

Guaymas Basin IODP Drilling and Theme Team II Extent of Life, Biogeography and Dispersal Workshop

Wrigley Marine Science Center, Catalina Island

February 27 to March 1, 2013

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Background. The Guaymas Basin IODP proposal workshop, proposed by Andreas Teske (UNC Chapel Hill, Dept of Marine Sciences), Ivano Aiello (Moss Landing Marine Lab), Daniel Lizarralde and S. Adam Soule (WHOI, Dept of Geology and Geophysics) took place at Wrigley Marine Science Center on Catalina Island, CA, from February 27 to March 2, 2013. The meeting was funded jointly by the United States Science Support Program (USSSP) of the Integrated Ocean Discovery Program (IODP), and by the NSF-funded Science and Technology Center for Dark Energy Biosphere Investigations (C-DEBI) at the University of Southern California. Proposal writing and organization efforts started in September 2012, in part in response to a workshop on US strategies to implement the 2013-2023 IODP science plan (April 29 to May 1, 2012, Denver, CO) and in response to C-DEBI's effort to foster new drilling projects, after the three foundational drilling projects within C-DEBI (South Pacific Gyre, North Pond, Juan de Fuca) had gone forward (**Figure 1**). Another, deep root of this workshop goes back to a Guaymas Basin IODP pre-proposal written and submitted in March 2009 by Teske, Lizarralde, Soule, and other proponents (IODP Pre-749). Revising and expanding this favorably reviewed IODP pre-proposal towards a full proposal, and to invite strong Mexican project participation, had been on the proponents' agenda since then. The stars finally aligned in fall 2012.

