International Ocean Discovery Program
Expedition 385 Scientific Prospectus

Guaymas Basin Tectonics and Biosphere: feedbacks between continental rifting, magmatism, sedimentation, thermal alteration of organic matter, and microbial activity

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Abstract

The Guaymas Basin in the Gulf of California is a young marginal rift basin characterized by active seafloor spreading and rapid deposition of organic-rich sediments from highly productive overlying waters. The high sedimentation rates in combination with an active spreading system produce distinct oceanic crust where the shallowest magmatic emplacement occurs as igneous intrusion into overlying sediments. The intrusion of magma into organic-rich sediments creates a dynamic environment where tightly linked physical, chemical, and biological processes regulate the cycling of sedimentary carbon and other elements, not only in a narrow hydrothermal zone at the spreading center but also in widely distributed off-axis venting. Heat from magmatic sills thermally alters organic-rich sediments, releasing CO_2, CH_4, petroleum, and other alteration products. This heat also drives advective flow, which distributes these alteration products in the subsurface and may also release them to the water column. Within the sediment column, the thermal and chemical gradients created by this process represent environments rich in chemical energy that support microbial communities at and below the seafloor. These communities may play a critical role in chemical transformations that influence the stability and transport of carbon in crustal biospheres. Collectively, these processes have profound implications for the exchange of heat and mass between the lithosphere and overlying water column and may determine the long-term fate of carbon accumulation in organic-rich sediments.

The fate of carbon deposited in Guaymas Basin, throughout the Gulf of California, and more broadly within similar marginal seas throughout the world, depends on the relative efficiencies of interacting physical, chemical, and microbial processes, some working to sequester carbon and others working to release carbon back to the ocean and the atmosphere. Drill core samples from Expedition 385 to Guaymas Basin will enable us to study these processes, their interactions, and their ultimate effects on carbon cycling. Samples obtained from scientific drilling are crucial to these goals, which include

- Quantifying the sedimentary and elemental inputs to the system through time and their variation with oceanographic and climatic conditions;
- Sampling igneous sills and the surrounding sediments to determine the products and efficiency of alteration and key hydrologic factors such as sediment type, faulting, and permeability evolution; and
- Studying subsurface microbial communities hosted by alteration products to determine their efficiency at capturing carbon-bearing alteration products and to further our understanding of the conditions that limit life in the deep biosphere.

Expedition 385 schedule

Expedition 385 is based on International Ocean Discovery Program (IODP) drilling Proposals 833-Full2 and 833-Add (available at **http://iodp.tamu.edu/scienceops/expeditions/guaymas_basin_tectonics_biosphere.html**). Following ranking by the IODP scientific advisory structure, the expedition was scheduled for the research vessel (R/V) *JOIDES Resolution*, operating under contract with the *JOIDES Resolution* Science Operator (JRSO). At the time of publication of this *Scientific Prospectus*, the expedition is scheduled to start in San Diego, California (USA), on 16 September 2019 and to end in San Diego on 16 November 2019. Accounting for 5 days of port call and 9 days of transit, a total of 47 days will be available for the drilling, coring, and downhole measurements described in this report (for the current detailed schedule, see **http://iodp.tamu.edu/scienceops**). Further details about the facilities aboard *JOIDES Resolution* can be found at **http://www.iodp.tamu.edu/publicinfo/drillship.html**.

Introduction

Guaymas Basin in the Gulf of California (Figure **F1**) is a young marginal rift basin characterized by active seafloor spreading and rapid sediment deposition, including organic-rich sediments from highly productive overlying waters and by terrigenous sediments from nearby continental margins (Van Andel, 1964). The juxtaposition of active seafloor spreading and thick sedimentary sequences has resulted in a dynamic environment where tightly linked physical, chemical, and biological processes regulate the cycling of sedimentary carbon. Formation of oceanic crust in Guaymas Basin involves the intrusion of sills into overlying sedimentary sequences (Einsele et al., 1980; Saunders et al., 1982). Heat introduced by intruding sills releases CO_2, CH_4, and petroleum from organic-rich sediments and drives fluid advection through sill/sediment sequences that can release these thermogenic products to the water column (Von Damm et al., 1985; Kawka and Simoneit, 1987; Didyk and Simoneit, 1989; Peter et al., 1991; Aarnes, 2010). Thermal and chemical gradients that form in response to heating of sediments and fluid flow create environments rich in chemical energy that support microbial communities at and below the seafloor that may play a critical role in chemical transformations that influence the stability and transport of carbon in crustal biospheres. Collectively, these processes have implications for the exchange of heat and mass between the lithosphere and overlying water column and may determine the long-term fate of carbon accumulation in organic-rich sediments. These complex magma-to-microbe interactions motivate this drilling project and are reflected in its title, "Guaymas Basin Tectonics and Biosphere."

Scientific background, geologic setting, and previous drilling

The Gulf of California is a narrow sea that lies between the Baja California Peninsula and the western margin of mainland Mexico. The gulf formed through continental rifting with the separation of the Baja Peninsula from North America beginning at ~12–15 Ma (Stock and Lee, 1994). At present, the gulf comprises of a number of short spreading segments separated by transform faults that together represent the northern extent of the East Pacific Rise plate boundary (Figure **F1**, inset). Most of these segments have rifted to completion, including the two spreading segments within Guaymas Basin. Seismic observations from the northern Guaymas spreading segment show that continental rupture was complete by ~6 Ma and that new igneous crust formation has been accommodating extension since that time (Lizarralde et al., 2007; Miller and Lizarralde, 2013).

The combination of distinct sedimentation patterns, active tectonics, and magmatism within the Gulf of California creates a rich environment for scientific discovery. Sedimentation and sediment thickness within the basins of the Gulf of California vary substantially from north to south, from the very thick (>4 km) sediments blanketing the Wagner, Tiburon, and Delfin Basins of the northernmost gulf (e.g., Persaud et al., 2003; González-Fernández et al., 2005) to the Alarcon Basin in the southern gulf, where the spreading center is only thinly sedimented (e.g., Sutherland et al., 2012). The northern Guaymas Basin segment, the primary focus of Expedition 385, lies between these extremes, and both sediment deposition and type vary significantly within the northern Guaymas segment itself. Sedimentation in the northwestern half of the segment is dominantly biogenic, driven by highly productive waters with only minor terrigenous input from the arid Baja California Peninsula. Sedimentation in the southeastern portion of the basin, in contrast, is dominated by terrigenous input from the Yaqui River and delta system of the Sonora Margin, and the ~200 m deep graben that defines the plate boundary in this segment tends to confine the turbidites from the Yaqui system to the southeastern part of this segment.

Sites drilled within Guaymas Basin during Deep Sea Drilling Project (DSDP) Leg 64 were motivated both by the sediments themselves and by the interaction of these sediments with magmatic processes. DSDP Sites 479 and 480 on the Sonora Margin (Figure **F1**) were “focused on the paleoceanography of laminated, homogeneous, diatom-rich, anoxic sediments within the zone of low oxygen” typical of this setting. Sites 477, 478, and 481 within the spreading segment were drilled to investigate “the nature of young ocean crust in the Guaymas Basin, where high accumulation rates are common and variable high heat flow indicates active rifting and hydrothermal activity” (Kelts et al., 1982). The scientific results from DSDP Leg 64 have contributed substantially to our understanding of the hydrothermal and geochemical processes driven by igneous intrusion into sediments (Curray et al., 1979, 1982; Einsele et al., 1980). Among other things, these results documented important changes in the sediments due to sill intrusion, including the expulsion of pore fluids and decreased porosity (Einsele, 1982), the breakdown and creation of organic compounds (Galimov and Simoneit, 1982; Simoneit and Bode, 1982), and the dissolution of old mineral phases and the formation of new ones (Kastner, 1982), with an implication that the vigor of fluid flow through the alteration zone is an important factor in the alteration process. At the time, it was believed that active magmatic emplacement was confined to these spreading centers (Einsele et al., 1980), and most of the subsequent work studying biogeochemical processes in Guaymas Basin has remained focused at the axial troughs. There is now strong evidence, however, that active magmatic intrusion into sediments occurs broadly to more than 40 km off axis (Lizarralde et al., 2011) (Figure **F2**).

Recognition that magmatism is not confined to the spreading axis but instead is distributed throughout Guaymas Basin suggests that models for the natural sequestration of carbon, the formation of oceanic crust, and life in the subsurface in marginal rift basins should be reconsidered. Broadly distributed magmatism expands the fraction of organic-rich sediments that may be subject to thermal alteration and associated carbon release far beyond the ridge axis, potentially limiting their role in the long-term removal of atmospheric CO_2. Differences in subsurface hydrology and thermal gradients in off-axis environments relative to the fault-bounded, higher heat flow spreading center greatly expand the range of environments that may support hydrocarbon generation and microbial populations in the subsurface. From the perspective of crustal generation models, a thick sedimentary cover and decreased hydrothermal circulation may affect lithospheric cooling to an extent that melt extraction from the mantle is less focused than at unsedimented mid-ocean ridges, providing feedback between magmatism and sedimentation (Maclennan et al., 2004; Hutnak and Fisher, 2007).

The impact of sill-driven thermogenic sediment alteration on carbon cycling extends to regions of large igneous province (LIP) formation. It has been postulated that the Paleocene/Eocene Thermal Maximum (PETM) was driven by widespread carbon release during sill intrusion into existing sedimentary basins during the emplacement of the North Atlantic Igneous Province (Svensen et al., 2004). Sill/sediment processes have similarly been implicated in other global-scale environmental crises, including proposed links between Early Jurassic and Permo-Triassic extinctions and the Karoo and Siberian Traps LIP events (Svensen et al., 2009; Sell et al., 2015), and Cretaceous ocean anoxia linked to Cretaceous submarine magmatism, such as in the Caribbean (Turgeon and Creaser, 2008; Bralower, 2008).

The fate of carbon deposited in Guaymas Basin, in similar marginal basins across the world, and during punctuated episodes of regional magmatism, depends on the relative efficiencies of interacting physical, chemical, and microbial processes, some working to sequester carbon and others working to release carbon back to the ocean and the atmosphere. The physical and chemical processes involved include thermal heating of sediments by the intruding sill, thermal cracking of organic compounds within sediments, mineral dehydration and dissolution, pore space desiccation, potentially host-sediment melting, and hydrothermal fluid convection (Simoneit et al., 1978, 1981; Simoneit and Lonsdale, 1982; Saxby and Stephenson, 1987; Kastner, 1982; Fisher and Narasimhan, 1991). The dominant thermogenic alteration products resulting from sill intrusion into organic-rich sediments are methane and CO_2 (Galimov and Simoneit, 1982; Seewald et al., 1990), which modeling suggests would be produced over timescales of 10–1000 y, with sensitivity to factors such as sill thickness, thermal conductivities, sediment permeability, and the effects of super-heated water (Aarnes et al., 2010). The extent and function of the deep subsurface biosphere in these settings has not been probed since DSDP Leg 64 demonstrated microbial methanogenesis in Guaymas Basin subsurface sediments; this was the first time that microbiological studies were performed on a DSDP expedition (Oremland et al., 1982; Galimov and Simoneit, 1982; Whelan et al., 1988). Because the present project has a strong microbiological research component, we briefly summarize how studies of pure cultures and natural enrichments from near-surface hydrothermal sediments of Guaymas Basin—usually obtained by submersibles—have outlined the thermal boundaries for microbial processes in Guaymas Basin sediments (Teske et al., 2014). At the hyperthermophilic end of the spectrum, the methanogen *Methanopyrus kandleri* survives at 110°C at 1 bar (Kurr et al., 1991) and at 122°C under deep-sea pressure (Takai et al., 2008). Sulfur-reducing *Thermococcales* thrive near 100°C (Teske et al., 2009; Edgcomb et al., 2007), and microbial sulfate reducers are active near 90°C (Elsgaard et al., 1994; Jørgensen et al., 1990; Weber and Jørgensen, 2002) and in one instance near 120°C (Jørgensen et al., 1992). A common denominator of these hyperthermophiles is hydrogen usage leading to selective hydrogen depletion in the hydrothermal subsurface (Wankel et al., 2011). Recently, anaerobic methane-oxidizing archaea that are active at temperatures as high as 75°C were identified in Guaymas Basin and other vent sites (Holler et al., 2011; Biddle et al., 2012; Merkel et al., 2012; McKay et al., 2016). At cooler off-axis locations and in the upper sediment column, less extreme microbiota gain a foothold, increasing overall microbial biomass and activity and broadening the chemical spectrum of microbially catalyzed reactions. For example, alkane-degrading sulfate reducers with a temperature preference of 50°–60°C thrive in Guaymas Basin (Rueter et al., 1994; Kniemeyer et al., 2007) and are detectable with gene assays for anaerobic hydrocarbon degradation (Callaghan et al., 2010). Recently, butane- and propane-oxidizing thermophilic archaea that form syntrophic consortia with hydrogenotrophic sulfate-reducing bacteria were isolated from Guaymas Basin sediments; these associations thrive at temperatures around 50°–60°C (Laso-Pérez et al., 2016; Krukenberg et al., 2016). Finally, surface sediments harbor microbial mats (Gundersen et al., 1992; McKay et al. 2012), mesophilic aromatics degraders (Goetz and Jannasch, 1993), and microbial communities that overlap compositionally with those in seeps and cold subsurface sediments (Teske et al., 2002; Teske, 2006). Taken as a whole, the microbial communities of surficial Guaymas Basin sediments and microbial mats are capable of assimilating different pools of fossil and inorganic carbon into microbial biomass (Pearson et al., 2005).

Although the habitat preference, biogeography, and activity patterns of Guaymas Basin microorganisms remain to be investigated in the subsurface, we must also remain open to the possibility of finding new organisms that have currently no precedent.

Site surveys and seismic studies

The intricate geological setting of Guaymas Basin required an unusually intense and detailed site survey effort involving five ships and chief scientists from three countries (US, Germany, and Mexico) that started 16 y ago. Seismic data were acquired on three separate cruises: R/V *Maurice Ewing* Leg EW0210 in 2002 (Chief Scientist Daniel Lizarralde, Woods Hole Oceanographic Institution), R/V *Sonne* Leg SO-241 in 2015 (Chief Scientist Christian Berndt, GEOMAR Helmholtz Centre for Ocean Research Kiel [GEOMAR]), and R/V *Alpha Helix* Leg AH1605 in 2016 (Chief Scientist Antonio González-Fernández, Centro de Investigación Científica y de Educación Superior de Ensenada [CICESE]). Multibeam and gravity-core samples were acquired with R/V *El Puma* in 2014 (Chief Scientist Carlos Mortera, National Autonomous University of Mexico [UNAM]), and near-bottom bathymetry and push-core samples were acquired via the human occupied vehicle (HOV) *Alvin* and the autonomous underwater vehicle (AUV) *Sentry* with the R/V *Atlantis* in 2016 (Cruise AT36-07; Chief Scientist Andreas Teske, The University of North Carolina at Chapel Hill). All resulting site survey data for Expedition 385 are archived at the IODP Site Survey Data Bank (**https://ssdb.iodp.org/SSDBquery/SSDBquery.php**; select P833 for proposal number).

