ☐	Density-Neutron ☐
Litho-Density X	Nuclear Magnetic Resonance ☐	Borehole Temperature & Pressure X	Resistivity-Gamma ray ☐
Gamma Ray X	Geochemical X	Borehole Seismic ☐	Acoustic ☐
Resistivity X	Side-Wall Core Sampling ☐		
Acoustic X			
Formation Image ☐		Others (Microbiology)	Others ( )

Max.Borehole Temp. :	*Expected value (For Riser Drilling)* Ca. 200°C (87°C at 168 mbsf, DSDP 477)
Mud Logging: *(Riser Holes Only)*	Cuttings Sampling Intervals from m to m, m intervals from m to m, m intervals *Basic Sampling Intervals: 5m*
Estimated days:	Drilling/Coring: 3 | Logging: 1 | Total On-Site: 4
Future Plan:	*Longterm Borehole Observation Plan/Re-entry Plan*

Hazards/ Weather:

Please check following List of Potential Hazards			*What is your Weather window? (Preferable period with the reasons)*
Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity X	Year-round due to protected Gulf of California location
Hydrocarbon X	Soft Seabed ☐	Landslide and Turbidity Current ☐	
Shallow Water Flow ☐	Currents ☐	Methane Hydrate ☐	
Abnormal Pressure ☐	Fractured Zone ☐	Diapir & Mud Volcano ☐	
Man-made Objects ☐	Fault ☐	High Temperature X	
H_2S X	High Dip Angle ☐	Ice Conditions ☐	
CO_2 ☐			

IODP Site Summary Forms:

Form 1 - General Site Information

Please fill out information in all gray boxes
Revised 7 March 2002

New X **Revised**

Section A: Proposal Information

Title of Proposal:	**The Guaymas Basin Transect – feedbacks between continental rifting, sedimentation, magmatism, thermal alteration of organic matter, and microbial activity and diversity**
Date Form Submitted:	April 1, 2009
Site Specific Objectives with Priority (Must include general objectives in proposal)	Redrilling of recent, hydrothermally active sediment and sill layers near DSDP site 477 at the active southern spreading center of Guaymas Basin based on heat flow measurements in the vicinity of site 477, with two objectives. A) Thorough investigation of hydrothermal alteration of sediments by recently emplaced, active sills, and the resulting gradients of temperature, geochemical regime, and microbial activity & community structure in the sediments. B) providing an additional site, seismically documented surficial sills and sediment layers topped with hydrothermal mounds approx. 2.5 km northwest of DSDP477. This additional site (in addition to GUAYM-09A and GUAYM-06A) will allow us a broader geological, geochemical and microbiological study of active sills at the Guaymas spreading center. The area was surveyed in detail by Lonsdale and Becker 1985 (Earth & Planet. Science Letters 73:211-225).
List Previous Drilling in Area:	In the vicinity of DSDP hole 477

Section B: General Site Information

Site Name: (e.g. SWPAC-01A)	GUAYM-10A	If site is a reoccupation of an old DSDP/ODP Site, Please include former Site #	Area or Location:	Guaymas Basin
Latitude:	Deg: 27°N	Min: 50.00'N	Jurisdiction:	Mexico
Longitude:	Deg: 111°W	Min: 23.00'W	Distance to Land:	25 km
Coordinates System:	WGS 84, Other ( )			
Priority of Site:	Primary: X	Alt:	Water Depth:	1998 m

Section C: Operational Information

	Sediments	Basement
Proposed Penetration: (m)	The upper 400 m are most likely a layerd sequence of sediments and sills, similar to DSDP 477. However, sills and their depth are probably discontinuous to those at DSDP 477.	Probably not reached
	What is the total sed. thickness? unknown ? m	
		Total Penetration: 400 m
General Lithologies:	Diatom ooze and mud turbidites, then dolorite sill, then hydrothermally altered sediments (to sandstone and gray claystones)	
Coring Plan: *(Specify or check)*	Sediments with APC coring, magmatic sills with XCB coring 1-2-3-APC: **X** VPC* ☐ XCB: **X** MDCB* ☐ PCS ☐ RCB ☐ Re-entry ☐ HRGB ☐ ** Systems Currently Under Development*	

Wireline Logging Plan:

Standard Tools	Special Tools		LWD
Neutron-Porosity X	Borehole Televiewer ☐	Formation Fluid Sampling ☐	Density-Neutron ☐
Litho-Density X	Nuclear Magnetic Resonance ☐	Borehole Temperature & Pressure X	Resistivity-Gamma ray ☐
Gamma Ray X	Geochemical X	Borehole Seismic ☐	Acoustic ☐
Resistivity X	Side-Wall Core Sampling ☐		
Acoustic X			
Formation Image ☐		Others (Microbiology)	Others ( )

Max.Borehole Temp. :	*Expected value (For Riser Drilling)* Ca. 200°C (87°C at 168 mbsf, DSDP 477)
Mud Logging: *(Riser Holes Only)*	Cuttings Sampling Intervals from m to m, m intervals from m to m, m intervals *Basic Sampling Intervals: 5m*
Estimated days:	Drilling/Coring: 3 | Logging: 1 | Total On-Site: 4
Future Plan:	*Longterm Borehole Observation Plan/Re-entry Plan*

Hazards/ Weather:

Please check following List of Potential Hazards

Shallow Gas ☐	Complicated Seabed Condition ☐	Hydrothermal Activity X
Hydrocarbon X	Soft Seabed ☐	Landslide and Turbidity Current ☐
Shallow Water Flow ☐	Currents ☐	Methane Hydrate ☐
Abnormal Pressure ☐	Fractured Zone ☐	Diapir & Mud Volcano ☐
Man-made Objects ☐	Fault ☐	High Temperature X
H_2S X	High Dip Angle ☐	Ice Conditions ☐
CO_2 ☐		

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

Year-round due to protected Gulf of California location