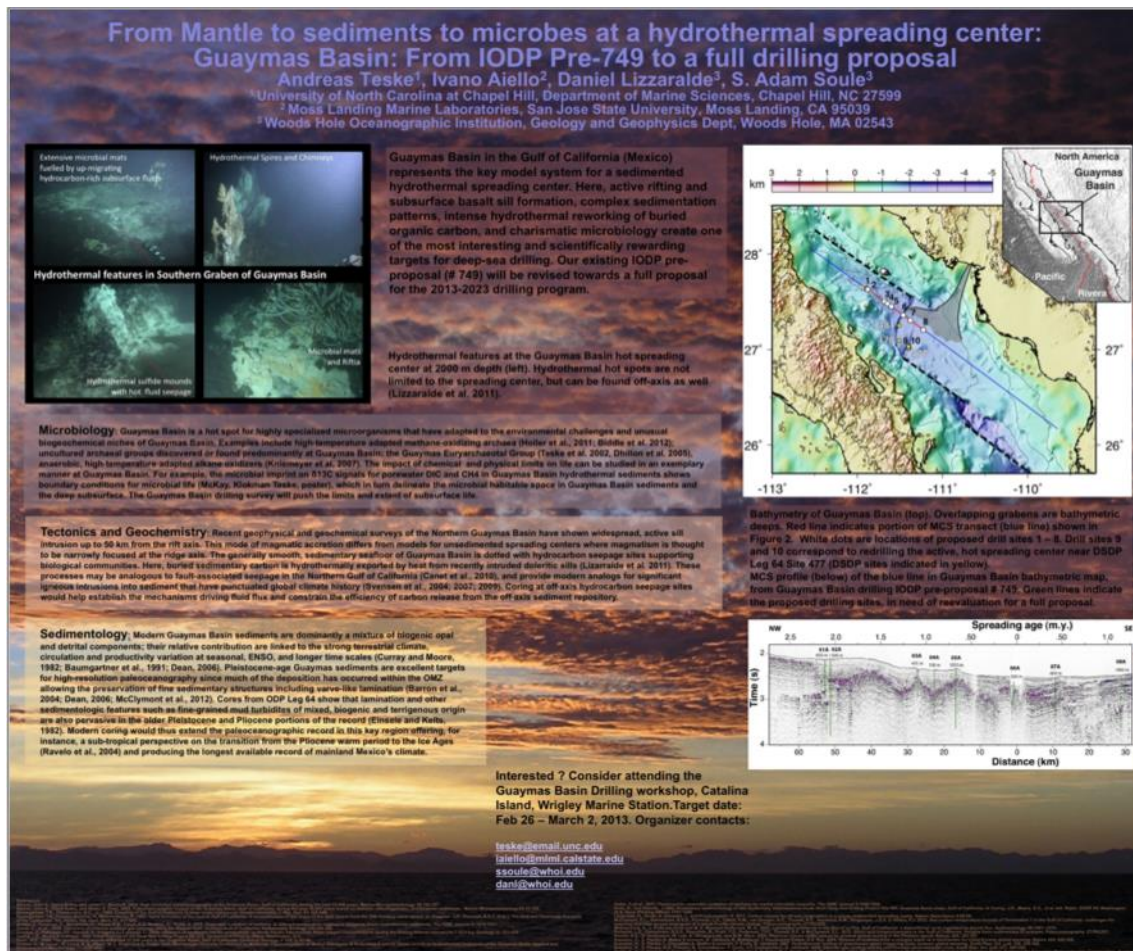


Figure 1. Poster at C-DEBI All Hands meeting, advertising the Guaymas workshop.

Participants. Twenty-three participants (see below for a detailed list) joined a packed three-day program of overview presentations, discussions, and project planning sessions. Participants responded to advertisement by C-DEBI, to calls for participation at the C-DEBI All Hands Meeting in Monterey, CA (October 21 to 23, 2012) and to informal inquiries across disciplinary, institutional and national boundaries. A goal of this workshop was to bring new people from different backgrounds together who had not previously collaborated, had not met or did not even know of each other's existence. As the workshop results showed, creatively mixing different scientific cohorts would be highly productive.

The workshop participants in alphabetical order:

Ivano Aiello, Moss Landing Marine Laboratories (Aiello@mlml.calstate.edu)
Amy Callaghan, University of Oklahoma (acallghan@ou.edu)
Carles Canet Miquel, Universidad Nacional Autónoma de Mexico, Mexico (ccanet@geofisica.unam.mx)
Virginia Edgcomb, Woods Hole Oceanographic Institution (vedgcomb@whoi.edu)
Anne Godfroy, IFREMER, France (agodfroy@ifremer.fr)
*Douglas LaRowe, University of Southern California (larowe@usc.edu)
Daniel Lizarralde, Woods Hole Oceanographic Institution (danl@whoi.edu)
Arturo Martin Barajas, CICESE, Mexico (amartin@cicese.mx)
Tom McCollom, University of Colorado (mccollom@lasp.colorado.edu)
Carlos Mortera Gutierrez, Universidad Nacional Autónoma de Mexico, Mexico (cmortera@geofisica.unam.mx)
*Raquel Negrete-Aranda, University of California at San Diego (rnegretearanda@ucsd.edu)
*Bill Orsi, Woods Hole Oceanographic Institution (william.orsi@gmail.com)
*Brandi Reese, University of Southern California (brandire@usc.edu)
*Alberto Robador, University of Hawaii (araeuber@gmail.com)
*Kirt Robinson, Arizona State University (kirobin@asu.edu)
Hans Røy, Aarhus University, Denmark (hans.roy@biology.au.dk)
Jeff Seewald, Woods Hole Oceanographic Institution (jseewald@whoi.edu)
*Ryan Sibert, University of Georgia at Athens (rsibert@uga.edu)
Ronald Spelz-Madero, Universidad Autónoma de Baja California, Mexico (rspelz67@yahoo.com.mx)
Adam Soule, Woods Hole Oceanographic Institution (ssoule@whoi.edu)
Andreas Teske, University of North Carolina at Chapel Hill (teske@email.unc.edu)
Fengping Wang, Jiaotong University Shanghai, China (fengpingw@sjtu.edu.cn)
Scott Wankel, Woods Hole Oceanographic Institution (sdwankel@whoi.edu)

Of the workshop participants, 7 are graduate students or postdocs, marked with asterisks. Five Mexican researchers - Carles Canet, Arturo Martin, Carlos Mortera, Raquel Negrete (based currently in the USA) and Ronald Spelz-Madero - and three additional international participants from France, China and Denmark (Anne Godfroy, Fengping Wang, and Hans Røy) attended the workshop.