Three seismic data sets were acquired. The EW0210 seismic data were acquired with a 6 km streamer recording shots from a large-volume source with center frequency ~30 Hz. These data provide seismic velocity control for time-to-depth estimation at all of the sites, and five of the drill sites described below were proposed based on the features observed in the migrated stack of the transect shown in Figure **F2**. The feature observed at proposed Site GUAYM-03B motivated the hypothesis that active magmatism occurs at substantial distances from the plate boundary. This hypothesis predicts that active, methane-hosted seafloor communities should be present throughout the Guaymas Basin. This hypothesis was tested during a deep-tow multibeam survey conducted on *Atlantis* Leg AT15-54 in 2009, when backscatter and chirp sub-bottom images, seafloor photography, and water chemistry samples identified multiple methane-hosted seafloor communities at off-axis locations (Lizarralde et al., 2011). These data are available via the Marine Geoscience Data System (MGDS) portal. The observations from Leg AT15-54 motivated several drill sites for which no seismic data were available. Our colleagues and co-proponents at GEOMAR (Germany) conducted the second seismic survey during Leg SO-241 with *Sonne* using a 150 m streamer (1.56 m group spacing) and a generator/injector (GI) source array with a flat response to 200 Hz, pursuing the goal of providing crossing lines at all of the proposed drill sites. These very high-quality data crossed some but not all of the proposed drill sites. The third seismic survey cruise was thus conducted by our colleagues and co-proponents from CICESE. It acquired a seismic data set with two major northwest–southeast profiles (AH01-02 and AH21-22) and crossing lines through all of our proposed sites using a 600 m streamer (12.5 m group spacing) and a single GI source.

Prospective drill sites were initially selected based on the Leg EW0210 seismic profiles (Lizarralde et al., 2007) along with the observations from Leg AT15-54 (Lizarralde et al., 2011). Following reprioritization of the scientific and drilling objectives during a Guaymas Basin drilling workshop (Puerto Vallarta, Mexico; November 2015), we removed, repositioned, and added sites, drawing on new results from a total of four Guaymas Basin survey cruises that are outlined in more detail below: the 2014 *El Puma* cruise (bathymetry and gravity coring), the 2015 *Sonne* cruise (seismic lines and seafloor sampling), the 2016 *Alpha Helix* cruise (seismic lines), and the 2016 *Atlantis* cruise with *Alvin* and *Sentry* (bathymetry, seafloor observations, and sampling).

Prospective drill sites were sampled during three Guaymas Basin survey cruises with *El Puma* (7–27 October 2014), *Sonne* (23 June–24 July 2015), and *Atlantis* (9–27 December 2016). The 2014 *El Puma* cruise performed a detailed bathymetric survey of the extended Guaymas Basin ridge flank region and collected sediment gravity cores 3 to 5 m in length from the northwestern end of ridge flanks, the Sonora Margin, the circular seep structure termed “Ringvent” near Isla Tortuga, and the central southeastern ridge flank region. These cores provided shallow subsurface sediments near several Expedition 385 proposed drill sites. The gravity coring results allowed a preliminary geochemical and microbial characterization of the proposed ridge flank drill sites. The 2015 *Sonne* cruise collected numerous sediment cores and seafloor grab samples from Guaymas Basin and the adjacent Sonora Margin (Núñez-Useche et al., 2018; Geilert et al., 2018). The major discovery of this cruise was an actively venting hydrothermal mound at the northern Guaymas graben, located on the edge of the eastern ridge flanks and supplied with hot and gas-rich hydrothermal fluids from the spreading center through axial-parallel fault lines (Berndt et al., 2016). In the last site survey cruise, the *Atlantis*, *Alvin*, and *Sentry* surveys focused on the Ringvent site on the northwestern ridge flanks, with *Alvin* Dives 4864 and 4865, as well as *Sentry* Dives 410 and 411, carried out on 15 and 16 December 2016, respectively. Here, faunal observations, mineralogical analyses, thermal gradient measurements in surficial sediments, and pore water chemistry demonstrated that this site retained hydrothermal activity. These results were used to flesh out the characterizations of proposed Ringvent drill sites and to adjust their positions in the Proposal Addendum 833-Add.

Scientific objectives

Guaymas Basin provides an exemplary opportunity to observe the processes that create our planet’s passive margins both today and throughout Earth’s history and to investigate how those processes mobilize and reinject sedimentary organic carbon into the ocean and the atmosphere (Lizarralde et al., 2011). The fate of carbon deposited in Guaymas Basin, throughout the Gulf of California, and more broadly within similar marginal seas throughout the world depends on the relative efficiencies of interacting microbial and chemical processes, some working to sequester carbon and others working to release carbon back to the ocean and the atmosphere. Expedition 385 to Guaymas Basin will investigate these chemical and microbial processes, their interactions, and their ultimate effects on carbon cycling across the flanks and the spreading center of Guaymas Basin. Sill-driven processes have a temporal arc over several thousand years that is clocked by the cooling history of the sill, beginning as robust hot systems, such as the newly discovered site just east of the northern Guaymas graben, and decaying to a system with characteristics much like passive-margin cold seeps. Drilling sill/sediment section sequences at the proposed sites will provide an integrated, basin-scale understanding of carbon cycling in a magmatic sedimentary basin by examining sediments in settings that span the time across the spectrum of evolutions, from unaltered near-surface sediments to those that have experienced multiple generations of sill intrusion at depth. This expedition will take full advantage of modern drilling tools and sample recovery techniques (e.g., advanced piston corer [APC] system) that have improved tremendously since DSDP Leg 64 and will enable the recovery of undisturbed—and critically, microbially uncontaminated—sediment samples throughout much of the drilling operations. In addition, methodologies for chemical and microbial analysis have evolved dramatically, enabling tremendous scientific returns once fresh, high-quality samples are available.

The Expedition 385 scientific objectives encompass many of the major science themes and challenges outlined in the IODP Science Plan for the 2013–2023 phase of scientific drilling. This expedition was proposed in the context of hypotheses and associated tests based on questions posed in the Science Plan, and the expedition objectives are presented again here in this form.

1. *What properties and processes govern the flow and storage of carbon in the subseafloor?*

Hypothesis: the overarching hypothesis motivating Expedition 385 is that chemical, mass, and thermal budgets in Guaymas Basin and other similar settings are controlled by the interplay of tectonic processes that create conditions for sediment deposition; magmatic processes that provide energy to the sedimentary system and drive fluid circulation; oceanographic processes that control biogenic sediment accumulation; and microbial processes that represent a source and sink for carbon compounds within the sediment pile, water column, and potentially the atmosphere.

Scientific objective: by determining rates of carbon burial and sedimentation, the extent of carbon mobilization during hydrothermal and authigenic processes, and rates of microbial carbon processing and assimilation, we will assess the balance of abiotic and biotic subsurface carbon transformation under contrasting thermal and chemical regimes.

2. *How do fluids link subseafloor tectonic, thermal, and biogeochemical processes?*

Hypothesis: fluids link subseafloor tectonic, thermal, and biogeochemical processes via their influence on lithospheric thermal structure, sediment alteration, mobilization of organic carbon, and microbial utilization of subsurface-derived carbon and energy sources. These linkages are expected to vary in space because of regional heat flow patterns, melt availability, and sedimentation and to vary in time because of the thermal evolution of sill intrusions and the feedbacks between sediment alteration and permeability enhancement.

Scientific objective: by comparing on- and off-axis sediments, we will explore the spatial and temporal evolution of sediment alteration, organic matter preservation, and hydrothermal activity over a broad range of thermal gradients to constrain carbon mobilization from subsurface environments to the seafloor.

3. *How are seafloor spreading and mantle melting linked to oceanic crustal architecture?*

Hypothesis: the mechanisms that focus melt to a narrow crustal zone at unsedimented mid-ocean ridges (MORs), including flow along the base of the lithosphere and deep hydrothermal circulation, are influenced by the lithospheric thermal regime. Blanketing sediments generally impede hydrothermal cooling and thus may influence melt extraction and focusing, which link mantle processes and the distinct crustal architecture of Guaymas Basin.

Scientific objectives: thermal and physical property measurements within the suite of proposed drill sites will advance our understanding of the thermal regime of this system, constraining the influence of sediments on lithospheric cooling. The geochemistry of igneous rocks will constrain the degree of melt focusing in the mantle.

4. *What are the mechanisms, magnitude, and history of chemical exchanges between the oceanic crust and seawater?*

Hypothesis: similar to on-axis sites, off-axis vent sites are driven by igneous intrusion into sediments. Sill-driven hydrothermal circulation, both at off-axis sites and near the spreading centers, links the long-term chemical evolution of the oceanic crust, sediments, and seawater. Off-axis vent sites, removed from active tectonic deformation, will differ in their alteration efficiency and their chemical and microbial evolution relative to on-axis sites because of hydrologic differences.

Scientific objectives: quantifying chemical exchanges between oceanic crust, sediment, and seawater is a central focus of the proposed drilling. We will target all aspects of these exchanges, including the thermal drivers of hydrologic flow; the hydrologic properties of sediments, sediment diagenesis, altered sediments, and sill/sediment complexes; the alteration processes that dissolve minerals and evolve hydrocarbons; and the microbial processes that consume and transform the products of this alteration.

5. *How resilient is the ocean to chemical perturbations?*

Hypothesis: (1) Sill/sediment interaction amplifies carbon exchange from sediments to the oceans, increasing the partial pressure of oceanic CO_2 and thus contributing to ocean acidification from below and damping the uptake of atmospheric CO_2 from above. (2) Widespread, synchronous, rapid emplacement of sills into organic-rich sediments leads to voluminous release of buried organic carbon into both the ocean and the atmosphere.

Scientific objective: drilling results will provide constraints on hydrothermally catalyzed carbon released from sediments into the ocean, an ongoing process in Guaymas Basin, and geochemical sediment signatures of specific large-scale sill emplacement and carbon release events in the form of marine carbon isotopic anomalies that reflect the geochemical consequences of buried carbon release within the water column. Such events would provide modern analogs (and critical tests) to sedimentary carbon release during LIP emplacements, possible triggers for warming events in Earth's history, most conspicuously the PETM (e.g., Higgins and Schrag, 2006).

6. *What are the origin, composition, and global significance of deep subseafloor communities?*

Hypothesis: multiple carbon and energy sources are present in the subsurface of Guaymas Basin, including buried organics, pyrolysis products such as hydrocarbons, and inorganic electron donors. This combination reflects the intersection of hydrothermal, cold seep, and deep-sea sediment environments characteristic of early drift state rifted margins, and it selects for an unusual hybrid microbial ecosystem that combines hyperthermophiles similar to those at hydrothermal vents, thermophilic and mesophilic hydrocarbon degraders, and slow-growing polymer degraders such as those found typically in deep marine subsurface sediments on continental margins.

Scientific objective: with a combination of enrichment and cultivation approaches, microscopic counts and detection assays, and high-throughput sequencing surveys and genomic analyses, we will identify the full range of subsurface life in Guaymas Basin sediments and, as much as possible, link subsurface life to specific biogeochemical processes and process rates. We will investigate microbial carbon processing and assimilation and the microbial contribution to subsurface carbon cycling.

7. *What are the limits of life in the subseafloor realm?*

Hypothesis: the Guaymas Basin subsurface harbors novel evolutionary lineages and metabolic types of microbial life distinct from those of the nonhydrothermal subsurface, which systematically exploit every compatible thermal and chemical niche. Their thermal and energetic limits shape the extent and persistence of microbial life.

Scientific objective: by a systematic examination of the thermal and chemical gradients of Guaymas Basin for microbial life, we will infer the in situ limits of microbial processes and rates and contrast them to abiotic transformations. In doing so, the thermal and energetic limits of life itself will be constrained.

8. *How sensitive are subsurface ecosystems and biodiversity to environmental change?*

Hypothesis: the subsurface microbial communities vary in space and time as sill/sediment systems evolve thermally and chemically. The sills, as they cool and age, will provide a different menu of redox reactants for microbial basalt alteration. Furthermore, the spectrum of buried organic matter and pyrolysis products will control the composition and activity of subsurface microbiota.

Scientific objective: we will determine correlations between different types of subsurface carbon substrates and microbial community structure and activity. The Guaymas Basin subsurface offers strongly contrasting environmental settings, including hydrothermally active sills and sediments, cool sills, and non-hydrothermal sediments and thus provides a model system in which to study microbial adaptations to evolving environmental regimes.

Drilling and coring strategy

The Expedition 385 coring program prioritizes seven primary sites and three alternate sites in ~1600–2000 m water depth. All sites are located in Mexican territorial waters. The final operations plan and number of sites to be cored is contingent upon the overall *JOIDES Resolution* operations schedule (**http://iodp.tamu.edu/scienceops/index.html**), the outcome of requests for territorial permission to occupy these sites, and any operational risks (see **Risks and contingency**).

Addressing the diverse scientific objectives requires a coring strategy of three holes at each site (outlined in Tables **T1** and **T2** for primary and alternate sites, respectively). Every hole will be established by the APC/half-length advanced piston corer (HLAPC) system (see **http://iodp.tamu.edu/tools**) penetrating to refusal using nonmagnetic core barrels. The refusal is expected to occur in indurated sediments near the first sill. In the third hole, further deepening to the target depth of the corresponding site will be achieved with the extended core barrel (XCB) system (**http://iodp.tamu.edu/tools**). Penetration of (thicker) sills may require deployment of the rotary core barrel (RCB) coring system in a fourth hole (see **Risks and contingency**). The APC coring system ensures recovery of the cleanest possible cores for addressing microbiology and sediment geochemistry with minimized seawater contamination (House et al., 2003; Lever et al., 2006). XCB coring will still produce intermediate-quality cores suitable for some microbiology and most geochemistry sampling and analysis purposes, if necessary. At each site, cores from Hole A will be dedicated to pore water and solid phase geochemistry. Hole B cores will be subject to microbial sampling. Cores recovered from Hole C will be used for lithologic, mineralogical, structural, and micropaleontological analyses. In this regard, proposed Site GUAYM-02B may form an exception by establishing two APC holes only. Because this location shows no seepage or hydrothermal activity, we expect smooth geochemical gradients, allowing integrated microbiology and geochemistry sampling within the same APC core, as implemented during ODP Leg 201 (Shipboard Scientific Party, 2003a). All full-length cores will be oriented using the Icefield MI-5 core orientation tool. Time-efficient temperature measurements will be taken in Holes A and B using the advanced piston corer temperature (APCT-3) tool, which is part of the APC cutting shoe. Additional temperature measurements may be taken using the Sediment Temperature 2 (SET2) or sediment temperature pressure tool (SETP) in sediments that are too consolidated to deploy the APCT-3 tool. Temperature monitoring in holes that intersect sills and/or indicate downhole temperatures exceeding the ratings of both the APCT-3 and SET2/SETP tools (55°C and 75°C, respectively; see **http://iodp.tamu.edu/tools/logging**) will require the deployment of an ultrahigh-temperature probe (see **Logging/Downhole measurements strategy** and **Risks and contingency**). Following coring, downhole wireline logging is planned in Hole C at each site if borehole conditions permit (see **Logging/Downhole measurements strategy**).

Proposed drill sites

Sites were initially selected based on the EW0210 multichannel seismic profiles (Lizarralde et al., 2007) along with the observations from AT15-54 (Lizarralde et al., 2011). Following reprioritization of the scientific and drilling objectives during a Guaymas Basin drilling workshop (Puerto Vallarta, Mexico, 6–10 November 2015), we removed, repositioned, and added sites, drawing on site survey results obtained during *El Puma* (bathymetry and gravity coring) and *Sonne* (seismic lines and seafloor sampling) cruises. The sites were refined again in the 2016 expedition proposal (833-Full2) and in the 2017 proposal addendum (833-Add) based on seismic lines obtained with *Alpha Helix* and bathymetry, seafloor observations, and push core sampling by *Atlantis* with *Alvin* and *Sentry*.

