An IODP Workshop REPORT
August 20, 2014

With funding provided by the United States Science Support Program (USSSP) and Brazil PAEP program of the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), and Université Pierre et Marie Currie, an IODP workshop was held in March, 2014, in Buzios, Brazil. The workshop facilitated the development of two proposals for scientific drilling on the Amazon continental margin: a pre-proposal (submitted in April, 2014 and approved by IODP in June, 2014) for deep drilling on the Amazon margin that focuses on the evolution of Cenozoic climate and biodiversity and a second pre-proposal (in preparation) that focuses on the causes and significance to margin evolution of Amazon margin sediment failures. This workshop report outlines the major scientific objectives, activities, and results of the workshop.

2. Workshop Steering Committee

Paul A. Baker, Duke University
Cristiano Chiessi,Universidade de São Paulo
Laura L. Lapham, University of Maryland
Antonio Tadeu Dos Reis, Univ. do Estado do RJ
Catherine Rigsby, East Carolina University
Enno Schefuss, Universität Bremen
Cleverson Silva, Univ. Federal Fluminense
Geoffrey Wheat, Univ. of Alaska Fairbanks

3. Scientific Motivation and Goals of the Workshop

The origin of the great biodiversity observed in tropical South America has spurred debate for well over a hundred years (Darwin 1859, Agassiz and Agassiz 1868, Wallace 1878) and it remains one of the foundational problems in modern science. Here we propose a workshop for IODP drilling that will continuously sample sediment from late-Cenozoic to modern age in the "Foz do Amazonas" basin (that includes the Amazon Fan) on the equatorial Atlantic continental margin of Brazil. It is only here where high resolution, marine biostratigraphy can date continuous sedimentary sequences and put into accurate chronologic context the important environmental milestones on the adjacent continent. One of the primary goals of this drilling is to recover and study the geological record of changing surface environments and the contemporaneous floral record of the Amazon rainforest during the Cenozoic, when

the neotropical rain forest became established and flourished. By clarifying the geological history of the Amazon, we will also clarify the biogeographic framework of its diversity.

But, the proposed drilling of the Amazon continental margin will also address several other issues that are of great scientific and practical interest in their own right. For on this margin, high burial rates of organic matter in extremely rapidly accumulating sediments create an ideal environment for methane generation. The rapid sediment loading and overpressuring – combined with gravitational instability, hydrate formation/dissociation, and neotectonic activity – create ideal conditions for submarine slope failure on very large spatial scales. Dramatic slump scars, convolute bedding, listric and normal faulting, and large-scale sedimentary disruption are nearly ubiquitous in the seismic record of the region. They occur alike in shallow and deep sequences recording respectively short and long time-scale gravity tectonism. Structures piercing the modern sediment-water interface indicate that faulting and slumping is ongoing. This slope instability creates hazardous conditions for structures located on the sea floor, tsunami dangers across the Atlantic basin, and the potential for large releases of methane gas to the ocean and atmosphere.

Despite its singular significance, to date there has been limited scientific drilling on the Amazon margin. On the Ceara Rise far offshore of the mouth of the Amazon, drilling on ODP Leg 154 recovered long sequences of sediment with minor Amazonian provenance (Harris and Mix 2002; Dobson et al. 2001). ODP Leg 155 was primarily focused on the stratigraphic architecture of the most recently active channel-levee system of the distal Amazon Fan. The longest core recovered on that expedition was only 434 meters and reached an age of middle Pleistocene (Mikkelsen et al. 1997); these cores were unsuited to addressing questions about the origins of the River, the Fan, and the forest. Much longer stratigraphic records have been recovered in industry exploration wells on the Amazon slope and shelf (e.g., Figueiredo et al. 2009) – these were well dated using marine microfossils. However, this core material is inaccessible and was not studied for paleoclimate or paleodiversity. The objectives of the proposed study can only be accomplished by collecting fresh, long, continuous drill cores from the Amazon continental margin.