Figure 2. The workshop participants on Catalina Island, from left to right: Carles Canet, Carlos Mortera, Arturo Martin, Raquel Negrete-Aranda, Anne Godfroy, Brandi Reese, Alberto Robador, Fengping Wang, Scott Wankel, Hans Røy, Amy Callaghan, Andreas Teske, Daniel Lizarralde, Bill Orsi, Adam Soule, Ivano Aiello, Ronald Spelz-Madero, Ryan Sibert, Virginia Edgcomb, Tom McCollom, Jeff Seewald, Doug LaRowe, Kirt Robinson.

Workshop narrative. Although ice storms in the Midwest had delayed some flights, almost all attendees arrived in time for an excellent ice breaker dinner in San Pedro on the evening of February the 26th. The next morning, the participants were ferried over to Catalina Island and arrived on schedule at 9:00 am. Catalina Island regulars commented on the singularly calm seas.

Day 1/February 27. The first full day of this meeting (February 27) doubled as a C-DEBI Theme Team II (Biogeography and Dispersal) meeting to discuss research strategies of microbial biogeography and dispersal in the marine subsurface, drawing on the scientific capacity of the entire workshop group and using Guaymas Basin as a model case. The program started in the lecture hall of Wrigley Marine Science Center with overview presentations on Guaymas Basin and the Gulf of California by the four project proponents, by Jeff Seewald (WHOI), and by four Mexican workshop participants (Arturo Martin, Carlos Mortera, Carles Canet, and Ronald Spelz who presented a poster on recent mapping of the Alarcon Rise) from different geological, chemical and microbiological angles. These presentations from 10:00 AM to 2:30 PM brought all workshop participants up to date on Guaymas Basin and the Gulf of California, and set the stage for subsequent discussions that took place in the more informal meeting space of Boone House. [Author comment: The flexible seating, natural lighting, and effective projection facilities of Boone House, the good coffee, and the tireless efforts of the resident staff to facilitate live internet connectivity (off-site conference participant Mandy Joye was Skyping in from the University of Georgia at Athens) deserve high praise, and contributed very significantly to the success of the workshop. The meeting space suited the workshop

so well that, contrary to initial planning, it never became necessary or even desirable to divide the plenum into breakout groups. Therefore, discussions of primary scientific questions and suitable research and drilling strategies in Guaymas Basin easily crossed the disciplinary boundaries. Right from the start, the subsurface microbial communities were viewed in terms of how they affected subsurface biogeochemical cycling in feedback loops called microbial gauntlets (**Figure 3**) where active subsurface microbes modulate carbon cycling (specifically, by counteracting carbon loss after organic matter pyrolysis and mobilization) as much as the site-specific geochemical regimes shape in-situ microbial populations and activities.