The proposed drill sites generally form a transect across the northern Guaymas Basin, from the northwest to the southeast with some deviations from a straight line, to explore locations of particular interest (Figure **F1**). Primary proposed sites, from northwest to southeast, are GUAYM-1B and GUAYM-2B, ~52 km northwest of the spreading axis; proposed Sites GUAYM-3B and GUAYM-12A at an off-axis vent site (Ringvent), ~28 km northwest of the spreading axis (near Isla Tortuga) and sustained by a shallow active sill; proposed Site GUAYM-16A, near a methane-rich cold seep mound that is sustained by a deep sill and ~9 km northwest of the spreading axis; spreading center reference Site GUAYM-6B, within the northern axis graben close to DSDP Site 481; and proposed Site GUAYM-15A, located ~29 km southeast of the spreading axis. Alternate sites include Sites GUAYM-4B and GUAYM-11A as localized positional variants of Site GUAYM-15A; and Site GUAYM-10B, near a methane-rich seep area with a deep sill and located ~15 km northwest of the spreading axis and near the northern edge of spreading segment, close to the base of the Sonora Margin. For each drill site, bathymetric maps and seismic line positions are shown on the site description pages (see **Site summaries**).

Northwestern ridge flank sites

Proposed Site GUAYM-01B, located ~52 km northwest of the axial rift valley at a spreading age of ~2.1 Ma (Figures **F1**, **AF1**), contains undisturbed sediments unaffected by sill intrusion (Figure **AF1**). This site is the most distal to the spreading axis and will recover the oldest and most extensive (~600 meters below seafloor [mbsf]) continuous sedimentary sequence in the northwest region of northern Guaymas Basin. It will thus serve as a reference for the less extensive, younger sediment layers that are drilled at the other sites with more recent spreading ages. Site GUAYM-01B also constitutes a reference site for predominantly marine sedimentation because it is located near the Baja California slope of Guaymas Basin where biogenic input from the highly productive water column (mostly diatoms) predominates over terrigenous input (Van Andel, 1964). The lack of hydrothermal overprinting means that this site should provide a long-term sedimentary climate archive for Guaymas Basin. By the same token, biogeochemical sediment alteration is driven by non-hydrothermal diagenetic processes, and the microbial community should match the type of community commonly found in organic-rich continental slope sediments. Proposed Site GUAYM-02B, located ~1.5 km southeast (Figures **F1**, **AF2**), provides access to the same sediments, with the key difference that they have been disturbed and thermally altered by a recent sill intrusion (~120 ka) (Figure **AF2**), resulting in sediment induration, organic matter mobilization and loss, and microbial sterilization around the sill, which may or may not be mitigated by recolonization over time.

Ringvent sites

Ringvent is situated on the ridge flanks 28.5 km northwest of the Guaymas Basin spreading center (Figures **F1**, **AF3**), corresponding to a spreading age of 1.1 Ma. Here, a still-active shallow sill at approximately 200 mbsf (Figure **AF3**) drives seafloor methane seepage and hydrothermal activity. Deep-towed sidescan sonar backscatter (Lizarralde et al., 2011) showed a ring structure ~800 m in diameter that was recovered again in cross section during the 2016 *Alpha Helix* site survey. Gravity coring into the ring structure during the 2014 *El Puma* site survey revealed shallow buried carbonates, pore water methane near seawater saturation with δ^{13}C isotopic signatures that are intermediate between thermogenic and biogenic methane, and DNA sequences of anaerobic methane-oxidizing archaea (Buckley et al., 2015). The 2016 *Atlantis* expedition to the Guaymas Basin mapped this structure with *Sentry* and *Alvin*. Near-bottom redox and thermal anomalies as recorded by the former and thermal gradients and sediment sampling by the latter provided additional context. Our *Alvin* observations from Dives 4864 (starting near the position of proposed Site GUAYM-03B) and 4865 showed that pockmark-like gullies and depressions within the topographically elevated ring (highlighted by shaded relief and most prominent within the southwestern and western ring segment) coincide precisely with active seepage, tubeworm colonies and microbial mats, authigenic mineral precipitates, and conspicuous thermal gradients of ~5°C/m in surficial sediment. In contrast, at the base of the ring structure, thermal gradients in surficial sediments are reduced by an order of magnitude and mineral concretions and seep communities disappear and are replaced by ordinary seafloor sediment. Drilling locations at Ringvent were selected to avoid the active ring structure and its benthic communities.

Proposed Site GUAYM-03B at the crossing of Lines AH01-02 and AH26-27 is positioned ~150 m southwest from the active ring structure (Figure **AF3**) and aims at the steep subsurface gradient of disturbed and seepage-influenced sediments on the southwestern margin of the ring structure, as visualized by the seismic profiles. The drilling depth for the three holes was set to 200 m, or sill depth (Table **T1**), to sample the laterally and downward extending “halo” of sediments that are chemically and thermally impacted by the sill (i.e., within the metamorphic aureole of thermogenic alteration). Proposed site GUAYM-03B will be targeted if predrilling camera surveys of the seafloor show that seep fauna is absent from the drilling area.

Proposed Site GUAYM-12A is located on Line AH26-27 ~200 m southwest of the crossing of Lines AH26-27 and AH21-22 in the center of the ring structure (Figure **AF4**). This location is sufficiently distant (500 m) from proposed Site GUAYM-03B to require its own decimal coordinates, and it constitutes a distinct site. The seismic profiles show that this location provides optimal drilling access to the center of the subsurface sill and its disturbed sediments (Figure **AF4**); it also keeps a safe distance of ~250 m from the potentially active northeastern ring segment. Buried sills associated with paleoseafloor seep features at their margins show that seepage does not occur in the central sill region but is focused in a ring-like pattern along sill margins (Berndt et al., 2016). To sample the complete suite of hydrothermally altered sediments on top of the still active, gradually cooling sill, the holes at Site GUAYM-12A will be drilled to the most likely sill depth of 200 m or until the actual sill is encountered (Table **T1**). The microbial community in these sediments could show the impact of sill emplacement and hydrothermal heat that kill off sedimentary microbes with increasing proximity to the sill, whereas hydrothermal carbon mobilization—including thermal release of low-molecular weight organic acids (Martens, 1990; Wellsbury et al., 1997)—and the availability of hydrothermally generated carbon and energy sources are likely to select for distinct microbiota that are characteristic for vent and seep sites. The central ring area is suitable for coring; in 2014, 5 m long Gravity Core P11 (the longest core of the 2014 *El Puma* expedition) was obtained nearby (27°30′5090′N, 111°40′6860′W). A camera survey of the site will be required before drilling to ensure no seeps communities are present.

Cold seep analogs on the northwestern ridge flanks

Proposed Site GUAYM-16A is located northwest of an off-axis seep feature where active cold seep communities have been observed (Lizarralde et al., 2011) ~9.5 km distant from the spreading center (Figures **F1**, **AF5**). Compared to Ringvent, this site is distinguished by closer proximity to the ridge axis, its mound-shaped morphology, the deeper position of its sill at ~450 mbsf (Figure **AF5**), the loss of sediment stratification and presumable gas upflow along a single central pipe, and a conspicuously shallow bottom-simulating seismic reflector (BSR) layer indicative of hydrates and methane accumulation below. This unusual combination of deep sill emplacement and shallow hydrate formation is relevant for carbon sequestration and budgets within the Guaymas Basin hydrothermal system. This site was surveyed during 2016 *Atlantis* Leg AT36-07 and mapped in detail by *Sentry* and *Alvin*. The northern end of this mound, in particular an east–west cleft or gully that separates the northernmost hill from the rest of the mound, hosts classic cold seep features; this area coincides with near-surface gas bulges visible in underlying Seismic Line SO-011 (Figure **AF5**). Here, surficial sediments consistently show in situ temperatures of 2.9°C to 3°C, as determined by the *Alvin* heat flow probe. Seep features include surficial gas hydrates, carbonates, tubeworm colonies, and mats of benthic polychaetes. To avoid these seep features and deep subsurface gas accumulation around the methane-soaked mound and the seep pipe, Site GUAYM-16A was placed northwest of the seep mound and will be drilled to 182 mbsf. Sea surface bubble watches will be implemented for safety monitoring during drilling.

Spreading center reference site

Proposed Site GUAYM-06B in the northern Guaymas spreading center, 360 m north-northeast of DSDP Site 481 as defined by MCS crossing lines (Figures **F1**, **AF6**), represents the primary spreading center reference site. The site is located at the southern end of the northern Guaymas Basin axial graben in an area of relatively low heat flow (Shipboard Scientific Party, 1982), ~5 km northwest of a local heat flow maximum (Lawver and Williams, 1979) and is thermally compatible with drilling. This site provides access to exemplary indurated and organic carbon–depleted sediments and sills—beginning downhole at ~169 mbsf at nearby DSDP Site 481—at the hydrothermal spreading center (Gieskes et al., 1982). Redrilling this sequence of sediments and sills to 250 mbsf with improved coring tools will lead to increased resolution and substantially improved recovery.

Southeastern ridge flanks

Proposed Site GUAYM-15A is located ~29 km southeast of the northern Guaymas spreading center (Figures **F1**, **AF7**); here, a saucer-shaped sill has intruded predominately terrigenous turbidite sediments near the depositional fan of the Yaqui River at the Sonora Margin. This site targets the thermal aureole of the southeastern edge of the buried saucer-shaped sill. Sill morphology is dependent on sediment physical properties. Sills observed southeast of the spreading axis tend to be larger and more saucer-shaped than those in the northwest, presumably owing to the physical property differences between terrigenous versus biogenic sediments. Sediment physical properties also impact permeability evolution with induration and thus impact the vigor of hydrothermal circulation and the consequent efficiency of thermogenic alteration. The site also touches the edge of a seismically imaged “eye structure” higher up in the sediment column that is believed to represent the paleoseafloor deposits resulting from the upward limb of hydrothermal flow emanating from the edges of the sill. Initial analyses of gravity cores from the 2014 *El Puma* survey of this area showed that the concentrations of organic matter in and δ^{15}N isotopic signatures of these sediments differ from the predominantly marine sediments northwest of the axial graben. These differences, and also the greater presence of metals in terrigenous versus biogenic sediments, will most likely affect sediment alteration and pyrolysis, which is sensitive to metals. This site will constrain the influence of sediment type—here, predominantly terrigenous sediment—on sill-driven sediment alteration and on carbon processing. Site GUAYM-15A is positioned at the crossing of *Alpha Helix* Line AH01-02 and *Sonne* Line SO-005 between proposed alternate Sites GUAYM-04B and GUAYM-11A, both of which lack crossing lines.

Alternate sites

At proposed alternate Site GUAYM-04B, ~29 km southeast of the northern Guaymas spreading center (Figures **F1**, **AF8**), a saucer-shaped sill has intruded predominately terrigenous turbidite sediments near the depositional fan of the Yaqui River in the Sonora Margin. Proposed Sites GUAYM-04B and GUAYM-15A share the same general objectives: exploring sill-driven alteration of terrestrially dominated sediment and the consequences for subsurface carbon processing. Yet, compared to nearby Site GUAYM-15A, Site GUAYM-04B is located centrally in the buried sill and does not sample the thermal aureole where the greatest alteration is expected, near the lip of the sill. It also bypasses the eye structure, which may represent seafloor deposits of hydrothermal venting from the time the system was active.

Proposed alternate Site GUAYM-11A is located southeast of proposed Site GUAYM-04B on Seismic Line AH01-02 (Figure **AF9**); it targets the center of a seismically imaged eye structure that is believed to represent the paleoseafloor deposits of sill-driven hydrothermal activity produced by the adjacent buried sill (Figure **AF9**). This alternate site is suitable to constrain the influence of sediment type on sill-driven sediment alteration and on carbon processing. Both the eye structure and the saucer-shaped sill are traversed and consistently imaged by congruent seismic lines from the *Maurice Ewing* (EW-TRAN3) and *Alpha Helix* cruises (AH01-02).

Proposed alternate Site GUAYM-10B provides access to hydrate-rich sediments overlying deep sills on the northern flank of Guaymas Basin near the transition to the Sonora Margin (Figures **F1**, **AF10**). Here, geochemical and microbial changes can be monitored throughout the gas hydrate stability zone into the sediment below and to some extent toward the underlying sill at ~700 mbsf (Figure **AF10**). Complementing proposed Sites GUAYM-03B and GUAYM-16A, this site illustrates the geochemical and microbiological contrasts of off-axis seepage and the role of hydrates as intermediate carbon storage buffer. After this area was surveyed with crossing lines during the *Alpha Helix* and the *Sonne* cruises, Site GUAYM-10B was placed at the intersection of the high-quality *Sonne* lines on the margin of the seep pipe (Figure **AF10**). Sidescan sonar backscatter data (*Atlantis* Cruise AT15-54, November 2009) display that Site GUAYM-10B is ~300 m distant from the central seep area. This site can be drilled if a camera survey of the site shows that no seep communities are present.

Logging/Downhole measurements strategy

Downhole wireline logging will be crucial for the characterization of subseafloor lithologies and their structures, particularly with respect to extrapolation to complete sections in deeper depth intervals where XCB and RCB coring may retrieve cores of lower recovery in stiff sediments and igneous hard rocks. We intend to deploy the available standard suites of downhole logging tools (**http://iodp.tamu.edu/tools/logging**) at all proposed drill sites, including the triple combo and the Formation MicroScanner (FMS)-sonic tool strings. The logging tools will be run in the final hole at each site. However, coring is the top priority for every site, and the scheduled logging program may be modified or abandoned if the coring objectives are not met in the allotted time. Furthermore, the actual deployment of the logging tools will depend on downhole temperatures, which will be determined prior to each planned logging run by using (1) the APCT-3 (soft sediments) and SET2/SETP (consolidated sediments) tools (**http://iodp.tamu.edu/tools/logging**) and (2) an ultrahigh-temperature probe—the elevated borehole temperature sensor (ETBS) memory tool—in sediments that are too rigid to deploy the SET2/SETP tool and in sills, respectively, or once the temperature environment indicates values exceeding 75°C. The ETBS tool is rated at 400°C and was successfully deployed on the coring line at Brothers volcano during the most recent IODP expedition (376) (see **http://iodp.tamu.edu/scienceops/sitesumm/376/index.html**). Occasionally, the in-hole temperatures at depth may exceed the temperature ratings published for the triple combo and FMS-sonic tool strings (Figure **F5**), based on temperature measurements and gradients and mineral assemblages reported for DSDP Leg 64 (Shipboard Scientific Party, 1982; Gieskes et al., 1982). Priority will be given to minimizing the risk to the logging tools (see **Risks and contingency**).

The triple combo tool string consists of the logging equipment head-mud temperature (LEH-MT) sonde, the Accelerator Porosity Sonde (APS), the Hostile Environment Litho-Density Sonde (HLDS), the Hostile Environment Natural Gamma Ray Sonde/Enhanced Digital Telemetry Cartridge (HNGS-EDTC), the High-Resolution Laterolog Array (HRLA)/Phasor Dual Induction-Spherically Focused Resistivity Tool (DIT), and the Magnetic Susceptibility Sonde (MSS) (Figure **F5**). The FMS-sonic tool string consists of the Dipole Sonic Imager (DSI) tool (acoustic velocity), the FMS (resistivity imaging), and the General Purpose Inclinometry Tool (GPIT), including the LEH-MT and HNGS-EDTC tools. The downhole logging data will be sent to the Lamont-Doherty Earth Observatory Borehole Research Group at Columbia University (New York, USA) for processing during the expedition and returned to the shipboard downhole logging scientists for interpretation within days upon completion of the downhole logging runs.

To better constrain the transport and sequestration of carbon in actively circulating subseafloor fluids and their overall composition in relation to the emplacement of sills, we will recover borehole hydrothermal fluids. Sampling of fluids that might be entering the borehole at depth will be implemented by using the water sampling temperature probe (WSTP) in soft to semiconsolidated sediments at temperatures ≤85°C (**http://iodp.tamu.edu/tools/logging**). At higher temperatures or in consolidated sediments and sills, we are going to deploy a high-temperature resistive water-sampling tool, such as the Kuster Flow-Through Sampler (FTS) (**http://www.swordtek.com/yahoo_site_admin/assets/docs/Kuster_FTS.314194716.pdf**), which is rated at 232°C. It successfully recovered borehole fluids from hard rock formations at downhole temperatures as high as 212°C during Expedition 376 (see **http://iodp.tamu.edu/scienceops/sitesumm/376/index.html**).