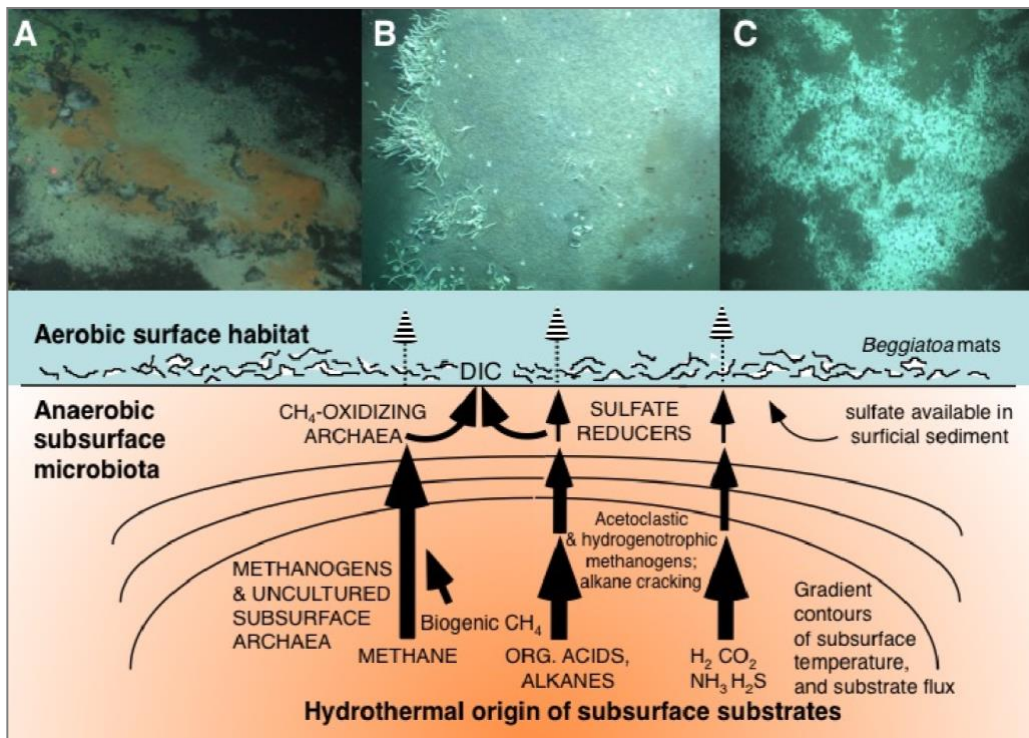


Figure 3. The microbial gauntlet modifies the fluxes of deep carbon and gases towards the sediment surface. Top row shows sulfur-oxidizing microbial mats at hydrothermal seepage on axis (left; McKay et al. 2012 Deep-Sea Research I 67:21-31) and off-axis (middle & right; Lizarralde et al. 2011. Nature Geoscience 4:50-54).

The extensive thermal and geochemical gradients of Guaymas Basin fulfilled a key criterion articulated during prior Evolution Theme Team meetings (Biddle et al. 2012 Frontiers in Microbiology, doi: 10.3389/fmicb.2011.00285) that abundance and activity of specific, physiologically and phylogenetically defined microbial groups should be studied within the context of well-constrained environmental gradients. This approach was now applied to Guaymas Basin. For example, the extensive microbial community data, in-situ temperature gradients, and porewater geochemistry analyses from pushcores of surficial sediments (during Atlantis/Alvin expeditions in December 2008 and 2009; Biddle et al. 2012 ISME J. 6:1018-1031, McKay et al., in prep.) had detected specific, phylogenetically distinct ANME-1

populations of methanotrophic archaea in high-temperature sediments at in-situ temperatures of up to 80°C, and concomitant $d^{13}C-CH_4$ and DIC signatures of biogenic methane oxidation. These high-temperature ANMEs are not limited to Guaymas Basin, but are widespread in methane-rich hydrothermal fluids (Merkel et al. 2012 AEM 79:915-923.). Similar strategies were discussed for the detection of high-temperature sulfate-reducing alkane oxidizing bacteria; model organisms have been isolated previously from Guaymas Basin (reviewed in Teske 2010, DOI 10.1007/978-3-540-77587-4_160), and their 16S rRNA and functional gene signatures of anaerobic alkane oxidation are within reach (Callaghan et al. 2010. Environ. Sci. Technol. 44:7287-7294).

To briefly summarize initial “Extent of life” theme results, microbial life in the Guaymas Basin subsurface reaches the following thermal limits: ca. 100 to 110°C with regard to methanogenesis, based on pure culture studies of the genus and species *Methanopyrus kandleri* from Guaymas Basin (Kurr et al. 1991. Arch. Microbiol. 156:239-247; Takai et al. 2008. PNAS 105:10949-10954); ca. 75-80°C with respect to sulfate-dependent anaerobic methane oxidation (Biddle et al. 2012. ISME J. 6:1018-1031; Holler et al. 2011. ISME J. 5:1946-1956; McKay et al., in prep.); ca. 85-90°C with respect to microbial sulfate reduction (reviewed in Amend and Teske 2005. Paleocube 219:131-155), approx. 100°C for remineralization of sedimentary organic matter (McKay et al., in prep), and at least 60°C for sulfate-dependent alkane oxidation (Kniemeyer et al. 2007. Nature 449:898-901; Kleindienst et al. 2012. Environ. Microbiol. 14:2689-2710). These thermal boundaries permit mapping the microbial habitat space of the deep Guaymas subsurface, and suggest extensive subsurface domains, especially in the cooler off-axis regions and ridge flanks of Guaymas Basin. A full publication of the Theme Team results, in the form of a “Theory and Hypothesis” paper in *Frontiers in Microbiology*, is planned for the second half of 2013.

Two after-dinner presentations by Anne Godfroy (IFREMER) on the 2010 French/Mexican Guaymas Basin and Sonora Margin Expedition, and by Fengping Wang (Jiaotong University, Shanghai) on current IODP drilling plans in the South China Sea, concluded the first day of the workshop.



Figure 4. Anne Godfroy (right, behind laptop) shows new bathymetric maps of the Southern Guaymas Trench and of the Sonoran Margin from the 2010 French/Mexican Expedition.

The discussions during Day 1 (and on subsequent days when these themes were revisited) also clarified that biogeographical mapping of steep microbial community gradients should begin with push cores and gravity cores collected on site survey cruises, to map the critical surficial sediments on a scale of 0.5 m (pushcores) and 5 m (gravity cores); these endmember sediments are either not recovered, or mixed with seawater during the initiation of IODP drilling holes. Subsequently, site survey cruise planning and sampling surveys in the Guaymas IODP proposal addressed these sampling gaps.

Day 2 / February 28. The Guaymas Basin Pre-proposal of Spring 2009 and its reviews were introduced during the morning session in the Wrigley Center Lecture Hall, as a background foil to think about improvements in research strategies, overall proposal design and scientific content. Several “sins” of the preproposal, among them an unrealistically high drilling volume, and a sketchy treatment of the in-situ temperature gradients in Guaymas Basin and high-temperature drilling issues were identified with the intention to avoid these in the new full proposal. The major initial question on the table was: should we continue to aim for a multidisciplinary drilling proposal that integrates geology, geochemistry, microbiology and palaeoclimatology? The answer was yes, without ambiguity or caveats. After the comprehensive Guaymas Basin surveys and discussions on Day 1 had demonstrated the multidisciplinary scientific potential of deep drilling in Guaymas Basin, the workshop participants were comfortable with a multidisciplinary scientific perspective and a complex, multilayered proposal as its logical consequence.

The subsequent discussion in the late morning (now in the Boone House meeting room) addressed the types of subsurface sediments, sills, and geological/geochemical regimes that were most desirable. The underlying idea was not to discuss specific drilling sites first, but to start with definitions of scientific targets and first-order objectives which are in a second step linked with promising drilling locations. Four targets were colloquially labeled “sills”, “hot vs cold seepage”, “Paleo” and “Hot Center” (**Figure 5**). “Sills” refers to sites that illustrate the stratigraphic and geochemical disturbances of volcanic sill insertion into the thick sediment blanket that covers the Guaymas Basin ridge flanks to the NW and SE. “Hot vs cold seepage” targets a comparison of sill-driven off-axis hydrothermal seepage at Guaymas Basin and compaction-driven cold seepage on the nearby Sonoran Margin. “Paleo” means sites with a continuous, finely resolved, mixed marine/terrestrial sedimentation record, unperturbed by sill formation or hydrothermal impact. “Hot Center” means a drilling project that targets the hydrothermally dominated processes surrounding freshly emplaced sills near the Guaymas Basin spreading center. Once we agreed on these primary scientific targets, preliminary drill locations were picked from the existing transects across Guaymas Basin and the Sonoran Margin (numbered 1 to 7 in the handwritten notes in **Figure 5**). Dan Lizarralde and Adam Soule provided the multichannel seismic line data and had the information for various site options (in part from the Guaymas preproposal) ready. A more detailed discussion of drilling effort and methodologies was

scheduled for Day 3. This strategy of organizing and justifying drilling sites found its way into the submitted drilling proposal.