Risks and contingency

Three different coring systems (APC, XCB, and RCB) will be available to complement each other and to ensure meeting the scientific objectives. For planning purposes in the three intended holes at each site, APC/HLAPC refusal depth is estimated at 150 mbsf (Tables **T1**, **T2**), although this depth may be exceeded at some sites. APC refusal is conventionally defined in two ways: (1) a complete stroke (as determined from the standpipe pressure after the shot) is not achieved because the formation is too hard and (2) excess force of >445 kN (equivalent to a mass of >45,360 kg/>100,000 lb) is required to pull the core barrel out of the formation because the sediment is too cohesive or "sticking." In cases where a significant stroke can be achieved but excessive force cannot retrieve the barrel, the core barrel can be "drilled over" (i.e., after the inner core barrel is successfully shot into the formation, the bit is advanced to some depth to free the APC barrel). When APC/HLAPC refusal occurs in a hole before the target depth is reached, the XCB system will be used to advance the hole (Tables **T1**, **T2**). The implementation of RCB coring will mitigate the risks imposed on exceeding the operational limits for the XCB coring system. Therefore, if some depths are unattainable using the XCB system, another hole (in most cases a fourth deep hole) penetrating very firm sediments or tough sills will be drilled separately with RCB system (**http://iodp.tamu.edu/tools**) to reach the target depth without recovery of redundant sediments that are already available from APC and XCB coring.

Drilling and logging operations in an actively spreading rift basin exposed to deposition of organic-rich sediments bears some risks and presents challenges to achieving the expedition objectives. First, unstable hole conditions can occur, negatively impacting core recovery or even leading to abandonment of a hole. In particular, drilling a heterogeneous succession of sediments and sills, with fracturing and hydrothermal alteration most likely present in deeper intervals, may lead to a stuck bottom-hole assembly (BHA), resulting in lost time and possible loss of equipment. Additional hardware will be available on board to alleviate any losses. Extra time may be required for hole remediation (i.e., cleaning and stabilizing the hole). Moreover, hole instability may deny downhole logging operations or lead to an untimely stop of a logging run.

Second, another important consideration for deep drilling is the pore water concentrations of hydrocarbons in Guaymas Basin sediments, in particular the most abundant gaseous alkane, methane. For DSDP Leg 64 sediments, moderate methane concentrations reaching 1 to 3 mg methane/mg dry weight sediment, corresponding to 0.0625 to 0.1825 mmol methane/mg dry weight sediment, were reported (Whelan and Hunt, 1982; Whelan et al., 1988). Pore water methane concentrations exceeding 10 mM were found in short (40 to 60 cm) push cores from hot hydrothermal sediments taken by *Alvin* at the spreading center (McKay et al., 2012). These concentrations represent the high-concentration end-member that can be obtained from focused seafloor venting. Considerably lower methane concentrations were found during the 2014 *El Puma* site survey in sediments at off-axis seep locations, for example near proposed Site GUAYM-03B. Here, methane pore water concentrations of ~1.5 mM are reached and maintained in the upper 5 m of the sediment column (Buckley et al., 2015), which was recovered by gravity cores without disturbance by outgassing. The off-axis methane pore water concentrations in Guaymas Basin remain below those found in non-hydrothermal, organic-rich continental margin sediments, for example in the hydrate-bearing sediment column of Ocean Drilling Program (ODP) Site 1230 at the Peru Margin (D'Hondt et al., 2004). Here, unpressured cores contained 3 to 8 mM methane (Shipboard Scientific Party, 2003b). From the same sediments, the pressure core sampler (PCS), a downhole tool for recovering sediments at in situ pressure (Pettigrew, 1992), recovered methane samples with concentrations of ~13 to 400 mM, much above in situ methane saturation concentrations for these hydrate-rich sediments (Dickens et al., 2003). These examples show that gas concentrations in Guaymas Basin sediments are likely to remain within the range of methane concentrations that have been successfully dealt with during previous operations on *JOIDES Resolution*.

Third, high temperatures in Guaymas Basin sediments require extra precautions during operations, especially at the rift axis. We will avoid drilling into uncharted hydrothermal spots and focus on redrilling adjacent to previously cored DSDP Site 481 for proposed rift axis Site GUAYM-06B. For Site 481, in situ borehole measurements under the current thermal regime yielded 3.6°C at the mudline, 9.0°C at 42 mbsf, and 56.8°C at 330 mbsf, extrapolated from two temperature logs at the bottom (26.2°C and 51.0°C after 3.5 h and 20 h of equilibration, respectively) (Shipboard Scientific Party, 1982). The in situ mineralogy at Site 481 (sill/sediment contact metamorphism) is generally associated with temperatures below 200°C, and the oxygen isotopic composition of recrystallized calcites near the sill contact at 170 m depth indicates temperatures of 130°–170°C at the time when sill emplacement triggered mineral alteration (Gieskes et al., 1982). These temperatures remain compatible with conventional drilling, especially because the borehole is being cooled substantially by circulation of drilling fluid (seawater). For high-temperature core recovery, we will consider using ULTEM 1000 core liners, which are made of a thermoplastic polyetherimide high-heat polymer and remain intact at temperatures of ≤171°C (Huey, 2009). Plastic core liners can be used at in situ temperatures >200°C without melting because of virtually steady-state drilling fluid circulation, as demonstrated by IODP Expeditions 331 (Expedition 331 Scientists, 2011) and 376 (T.W. Höfig, pers. comm., 2018). If necessary, aluminum core liners can be used to recover core from high-temperature sills and indurated sediments.

In contrast to drilling, the subseafloor temperature environment may bear a significant risk for logging operations. Downhole fluid and/or formation temperatures encountered may be too high for parts of the standard logging suites to be employed, as permitted temperature limits would be exceeded (Figure **F5**). Because drilling fluid (seawater) will not be circulated during logging operations, there will be no considerable cooling of the hole at this time. Downhole logging under high-temperature conditions can be implemented by equipping the tools with sealing elements (O-rings) and flasks for insulating the electronics from the external heat as long as possible. This approach ensures their application at their full temperature rating. The high-temperature triple combo (HTTC) string comprises the tools that can be used in this way. It has recently been deployed successfully during Expedition 376 (see **https://iodp.tamu.edu/scienceops/sitesumm/376**) and consists of the HLDS/HNGS-EDTC/LEH-MT logging tools rated at 260°C. They were operated on a high-temperature wireline cable permanently available on board and are rated at ~241°C (for 1 h) and ~232°C (for 8 h). Downhole temperature measurements (APCT-3, SET2/SETP, and ETBS) implemented prior to an intended logging run will determine which logging tool string suite can be deployed (see **Logging/Downhole measurements strategy**).

Inclement weather always affects latent issues because rough seas and the resultant heave may adversely impact drilling operations. For example, quality and recovery of core can be negatively influenced. The Expedition 385 schedule coincides with the late peak and end of the hurricane season (September to November). Thus, delays triggered by weather are possible. The currently scheduled contingency time to make up for delays caused by operational issues or weather is 3.0 days (Table **T1**).

Sampling and data sharing strategy

Shipboard and shore-based researchers should refer to the IODP Sample, Data, and Obligations Policy and Implementation Guidelines posted on the Web at **http://www.iodp.org/top-resources/program-documents/policies-and-guidelines**. This document outlines the policy for distributing IODP samples and data to research scientists, curators, and educators. The document also defines the obligations that sample and data recipients incur. The Sample Allocation Committee (SAC; composed of the Co-Chief Scientists, Expedition Project Manager/Staff Scientist, and IODP Curator on shore and curatorial representative aboard the ship) will work with the entire science party to formulate a formal expedition-specific sampling plan for shipboard and postexpedition sampling.

Every member of the science party is obligated to carry out scientific research for the expedition and to publish the results. All shipboard scientists and any potential shore-based scientists are required to submit a research plan and associated sample/data requests using the IODP Sample and Data Request Management System (at **http://iodp.tamu.edu/curation/samples.html**) eight months before the beginning of Expedition 385. Based on the research plans and sample requests (shipboard and shore-based) submitted by this deadline, the SAC will prepare a tentative sampling plan that will be revised on the ship as dictated by recovery and expedition scientific objectives. That is, the sampling plan will be subject to modification depending on the actual material recovered and collaborations that may evolve between scientists during the expedition. Any modification of the strategy during the expedition must be approved by the SAC.

Shipboard sampling will include samples taken for shipboard analyses and ephemeral samples (e.g., microbial samples) needed for personal, postexpedition research. All remaining personal samples for postexpedition research will be taken at a postexpedition sampling party to be held within 3–5 months of the end of the expedition at the IODP Gulf Coast Repository (GCR) in College Station, Texas, USA. The GCR will receive the working- and archive-half core sections from Expedition 385 for permanent storage. The minimum permanent archive will be the standard archive half of each core. All sample frequencies and sizes must be justified on a scientific basis and will depend on core recovery, the full spectrum of other requests, and the expedition scientific objectives. Some redundancy of measurement is unavoidable, but minimizing the duplication of measurements among the shipboard science party and their identified shore-based collaborators, as well as approved shore-based participants, will be a factor in evaluating sample and data requests.

If some critical intervals are recovered, there may be considerable demand for samples from a limited amount of cored material. These intervals may require special handling, a higher sampling density, reduced sample size, or continuous core sampling by a single investigator. A specific sampling plan coordinated by the SAC may be required before critical intervals are sampled.

All Expedition 385 data and samples will be protected by a 1 y moratorium period that will start at the end of the postexpedition sample party. During this moratorium, all data and samples will be available only to the expedition shipboard scientists and approved shore-based participants.

Expedition scientists and scientific participants

The current list of scientific participants for Expedition 385 can be found at **http://iodp.tamu.edu/scienceops/expeditions/guaymas_basin_tectonics_biosphere.html**.

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Table T1. SP primary operations summary, Expedition 385.

Site No.	Location (Latitude Longitude)	Seafloor Depth (mbrf)	Operations Description	Transit (days)	Drilling Coring (days)	WL Log (days)
San Diego, USA			**Begin Expedition** 5.0	**Port call days**		
			Transit ~1175 nmi to GUAYM-01B @ 10.5	4.7		
GUAYM-01B	27° 38.2315' N	1611	Hole A - APC/XCB to 600 mbsf	0.0	3.5	0.0
EPSP	111° 53.3396' W		Hole B - APC with orientation to 250 mbsf	0.0	1.0	0.0
to 600 mbsf			Hole C - APC/XCB to 600 mbsf and log with triple combo and FMS-Sonic	0.0	3.0	1.0
			Sub-Total Days On-Site: 8.6			
			Transit ~1nmi to GUAYM-02B @ 1.5	0.0		
GUAYM-02B	27° 37.8840' N	1611	Hole A - APC/XCB to 350 mbsf with Orientation and APCT-3	0.0	2.0	0.0
EPSP	111° 52.7940' W		Hole B - APC w/o to 200 mbsf / HLAPC to 250 mbsf	0.0	1.3	0.0
to 600 mbsf			Hole C - Drill down to 250 mbsf/RCB from 250-600 mbsf - Log with triple combo and FMS-Sonic	0.0	4.3	1.0
			Sub-Total Days On-Site: 8.7			
			Transit ~13nmi to GUAYM-03B @ 10.5	0.1		
GUAYM-03B	27° 30.2460' N	1761	Hole A - APC w/o to 150 mbsf/XCB to 200 mbsf or sill	0.0	1.7	0.0
EPSP	111° 40.8660' W		Hole B - APC w/o to 150 mbsf/XCB to 200 mbsf or sill	0.0	1.2	0.0
to 200 mbsf			Hole C - APC w/o to 150 mbsf/XCB to 200 mbsf or sill - Log with triple combo and FMS-Sonic	0.0	1.3	0.6
			Sub-Total Days On-Site: 4.8			
			Transit ~0nmi to GUAYM-12A @ 1.5	0.0		
GUAYM-12A	27° 30.4560' N	1761	Hole A - APC w/o to 150 mbsf/XCB to 200 mbsf or sill	0.0	1.6	0.0
EPSP	111° 40.6980' W		Hole B - APC w/o to 150 mbsf/XCB to 200 mbsf or sill	0.0	1.1	0.0
to 200 mbsf			Hole C - APC w/o to 150 mbsf/XCB to 200 mbsf or sill - Log with triple combo and FMS-Sonic	0.0	1.3	0.8
			Sub-Total Days On-Site: 4.8			
			Transit ~11nmi to GUAYM-16A @ 6.0	0.1		
GUAYM-16A	27° 28.3315' N	1850	Hole A - APC with orientation to 182 mbsf	0.0	1.1	0.0
EPSP	111° 28.7848' W		Hole B - APC with orientation to 182 mbsf	0.0	0.7	0.0
to 182 mbsf			Hole C - APC with orientation to 182 mbsf - Log with triple combo and FMS-Sonic	0.0	1.0	0.7
			Sub-Total Days On-Site: 3.5			
			Transit ~22nmi to GUAYM-15A @ 6.0	0.1		
GUAYM-15A	27° 12.3900' N	1832	Hole A - APC with orientation to 200 mbsf	0.0	1.3	0.0
EPSP	111° 13.1940' W		Hole B - APC with orientation to 200 mbsf	0.0	0.9	0.0
to 670 mbsf			Hole C - APC with orientation to 200 mbsf/XCB to 670 mbsf and log with triple combo and FMS-Sonic tool strings	0.0	4.1	1.0
			Sub-Total Days On-Site: 7.2			
			Transit ~16nmi to GUAYM-06B @ 6.0	0.1		
GUAYM-06B	27° 15.3420' N	2024	Hole A - APC/XCB to 250 mbsf w/orientation and temperature	0.0	1.9	0.0
EPSP	111° 30.3360' W		Hole B - APC/XCB to 250 mbsf w/orientation	0.0	1.5	0.0
to 250 mbsf			Hole C - APC/XCB to 250 mbsf w/orienation and log with triple combo and FMS-Sonic tool strings	0.0	1.6	0.8
			Sub-Total Days On-Site: 5.8			
			Transit ~1145 nmi toSan Diego @ 10.5	4.5		
San Diego, USA			**End Expedition**	9.6	37.5	5.9

Port Call:	5.0	Total Operating Days:	53.0
Sub-Total On-Site:	43.4	Total Expedition:	58.0

Table T2. SP alternate operations summary, Expedition 385.

Site No.	Location (Latitude Longitude)	Seafloor Depth (mbrf)	Operations Description	Drilling Coring (days)	WL Log (days)
GUAYM-04B	27° 12.5340' N	1861	Hole A - APC with orientation to 200 mbsf	1.3	0.0
EPSP	111° 13.4160' W		Hole B - APC with orientation to 200 mbsf	0.9	0.0
to 650 mbsf			Hole C - APC with orientation to 200 mbsf/XCB to 650 mbsf and log with triple combo and FMS-Sonic tool strings	4.0	1.0
			Sub-Total Days On-Site: 7.1		
GUAYM-10B	27° 33.2880' N	1856	Hole A - APC w/o to 150 mbsf/XCB to 200 mbsf or sill	1.7	0.0
EPSP	111° 32.9640' W		Hole B - APC w/o to 150 mbsf/XCB to 200 mbsf or sill	1.1	0.0
to 200 mbsf			Hole C - APC w/o to 150 mbsf/XCB to 200 mbsf or sill - Log with triple combo and FMS-Sonic	1.4	0.8
			Sub-Total Days On-Site: 5.0		
GUAYM-11A	27° 12.0544' N	1832	Hole A - APC with orientation to 200 mbsf	1.3	0.0
EPSP	111° 12.6822' W		Hole B - APC with orientation to 200 mbsf	0.9	0.0
to 450 mbsf			Hole C - APC with orientation to 200 mbsf/XCB to 450 mbsf and log with triple combo and FMS-Sonic tool strings	2.8	0.8
			Sub-Total Days On-Site: 5.8		

Figure F1. Bathymetry of Guaymas Basin with Baja California in the southwest and the Sonora Margin in the northeast. Proposed drilling sites (circles) and existing seismic transects (solid black and purple lines) are indicated. Inset shows the tectonic setting of the Gulf of California, Guaymas Basin, indicated in green shading, and the area of the main site figure indicated by a blue box. IODP = International Ocean Discovery Program, DSDP = Deep Sea Drilling Project.