~~Wednesday~~ morning
Thursday morning

Sill [7) Sill SE of Guaymas B
 (1) Sill story I undisturbed sed
 (2) Sill story II sill disturbed sed nearby

hot vs cold seepage [3) Shallow sill + gas + surface manifest. (on PESC line 2
 (4) Sonora margin cold seepage PESC line 21 (on the dip high)

Pallo [5) NW of Guaymas Basin (on PESC line 21 deep sediment basin) / massive / multiple holes
 480 redrill or drilling on top diapirs 500 m (4-5 holes! for fine-scale overlapping)

Hot water [6) Spreading center site (same as No 6 in preproposal)
 Redrilling 477 Southern Trough making

Ⓢ Type site list - we have a good idea of science targets and we have enough reasonably well doc. sites to address the targets - we are open to modifications (shift site a few miles if site survey data support that) but it does not change scientific change & objectives

Figure 5. A. Teske’s notes from Thursday morning that capture the emergence of the “type site” or “target type” concept as a criterion for prioritizing and selecting drilling sites. Note that the scribe has difficulties telling which weekday it is.



After lunch and a short break (Figure 6, previous page), the afternoon discussions returned with force to the “Microbial gauntlet” concept which had started the previous day as a short hand for microbial attenuation of CH₄ fluxes, i.e. the notion that many subsurface microbes counteract the hydrothermal mobilization of buried organic carbon (in the form of methane) by assimilation and/or oxidation of methane carbon. The “CH₄ Gauntlet” of Guaymas Basin (Figure 7) quickly evolved into a discussion of the analogous “NH₄ gauntlet” and the “H₂ gauntlet” (Figure 8), understood as subsurface microbial pathways and processes of NH₄ and H₂ utilization. These are strongly suggested by the high concentrations of ammonia and hydrogen in Guaymas Basin porewater although they remain essentially unexplored. We recognized the need to target every class of microbial metabolic types in the context of how these microbes scavenged or produced their key substrate.

Thu. ~~Wed.~~ afternoon

Methane gauntlet - how does CH₄ get stuck, is processed, or escapes? The concept applies to all sites; a seepage site is nice for completeness, but not the primary focus

win win - high CH₄ flux & processing to geological environment

Concept; conceptual figures } isolating deep sediment vs. by diathermal escape - vs seepage escape - vs preservation & capture in subsurface

Make CH₄ gauntlet a theme & concept that permeates the proposal without turning into a single-item - agenda multidisciplinary interest!

create datasets ⇒ submodelling for diff. processes
there are even modelling papers for DIC/CH₄/Sill
modify to alternate C

from core & profile to model to global change =
How do the different filters work of the gauntlet work, & where does it begin?
What happens empirically to CH₄ & DIC as it comes

Figure 7. Notes of Methane gauntlet discussions. Note that the scribe is still warming up to the idea that it is Thursday, not Wednesday afternoon.

The notes provide the most immediate account of the discussions and show how ideas and suggestions from many sides were often exchanged much faster than the pen could record them. During this afternoon, the microbiologists, chemists, and chemistry-leaning geologists were particularly engaged (Lizarralde, Wankel, Seewald, Røy, Rowe). This expanded geochemical/microbial focus (beyond carbon) ultimately found its way into the drilling proposal.

After dinner, further discussions were kept informal; due to general exhaustion there were no more impromptu slide presentations and expedition

reports. However, a group of hydrocarbon aficionados and oenophiles planned to tackle hydrocarbon generation and microbial utilization in the next morning.

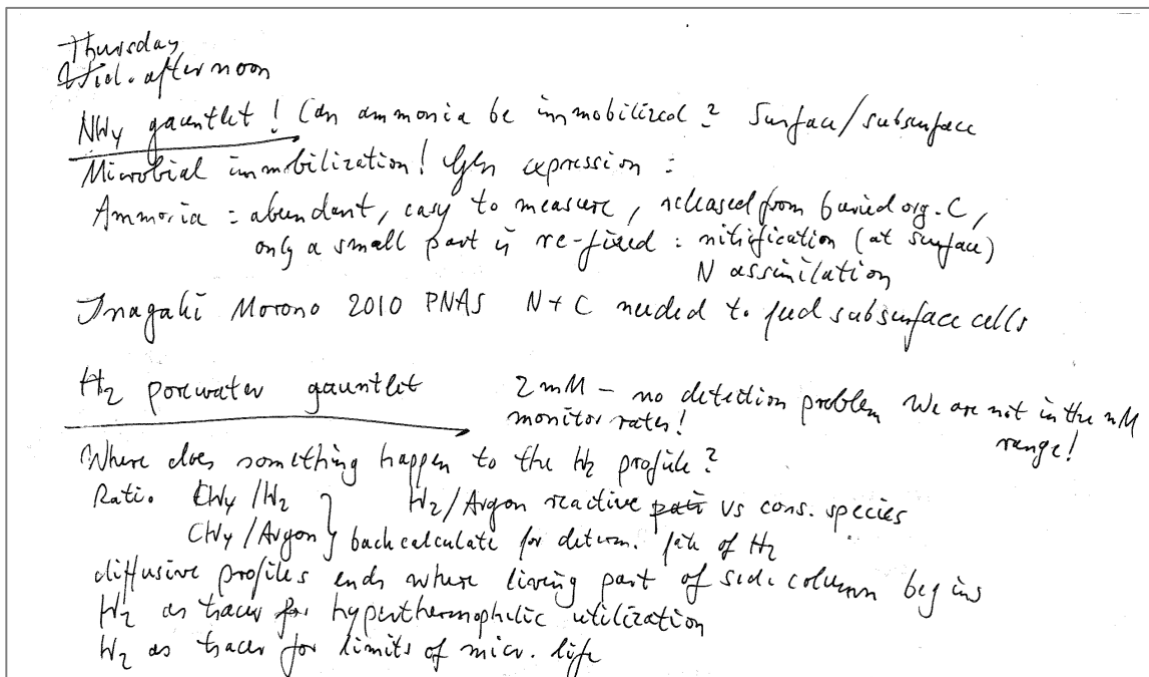


Figure 8. Notes on Ammonia and Hydrogen gauntlet discussions. The scribe continues to be challenged by the notion that it is in fact Thursday.

Day 3 / March 1. The morning discussions (now entirely in Boone House) emphasized hydrocarbon generation and degradation in the Guaymas subsurface, with an emphasis on process zonation: deep hydrothermal (abiogenic) hydrocarbon generation contrasting with more shallow microbial degradation and assimilation of hydrocarbons. Jeff Seewald reminded the disputants (edged on by Amy Callaghan and Andreas Teske, who tended to indulge in details of anaerobic hydrocarbon degradation pathways and metabolite formation, and again invented various gauntlets) that many basic research questions in abiotic hydrocarbon generation pathways in Guaymas Basin were unexplored and required systematic accounting and experimentation using fresh deep subsurface cores.

Later in the morning we focused on gaps in traditional geological disciplines that we had not addressed much at this workshop: petrology, micropalaeontology, paleomagnetism, absolute dates for rocks and sediments. These research fields are important and always included in IODP legs; at least four shipboard scientists on IODP cruises work on physical properties.

The afternoon was devoted to calculating time estimates for IODP drilling at our candidate sites using different drilling strategies. Workshop proponent Ivano Aiello, with extensive IODP cruise expertise, conducted the operation by taking up drilling site suggestions and requests from the audience, converting them into drilling time estimates using the IODP online calculator (projected simultaneously on the Boone Hall screen), and gradually filling out the cruise spreadsheet with

detailed time budgets. Drilling plans that were too time-demanding, optimistic or ambitious were weeded out or pruned until they were acceptable and did not blow up the overall time budget of the planned cruise (55 to 58 days). This interactive procedure yielded the drilling plan that, with minor modifications, was used for the IODP proposal. The last hour before dinner was used to compile a preliminary list of research ideas and suggestions by the remaining conference participants (several participants had trickled out during late Thursday and Friday to meet weekend obligations), and to start designing figures for the proposal.