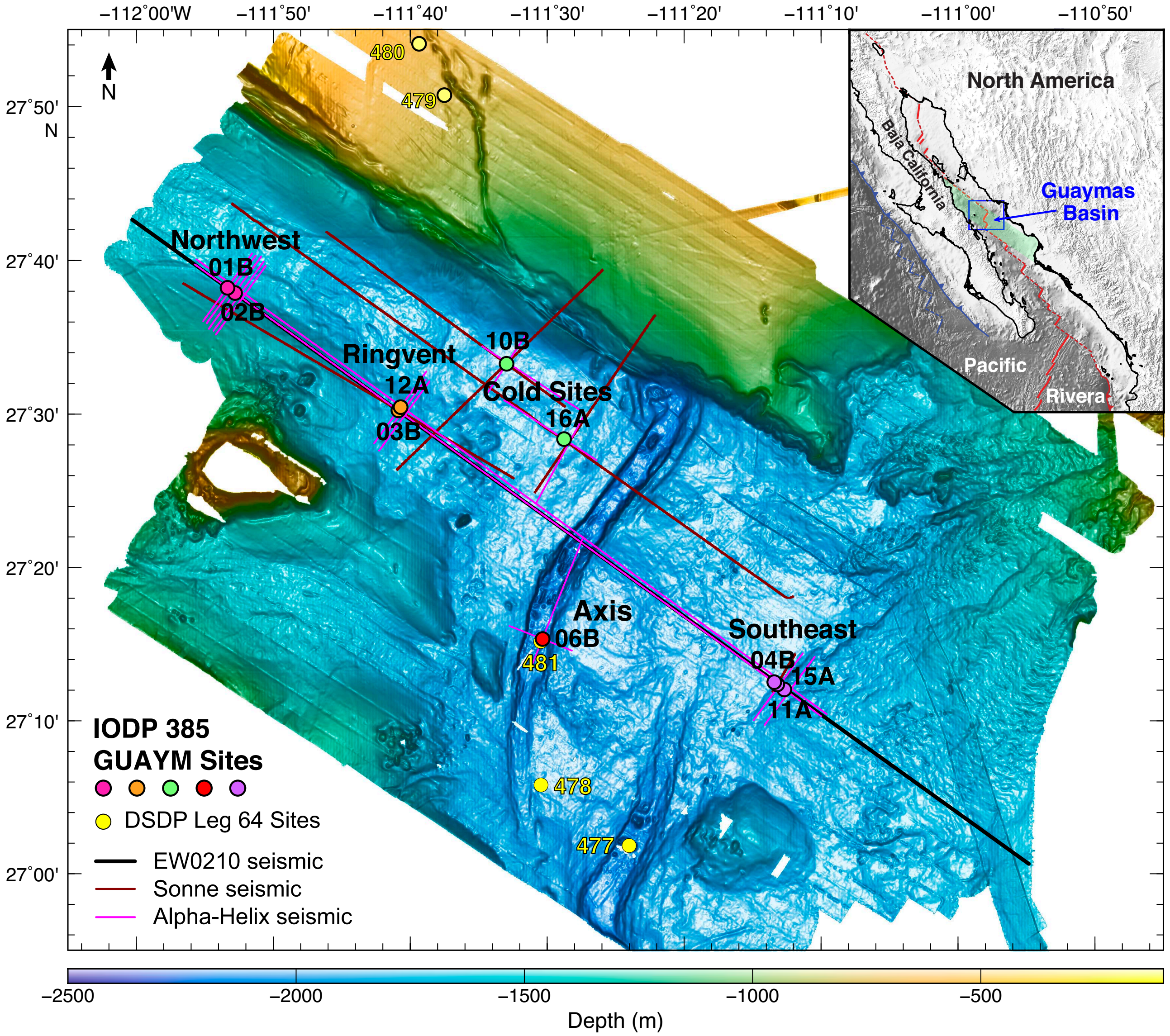


Figure F2. Migrated stack of seismic data from *Maurice Ewing* EW0210 Transect 3, along which proposed GUAYM Sites 01B, 02B, 03B, 04B, 11A, and 15A are located. This transect is coincident with *Alpha Helix* AH1605 Line 01-02.

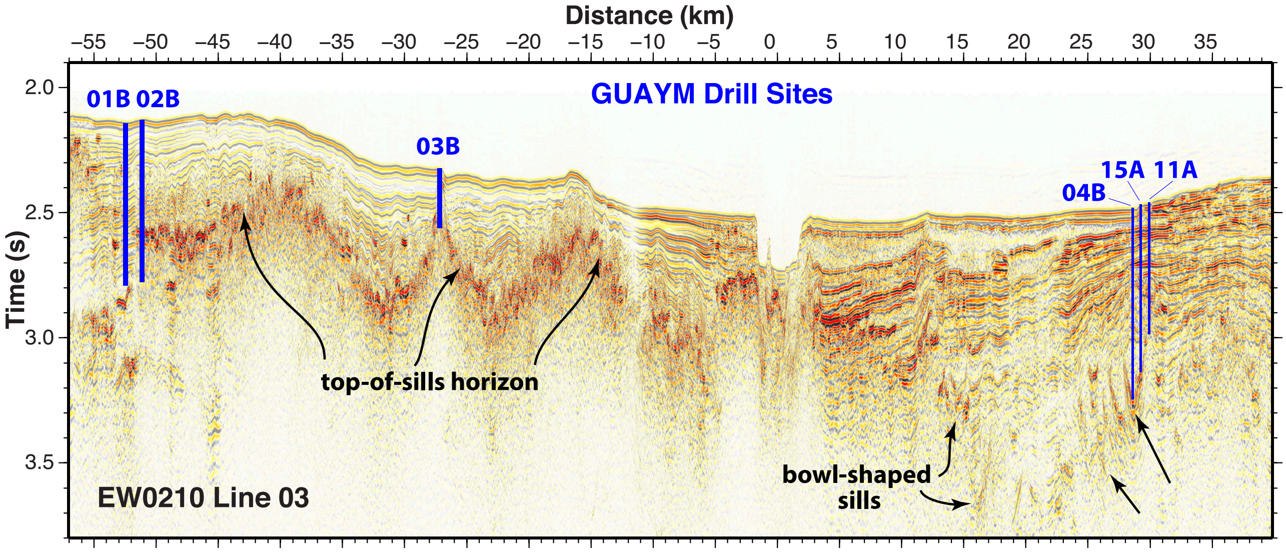


Figure F3. Integrated sedimentological, tectonic, magmatic, and microbial processes at work in Guaymas Basin and the associated carbon pathways.

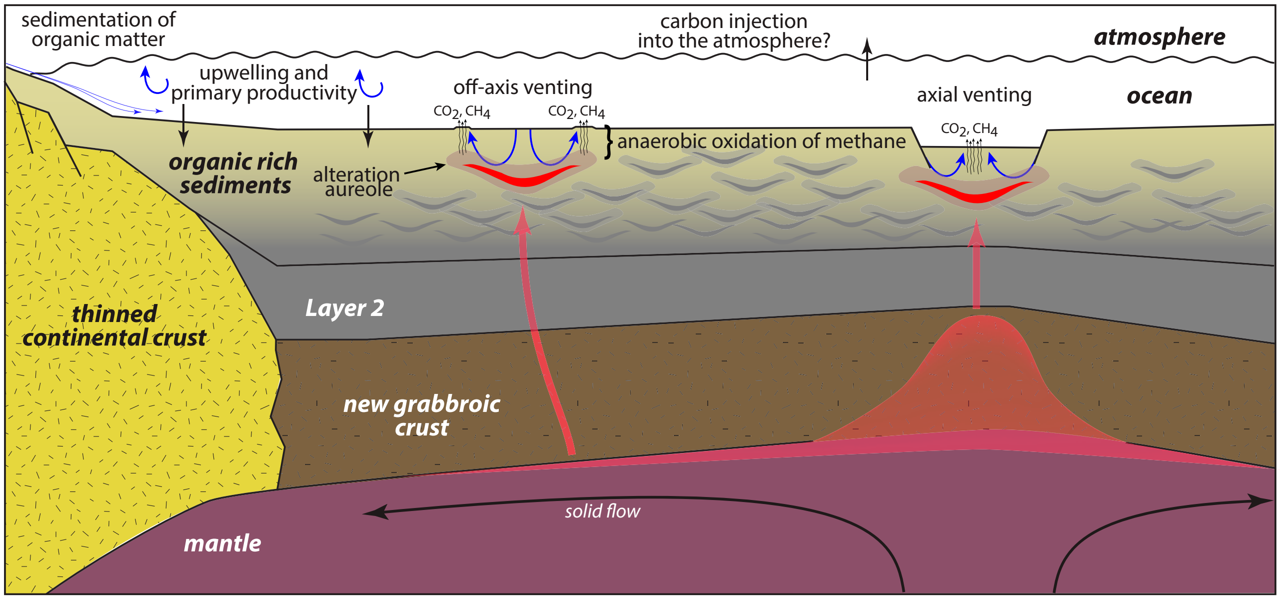


Figure F4. Hydrothermal mobilization of buried organic carbon as dissolved inorganic carbon (DIC), low-molecular weight organic compounds, methane, alkanes, and complex petroleum hydrocarbons, available for microbial oxidation and assimilation within the subsurface sediments, at the sediment surface, and in the water column.

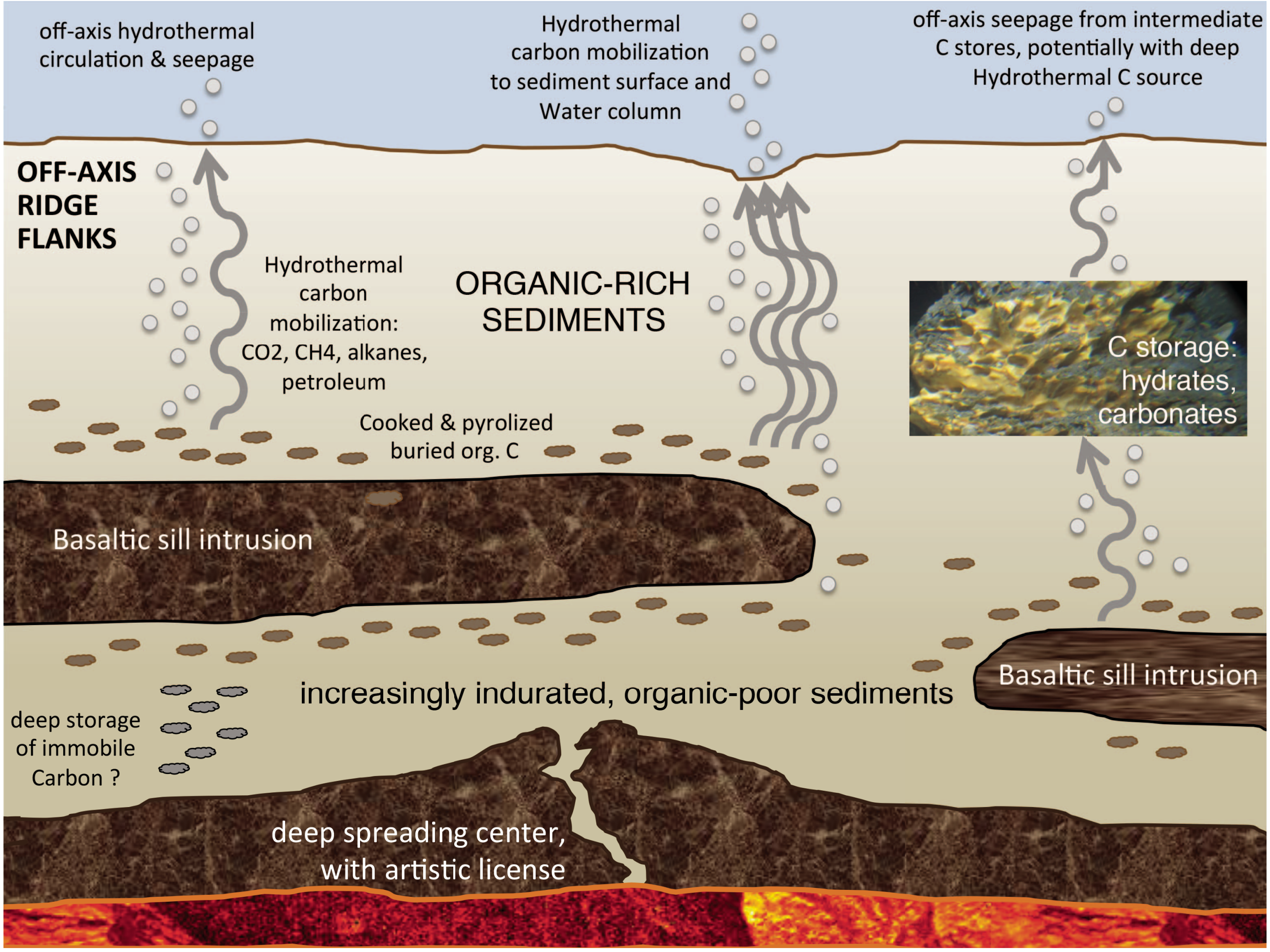
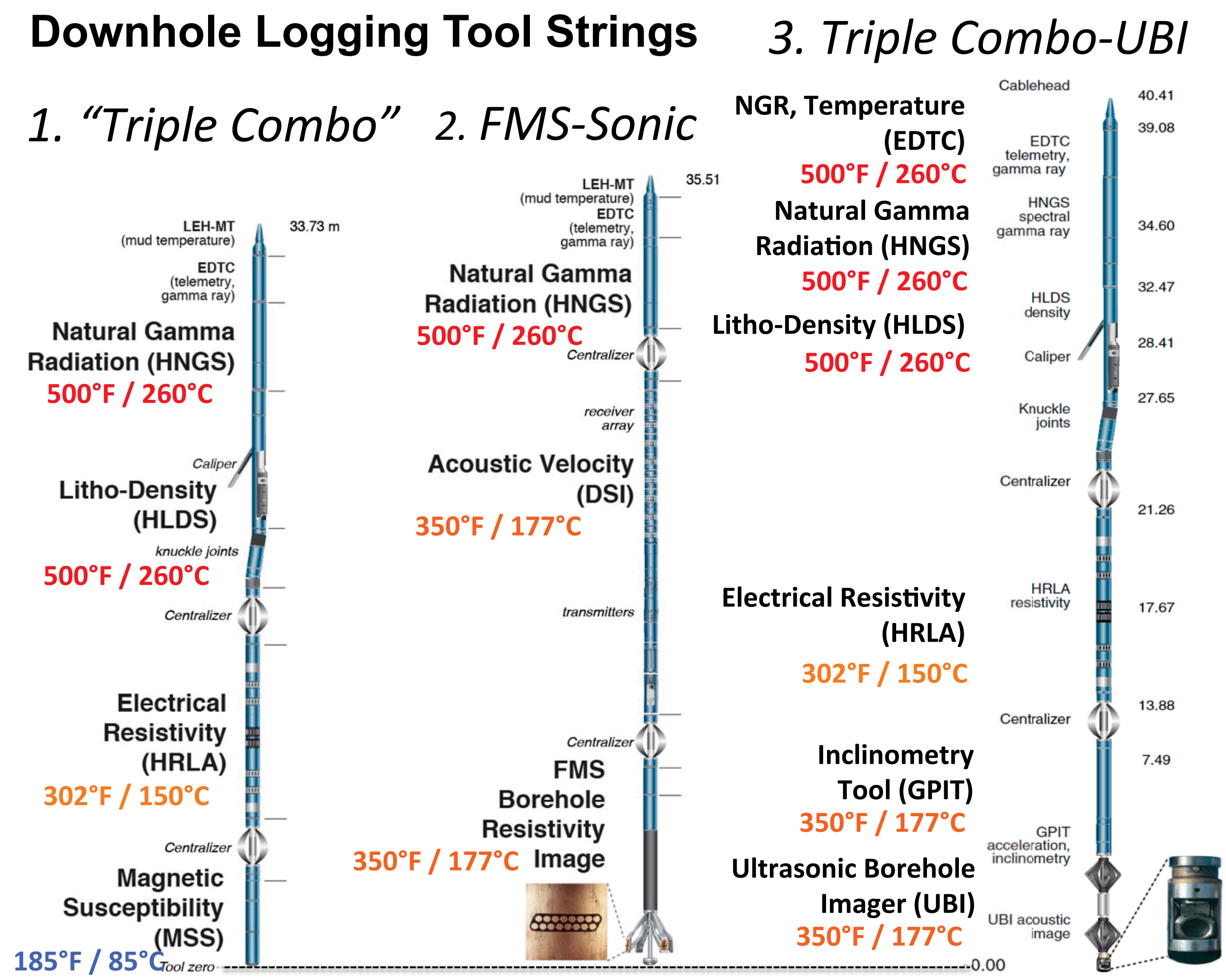


Figure F5. Standard wireline logging tool suites available on board *JOIDES Resolution*: triple combo, FMS-sonic, and triple combo-Ultrasonic Borehole Imager (UBI) downhole logging tool strings (see **http://iodp.tamu.edu/tools/logging**), including published tool temperature ratings (in both °F and °C). The triple combo and FMS-sonic tool strings are intended for use during Expedition 385 wireline logging (if formation temperature permits). Temperatures refer to the maximum temperature level of the corresponding tool. LEH-MT = logging equipment head-mud temperature, EDTC = Enhanced Digital Telemetry Cartridge, NGR = natural gamma radiation, HNGS = Hostile Environment Natural Gamma Ray Sonde, HLDS = Hostile Environment Litho-Density Sonde, HRLA = High-Resolution Laterolog Array Tool, MSS = Magnetic Susceptibility Sonde, DSI = Dipole Sonic Imager, FMS = Formation MicroScanner (borehole microresistivity imager), GPIT = General Purpose Inclinometry Tool.

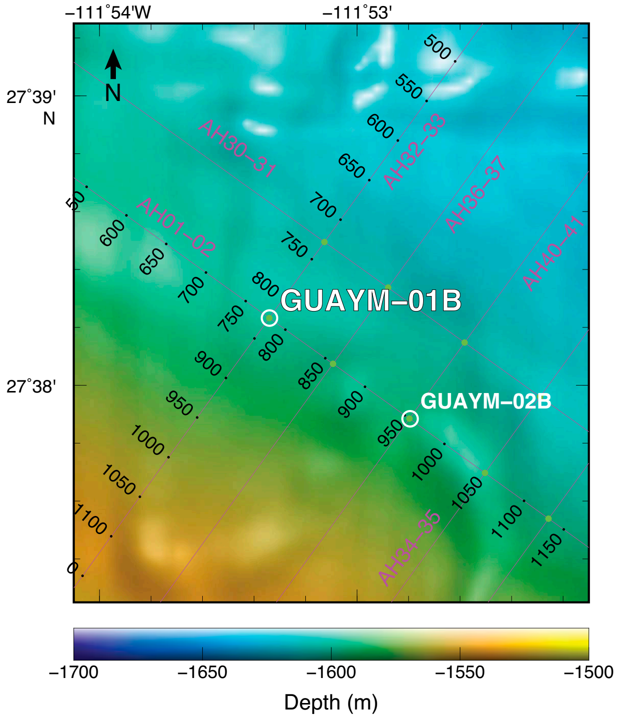


Site summaries

Figure AF1. Top: bathymetric map with the location of proposed primary Site GUAYM-01B at the northwestern Guaymas ridge flank. Bottom: interpreted seismic section at the intersection of Lines AH01-02 and AH32-33. CDP = common depth point.

Site GUAYM-01B

Priority:	Primary
Position:	27.637192°N, 111.888993°W (27°38.2315′N, 111°53.3396′W) Northwestern Guaymas ridge flank
Water depth (m):	1600
Target drilling depth (mbsf):	600
Approved maximum penetration (mbsf):	600
Survey coverage (track map; seismic profile):	Intersection of MCS Lines AH01-02 (CDP 780) and AH32-33 (CDP between 820 and 830)
Objective(s):	Recovering the full off-axis sedimentary sequence, providing information on background hemipelagic sedimentation
Drilling program:	• Hole A: APC/XCB to 600 mbsf • Hole B: APC with orientation to 250 mbsf • Hole C: APC/XCB to 600 mbsf and wireline logging
Logging/downhole measurements program:	Hole C: • Open hole temperature measurements • Wireline log with triple combo, FMS-sonic
Nature of material anticipated:	Mainly diatom ooze



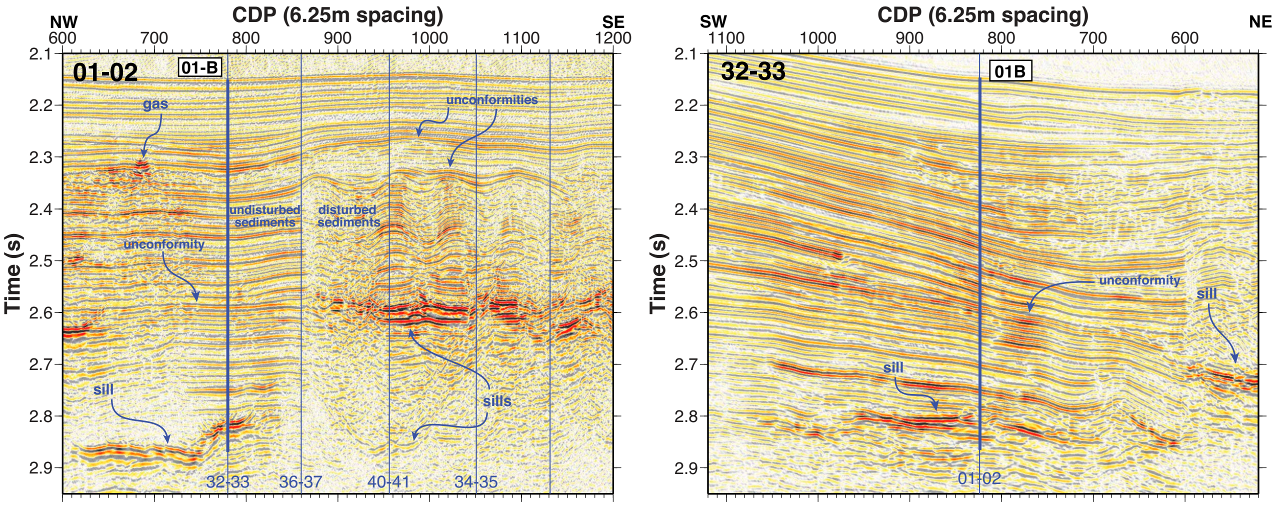
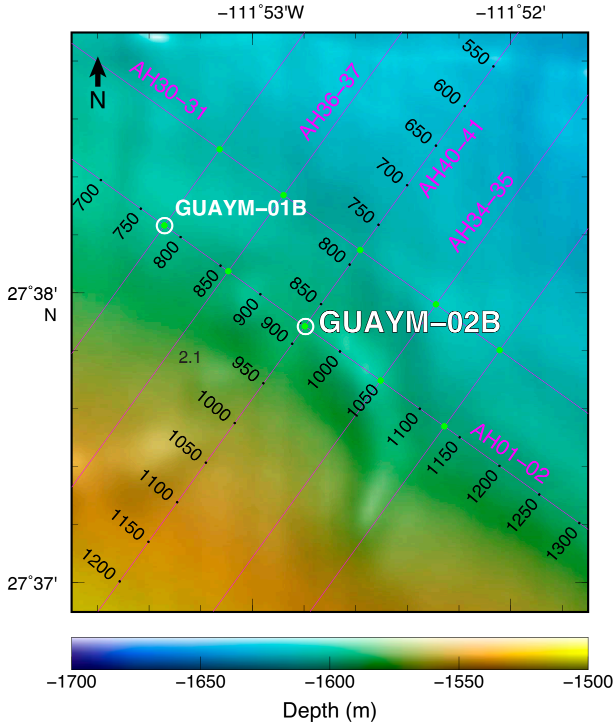


Figure AF2. Top: bathymetric map with the location of proposed primary Site GUAYM-02B at the northwestern Guaymas ridge flank. Bottom: interpreted seismic section at the intersection of Lines AH01-02 and AH40-41.

Site GUAYM-02B

Priority:	Primary
Position:	27.631406°N, 111.879936°W (27°37.8840′N, 111°52.7940′W) Northwestern Guaymas ridge flank
Water depth (m):	1600
Target drilling depth (mbsf):	600
Approved maximum penetration (mbsf):	600
Survey coverage (track map; seismic profile):	Intersection of MCS Lines AH01-02 (CDP between 950 and 960) and AH40-41 (CDP between 870 and 880)
Objective(s):	Recovering thick organic-rich sediment package (partially hydrothermally altered) and basaltic sill at oldest off-axis end-member site, thereby investigating consequences of sill emplacement in such a sequence
Drilling program:	• Hole A: APC/XCB with orientation to 350 mbsf • Hole B: APC with orientation to 200 mbsf; HLAPC to 250 mbsf • Hole C: drill down to 250 mbsf; RCB to 600 mbsf and wireline log
Logging/downhole measurements program:	Hole C: • Open hole temperature measurements • Borehole fluid sampling • Wireline log with triple combo, FMS-sonic
Nature of material anticipated:	Diatom ooze, hydrothermally altered sediments, dolerite sills intercalated with indurated sediments



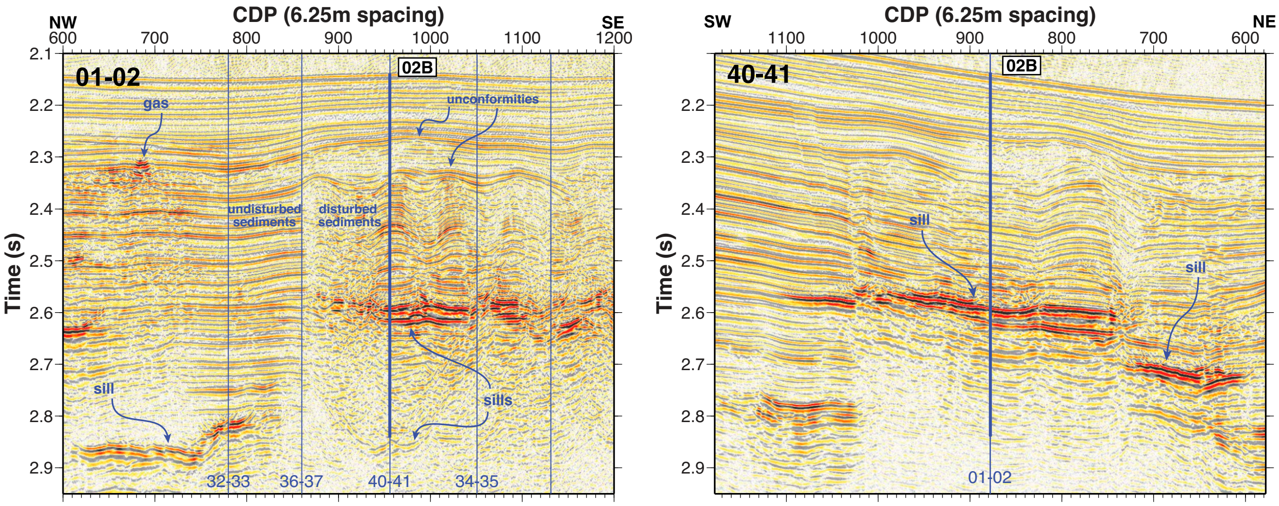
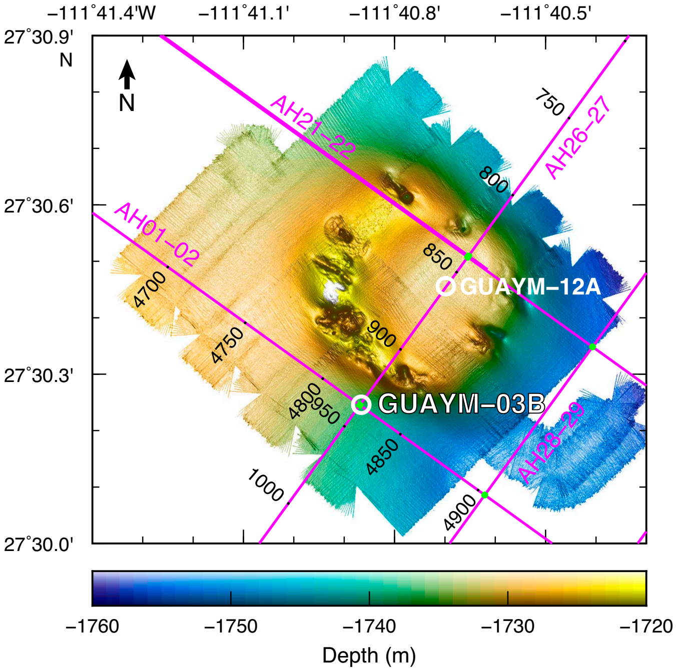


Figure AF3. Top: bathymetric map with the location of proposed primary Ringvent Site GUAYM-03B at the northwestern Guaymas ridge flank. Bottom: interpreted seismic section at the intersection of Lines AH01-02 and AH26-27.