Informal feedback about the workshop and the venue during the return boat trip on the morning of March 2 (**Figure 9**) was highly positive; some workshop participants entertained thoughts of hiring themselves out for any job at Wrigley Marine Science Center.



Figure 9. The last workshop participants are leaving Catalina Island on the charter ferry. Kudos to all workshop organizers at C-DEBI and Wrigley Station for smooth logistics and a very pleasant and productive stay!

After the workshop. The principal proponents - Andreas Teske, Ivano Aiello, Adam Soule, Dan Lizarralde, Jeff Seewald, Arturo Martin and Carlos Mortera - wrote the proposal during the month of March, with frequent feedback from other proponents. On April 2, the full Guaymas Basin and Sonora Margin proposal (“Guaymas Basin and Sonora Margin: Feedbacks between continental rifting, magmatism, sedimentation, climate history, thermal alteration of organic matter, and microbial activity”) with all-in-all 26 proponents, including workshop attendants, external

collaborators, and site survey cruise proponents, was finished and submitted, after a dramatic showdown with the IODP submission website and a two-day deadline extension to account for website breakdowns. The proposal has IODP number 833-Full.

Printed Workshop Program

Tuesday Arrival day
2/26/13

Afternoon	Arrive at hotel
6:30 PM	Dinner and Icebreaker

Wednesday Guaymas Basin as a model system for the biogeography and extent of life and the Theme Team workshop on Microbial Biogeography
2/27/13

6:45 AM	Shuttle to SCMI
7:30 AM	Boat to WMSC
9:00 AM	Arrival at WMSC
9:15 AM	Housing orientation & check-in
10:00 AM	Welcome by the workshop organizers, introduction of participants, and outline of what to expect
10:30 AM	Introduction to Guaymas Basin I: the unusual geology, biogeochemistry and microbiology of Guaymas Basin
12:00 PM	Lunch
1:00 PM	Introduction to Guaymas Basin II: Geochemical and tectonic controls on microbial zonation and biogeography
2:30 PM	Coffee break
3:00 PM	Guaymas Basin as a geological, biogeochemical and microbial model system – what can we learn from it for biogeography?
4:00 PM	Guaymas Basin: emerging knowledge gaps, research problems, research & publication ideas
5:00 PM	Break
6:00 PM	Dinner and informal discussion

Thursday Strategic planning for full Guaymas Basin drilling proposal
2/28/13

7:30 AM	Breakfast
9:00 AM	The Guaymas Basin pre-proposal (IODP Pre-749): Scientific rationale, drilling plan, panel evaluations
10:30 AM	Coffee Break
11:00 AM	Improving on the pre-proposal: What to avoid, what to do better; new scientific ideas?
12:30 PM	Lunch
2:00 PM	The Guaymas Basin Site survey: Existing data and planned cruises
3:30 PM	Coffee Break
4:00 PM	Rationales for Guaymas Basin and Sonora Margin drilling locations
5:30 PM	Break
6:30 PM	Dinner and continued informal discussions

Friday Specific challenges and organization of full drilling proposal / take home tasks
3/1/13

7:30 AM	Breakfast
9:00 AM	Key challenges in Guaymas drilling: Heat and hydrocarbons; should we consider riser drilling?
10:30 AM	Coffee Break
11:00 AM	Estimating the time needed for drilling (APC, XCB, other)
12:30 PM	Lunch
2:00 PM	Balancing scientific interests, drilling volume, No. of holes: An initial approximation
3:30 PM	Coffee Break
4:00 PM	Volunteers for full proposal writing; defining homework tasks
5:30 PM	Break
6:30 PM	Dinner and conclusion of workshop

Saturday Departure day
3/2/13

7:30 AM	Breakfast
9:30 AM	Boat to WMSC
11:00 AM	Arrive as SCMI
11:15 AM	Shuttles to LAX