Site GUAYM-03B

Priority:	Primary
Position:	27.504081°N, 111.681139°W (27°30.2460′N, 111°40.8660′W) Ringvent
Water depth (m):	1750
Target drilling depth (mbsf):	200
Approved maximum penetration (mbsf):	200
Survey coverage (track map; seismic profile):	Intersection of MCS Lines AH01-02 (CDP between 930 and 940) and AH26-27 (CDP between 4820 and 4830)
Objective(s):	Recovering organic-rich sediments influenced by active hydrothermal fluid flow driven by intrusion of basaltic sills
Drilling program:	• Hole A: APC with orientation to 150 mbsf; XCB to 200 mbsf or sill • Hole B: APC with orientation to 150 mbsf; XCB to 200 mbsf or sill • Hole C: APC with orientation to 150 mbsf; XCB to 200 mbsf or sill and wireline log
Logging/downhole measurements program:	Hole C: • Open hole temperature measurements • Borehole fluid sampling • Wireline log with triple combo, FMS-sonic
Nature of material anticipated:	Diatom ooze, hydrothermally altered sediments, dolerite sills intercalated with indurated sediments



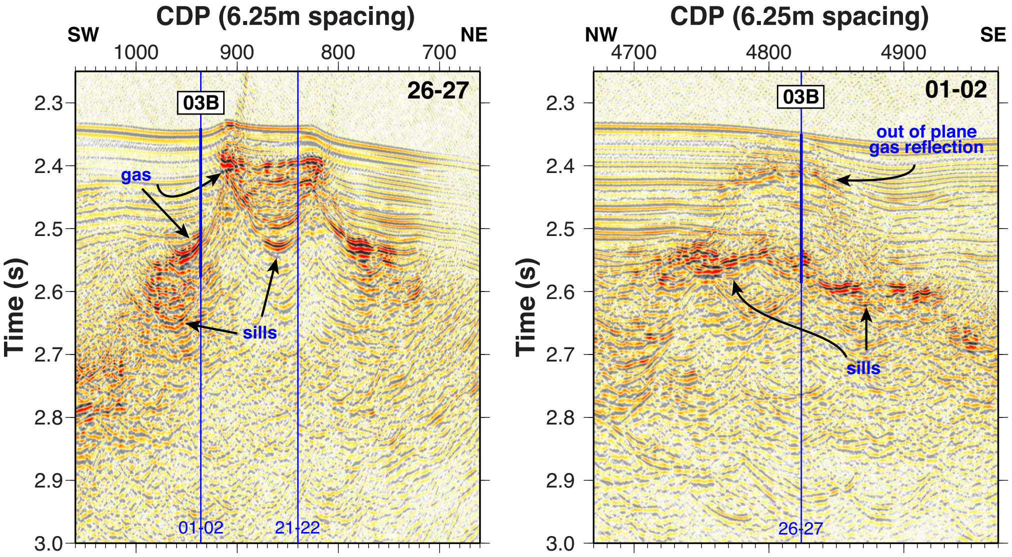
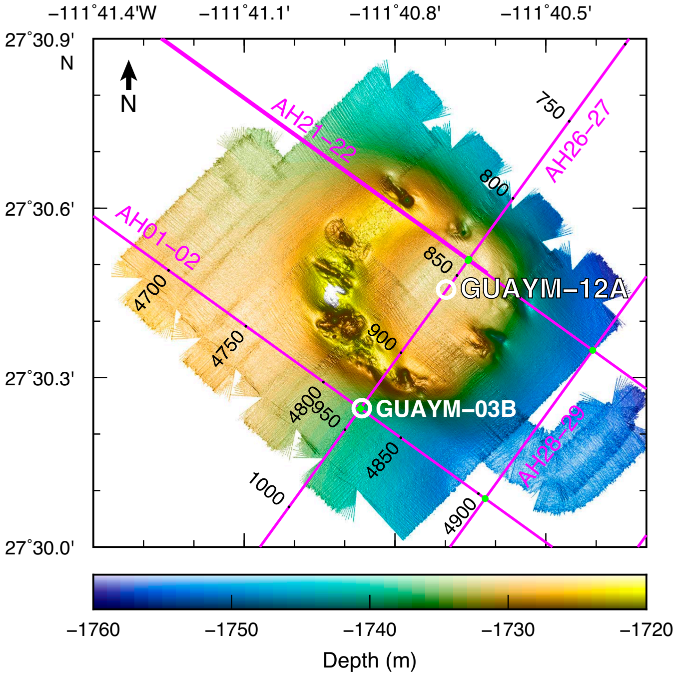


Figure AF4. Top: bathymetric map with the location of proposed primary Ringvent Site GUAYM-12A at the northwestern Guaymas ridge flank. Bottom: interpreted seismic section on Seismic Line AH26-27.

Site GUAYM-12A

Priority:	Primary
Position:	27.5076°N, 111.6783°W (27°30.4560′N, 111°40.6980′W) Ringvent
Water depth (m):	1750
Target drilling depth (mbsf):	200
Approved maximum penetration (mbsf):	200
Survey coverage (track map; seismic profile):	CDP 840 on MCS Line AH26-27
Objective(s):	Recovering an undisturbed and hydrothermally impacted organic-rich sedimentary sequence, as well as an off-axis basaltic sill
Drilling program:	• Hole A: APC with orientation to 150 mbsf; XCB to 200 mbsf or sill • Hole B: APC with orientation to 150 mbsf; XCB to 200 mbsf or sill • Hole C: APC with orientation to 150 mbsf; XCB to 200 mbsf or sill and wireline log
Logging/downhole measurements program:	Hole C: • Open hole temperature measurements • Borehole fluid sampling • Wireline log with triple combo, FMS-sonic
Nature of material anticipated:	Mostly diatom ooze, indurated sediments around sill, and dolerite sill



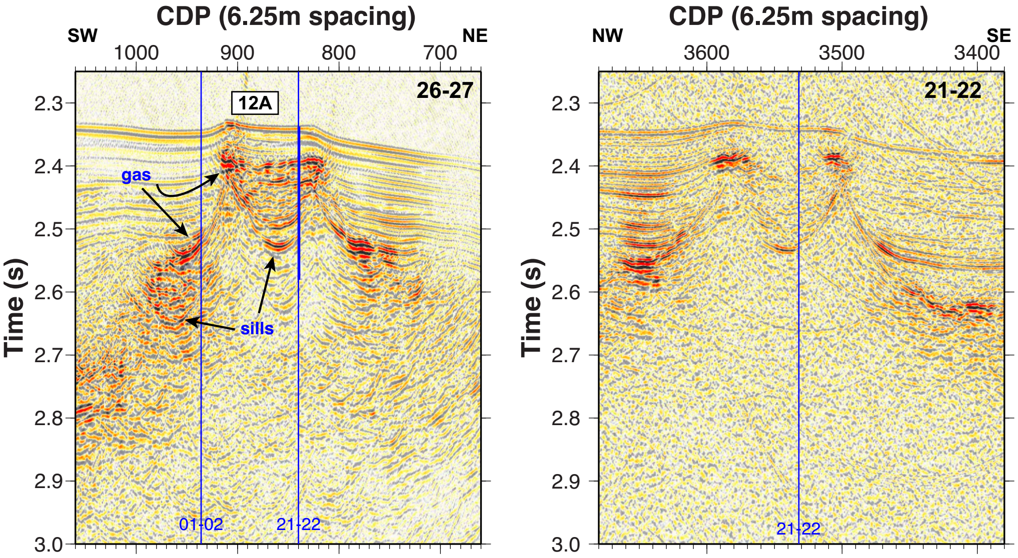
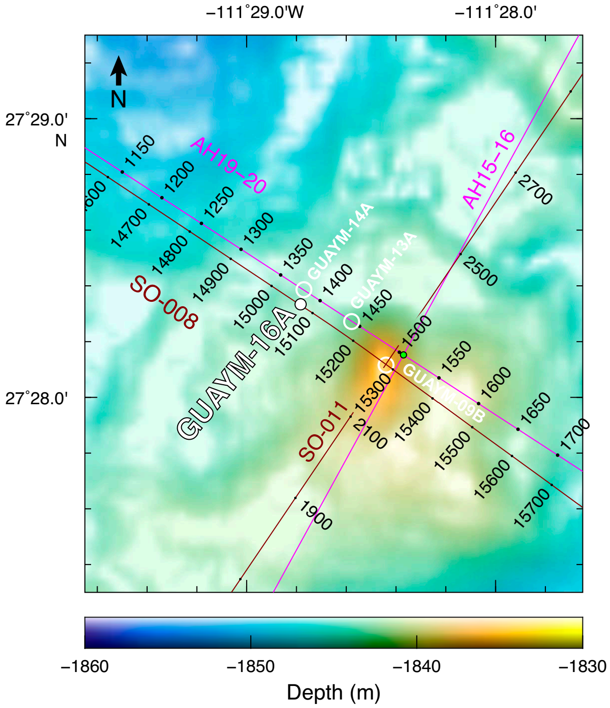


Figure AF5. Top: bathymetric map with the location of proposed primary cold seep Site GUAYM-16A at the northwestern Guaymas ridge flank. Bottom: interpreted seismic section on Seismic Line SO-008.

Site GUAYM-16A

Priority:	Primary
Position:	27.4721°N, 111.4797°W (27°28.3315′N, 111°28.7848′W) Cold seep at northwestern Guaymas ridge flank
Water depth (m):	1839
Target drilling depth (mbsf):	182
Approved maximum penetration (mbsf):	182
Survey coverage (track map; seismic profile):	CDP 15070 on MCS Line SO-008
Objective(s):	Studying consequences of deep sill emplacement combined with shallow hydrate formation through recovery of disturbed organic-rich sediments in a gas upflow zone
Drilling program:	• Hole A: APC with orientation to 182 mbsf • Hole B: APC with orientation to 182 mbsf • Hole C: APC with orientation to 182 mbsf and wireline log
Logging/downhole measurements program:	Hole C: • Open hole temperature measurements • Borehole gas/fluid sampling • Wireline log with triple combo, FMS-sonic
Nature of material anticipated:	Diatom ooze, possibly methane hydrate, authigenic carbonate



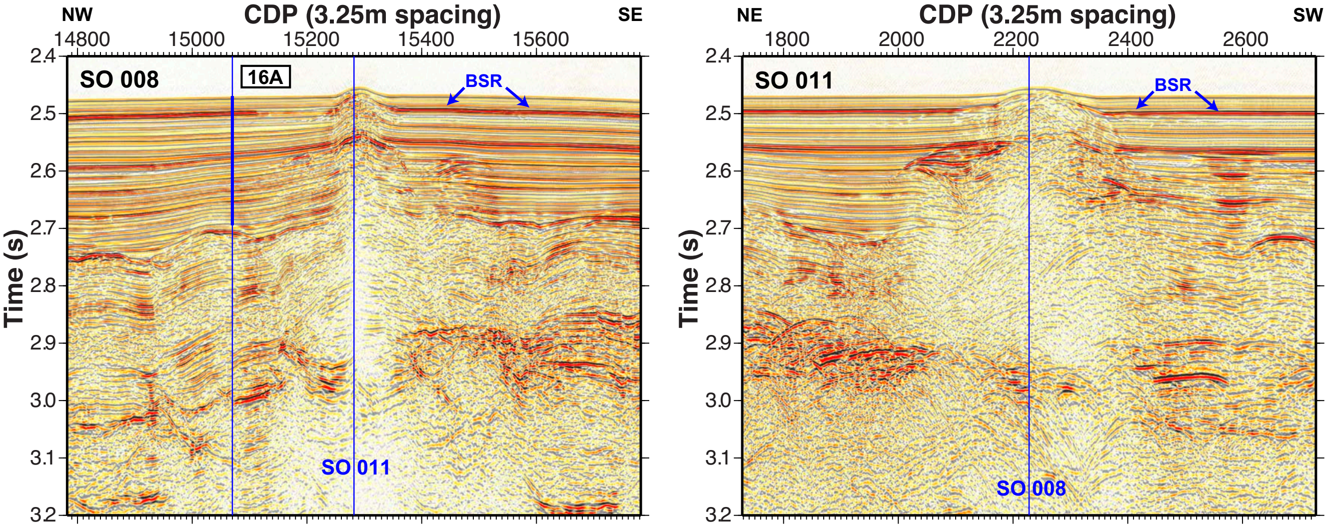
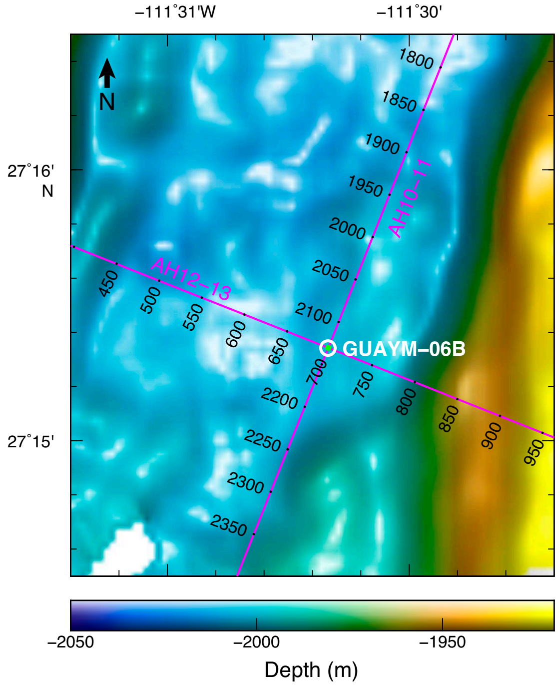


Figure AF6. Top: bathymetric map with the location of proposed primary spreading center reference Site GUAYM-06B near DSDP Site 481. Bottom: interpreted seismic section at the intersection of Lines AH10-11 and AH12-13.

Site GUAYM-06B

Priority:	Primary (reoccupation of DSDP Site 481)
Position:	27.255734°N, 111.505558°W (27°15.3420′N, 111°30.3360′W) Guaymas spreading center reference site
Water depth (m):	2013
Target drilling depth (mbsf):	250
Approved maximum penetration (mbsf):	250
Survey coverage (track map; seismic profile):	Intersection of MCS Lines AH10-11 (CDP 2130) and AH12-13 (CDP 700)
Objective(s):	Investigation of early stages of geochemical-microbial transformation of buried organic carbon through recovering organic-rich sedimentary sequence (partially indurated) and basaltic sill
Drilling program:	• Hole A: APC/XCB with orientation to 250 mbsf • Hole B: APC/XCB with orientation to 250 mbsf • Hole C: APC/XCB with orientation to 250 mbsf and wireline log
Logging/downhole measurements program:	Hole C: • Open-hole temperature measurements • Borehole fluid sampling • Wireline log with triple combo, FMS-sonic
Nature of material anticipated:	Disturbed diatom ooze, dolerite sill (assumed near ~150 mbsf)



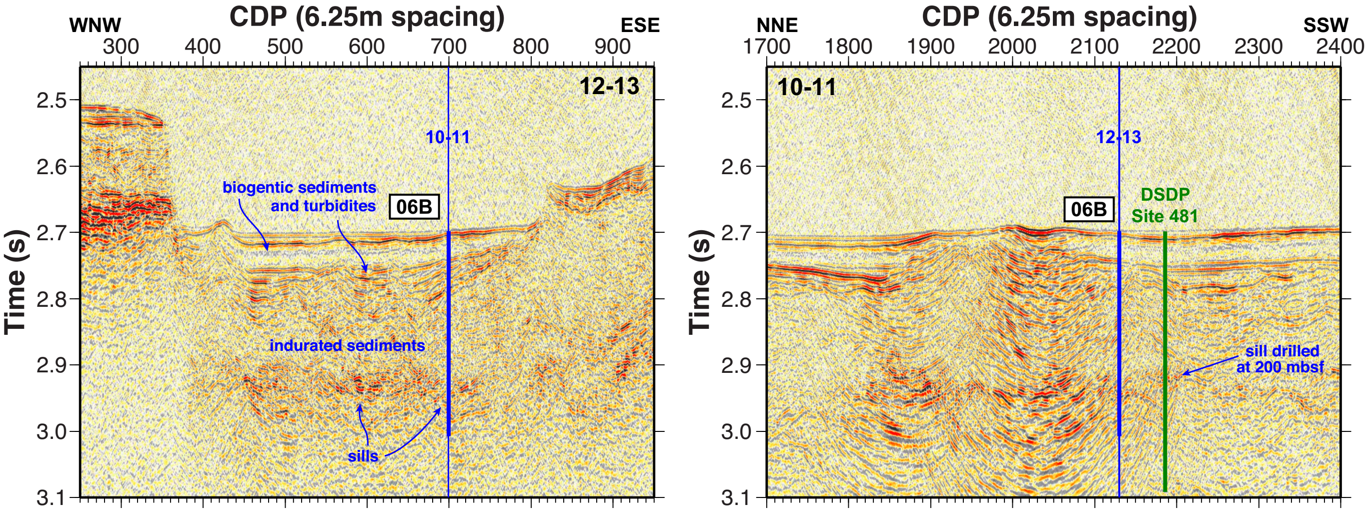
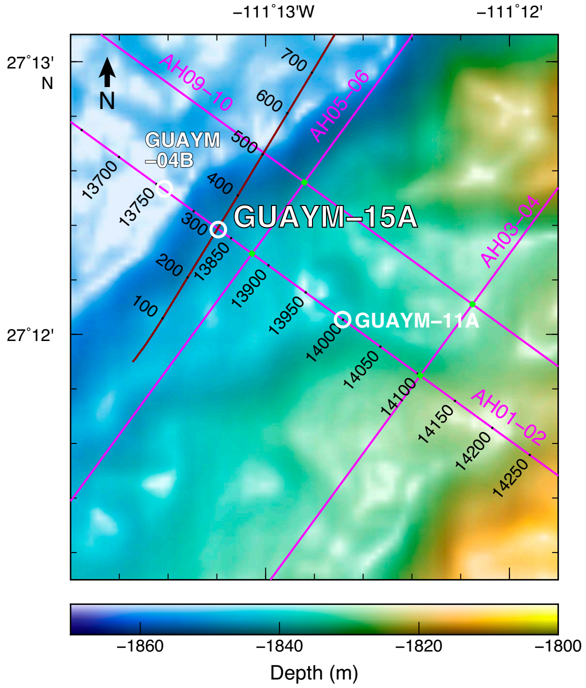


Figure AF7. Top: bathymetric map with the location of proposed primary Site GUAYM-15A at the southeastern Guaymas ridge flank. Bottom: interpreted seismic section at the intersection of Lines AH01–02 and SO-005.

Site GUAYM-15A

Priority:	Primary
Position:	27.2065°N, 111.2199°W (27°12.3900′N, 111°13.1940′W) Southeastern Guaymas ridge flank
Water depth (m):	1821
Target drilling depth (mbsf):	670
Approved maximum penetration (mbsf):	670
Survey coverage (track map; seismic profile):	Intersection of MCS Lines AH01-02 (CDP 13832) and SO-005 (CDP 319)
Objective(s):	Recovering terrigenous sediments and possibly intersecting the margin of the "eye structure" along with a sill at depth
Drilling program:	• Hole A: APC with orientation to 200 mbsf • Hole B: APC with orientation to 200 mbsf • Hole C: APC with orientation to 200 mbsf; XCB to 670 mbsf and wireline log
Logging/downhole measurements program:	Hole C: • Open hole temperature measurements • Wireline log with triple combo, FMS-sonic
Nature of material anticipated:	Terrigenous sandy clay turbidites with interlayered deep-marine sediments; sill at ~650 mbsf or deeper



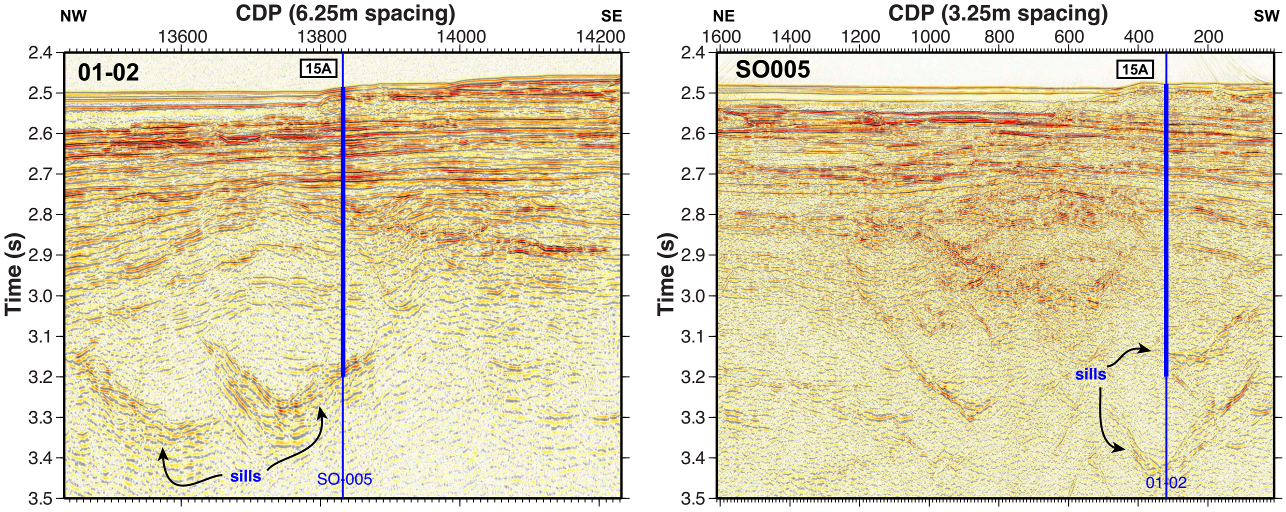
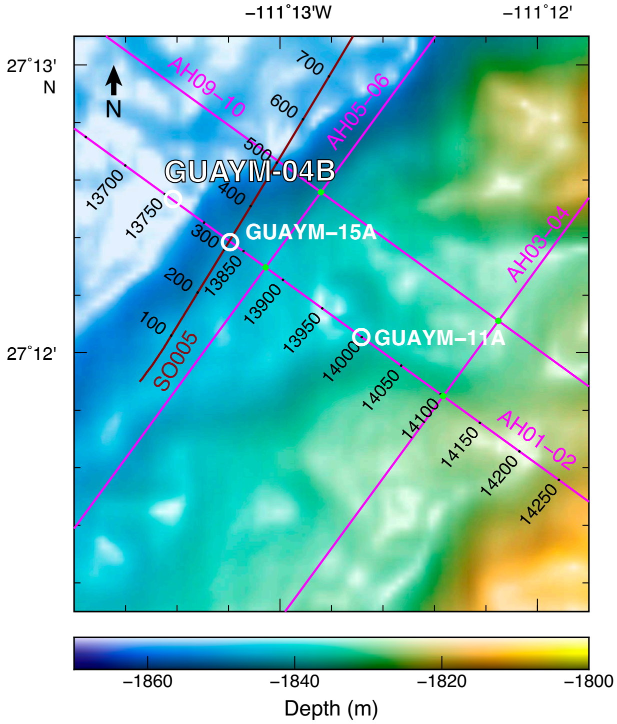


Figure AF8. Top: bathymetric map with the location of proposed alternate Site GUAYM-04B at the southeastern Guaymas ridge flank. Bottom: interpreted seismic section on Seismic Line AH01-02.

Site GUAYM-04B

Priority:	Alternate to GUAYM-15A
Position:	27.208855°N, 111.223624°W (27°12.5340′N, 111°13.4160′W) Southeastern Guaymas ridge flank
Water depth (m):	1850
Target drilling depth (mbsf):	650
Approved maximum penetration (mbsf):	650
Survey coverage (track map; seismic profile):	MCS Line AH01-02 (CDP between 13,750 and 13,760)
Objective(s):	Recovering terrigenous turbidite sediments, the lithologic and physical-chemical counterpart to northwestern Guaymas ridge flank; intersecting basaltic sill
Drilling program:	• Hole A: APC with orientation to 200 mbsf • Hole B: APC with orientation to 200 mbsf • Hole C: APC with orientation to 200 mbsf; XCB to 650 mbsf and wireline log
Logging/downhole measurements program:	Hole C: • Open hole temperature measurements • Wireline log with triple combo, FMS-sonic
Nature of material anticipated:	Terrigenous sandy clay turbidites with interlayered deep-marine sediments, partially hydrothermally altered; sill at ~650 mbsf or deeper



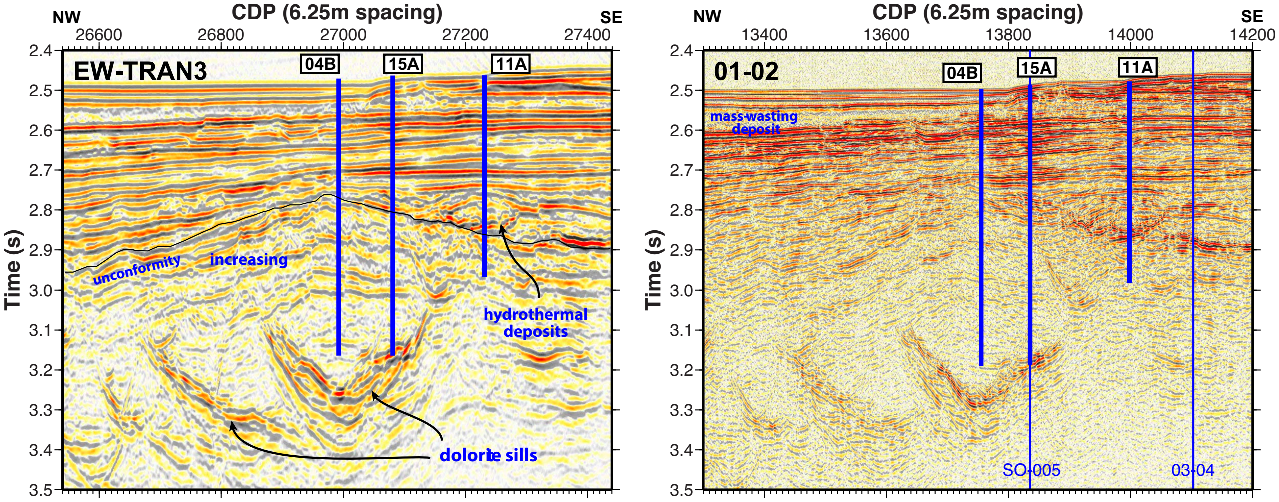
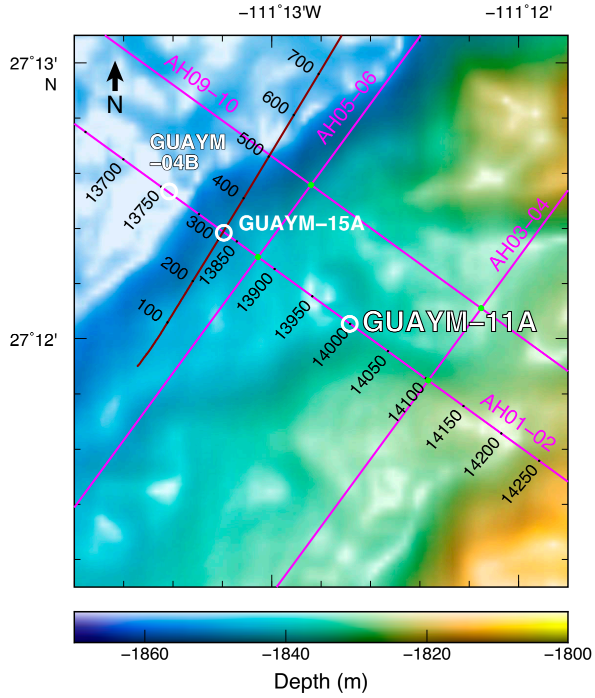


Figure AF9. Top: bathymetric map with the location of alternate Site GUAYM-11A at the southeastern Guaymas ridge flank. Bottom: interpreted seismic section at the intersection of Lines AH01-02 and EW-TRAN3.

Site GUAYM-11A

Priority:	Alternate to GUAYM-04B and 15A
Position:	27.200906°N, 111.211370°W (27°12.0544′N, 111°12.6822′W) Southeastern Guaymas ridge flank
Water depth (m):	1821
Target drilling depth (mbsf):	450
Approved maximum penetration (mbsf):	450
Survey coverage (track map; seismic profile):	Intersection of MCS Lines AH01-02 (CDP 14000) and EW-TRAN3 (CDP 27230)
Objective(s):	Recovering a sedimentary sequence with a higher terrigenous content than at northwestern Guaymas ridge flank
Drilling program:	• Hole A: APC with orientation to 150 mbsf; XCB to 200 mbsf or sill • Hole B: APC with orientation to 150 mbsf; XCB to 200 mbsf or sill • Hole C: APC with orientation to 150 mbsf; XCB to 450 mbsf or sill and wireline log
Logging/downhole measurements program:	Hole C: • Open hole temperature measurements • Borehole fluid sampling • Wireline log with triple combo, FMS-sonic
Nature of material anticipated:	Diatom ooze, turbidites, hydrothermally altered sediments, carbonates



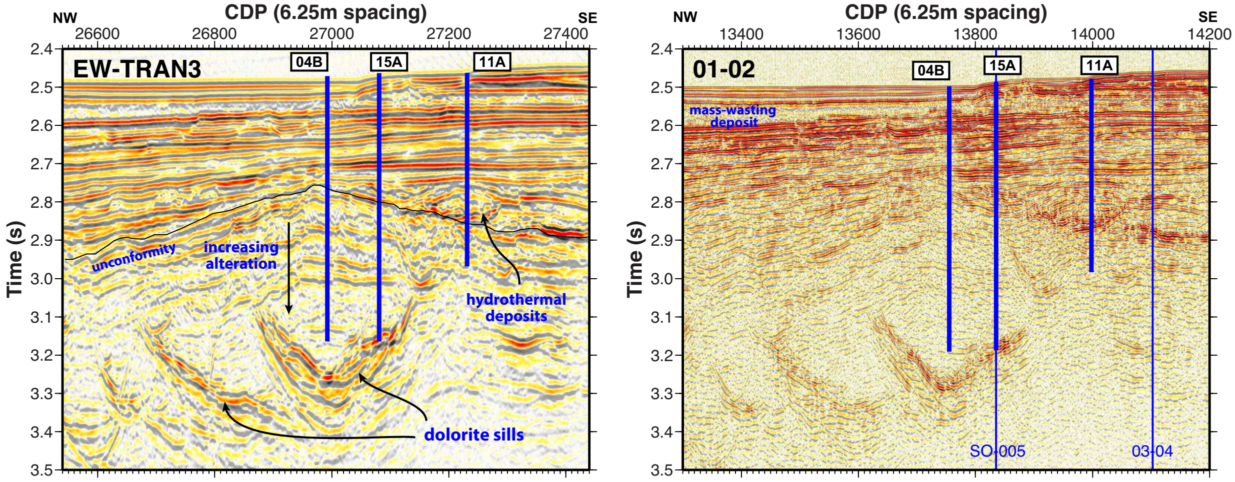


Figure AF10: Top: bathymetric map with the location of alternate cold seep Site GUAYM-10B at the northwestern Guaymas ridge flank. Bottom: interpreted seismic section at the intersection of Lines SO-014 and SO-112.

Site GUAYM-10B

Priority:	Alternate to GUAYM-03B and GUAYM-16A
Position:	27.5548°N, 111.5494°W (27°33.2880′N, 111°32.9640′W) Cold seep at northwestern Guaymas ridge flank
Water depth (m):	1845
Target drilling depth (mbsf):	200
Approved maximum penetration (mbsf):	200
Survey coverage (track map; seismic profile):	Intersection of MCS Lines SO-014 (CDP 5660) and SO-112 (CDP between 8270 and 8280)
Objective(s):	Studying geochemical-microbial changes throughout gas hydrate stability zone by recovery of hydrate-rich sedimentary sequence and sediments below, overlying deep sills
Drilling program:	• Hole A: APC with orientation to 150 mbsf; XCB to 200 mbsf or sill • Hole B: APC with orientation to 150 mbsf; XCB to 200 mbsf or sill • Hole C: APC with orientation to 150 mbsf; XCB to 200 mbsf or sill and wireline log
Logging/downhole measurements program:	Hole C: • Open hole temperature measurements • Wireline log with triple combo, FMS-sonic
Nature of material anticipated:	Mainly diatom ooze, possibly methane hydrate, minor authigenic carbonate