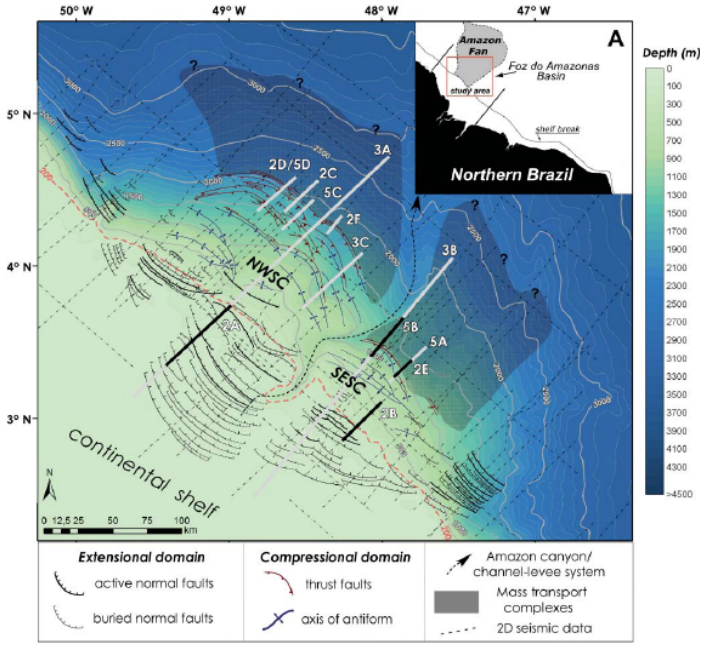

Figure 1. Location of the Foz do Amazonas basin with its upslope extensional faults and downslope compressive faults (Reis et al., 2011).

4. Research Themes and Questions

Three major research themes were addressed during the workshop: (1) Cenozoic tectonic, climatic, and biotic evolution of the terrestrial Amazon and origins of the transcontinental Amazon River and of the

Amazon Fan; (2) Amazon margin gravity tectonics on long and short time-scales; and (3) microbial activity, gas hydrates, fluid flow, and diagenesis. The specific objectives of our drilling proposal and subsequent drilling will be direct outgrowths of these themes that directly relate to three of the four themes of the new IODP Science Plan 2013-2020 (climate, deep biosphere, and geo-hazards).

5. Workshop Program

Monday, March 24, 2014

9:00: Introduction to the Workshop: Cleverson Silva and Paul Baker
Welcome; Introduction of the participants; Announcements; Background about the whole big picture; Fate of IODP pre-proposal; Plan for the workshop; Future deadlines; Expectations for the workshop and beyond

Part 1. Tectonic, climatic, sedimentary, and biotic history of the Amazon continent

10:00 - 10:30: The stratigraphic margin evolution, including the major events influencing the margin, such as: the Amazon Fan onset, sediment provenance, Amazon River drainage. *Jorge Picanço de Figueiredo, OGpar*
10:30 - 11:00: Record of Neogene climate change. *Paul Baker - Duke University*
11:30 - 12:00: Biotic evolution of the Amazon Forest. *Sherilyn Fritz - Univ. of Nebraska*
12:00 - 12:30: Amazon Biogeography. *Camila Ribas, INPA*
14:00 - 14:30: The Cenozoic paleoceanography of the equatorial Atlantic. *Luigi Jovane, USP*

Part 2. Sediment accumulation, deformation, megaslides, gas hydrates, fluid flow of the Amazon Fan

14:30 - 15:00: The Foz do Amazonas Basin Tectonics in the context of the Brazilian Equatorial Margin. *Juliano Stica, Petrobras*
15:00 - 15:30: The Late Quaternary Amazon fan. *Roger Flood, Stony Brook Univ.*
15:30 - 16:00: Stratigraphic architecture of the older portions of the Amazon Fan, including gravity tectonics framework. *Tadeu Reis, Rio de Janeiro State Univ. (UERJ)*
16:30 - 17:00: Megaslides on the Amazon margin. *Cleverson Silva, Fluminense Federal University (UFF)*
17:00 - 17:30: Gas hydrates, fluid flow, geochemistry, microbiology. *Marcelo Ketzer, PUC-RS*
17:30 - 19:00: Plenary discussion section

Tuesday, March 25, 2014

9:00 AM: IODP operations. *Kara Bogus, IODP, Texas A&M*
9:30 - 12:30: Break-out groups to elaborate upon key scientific questions, research approaches, etc.
14:00 - 14:30: Database: What kind of data are available and what is needed for the proposals? *Cleverson Silva, Fluminense Federal University (UFF)*
14:30 - 16:00: Plenary Discussion with Break-out group presentations
16:30 - 18:30: Plenary Discussion with Break-out group presentations

Wednesday, March 26, 2014

9:00 - 11:00: Discussion about technical strategies and methodologies to be put forward

11:00 - 12:30: Split participants into groups to write down main conclusions, ideas and to establish a calendar (both for proposals elaboration and submission).

6. Workshop Participants

1. Paul A. Baker, **workshop co-convenor**, Professor, Duke University
2. Catherine A. Rigsby, **workshop co-convenor**, Professor, East Carolina University
3. Stephen J. Burns, University of Massachusetts
4. Beth A. Christensen, Adelphi University
5. Roger D. Flood, University of Stony Brook
6. Sherilyn C. Fritz, University of Nebraska
7. Clifford W. Heil, University of Rhode Island
8. Kelly H. Kilbourne, University of Maryland Center for Environmental Science
9. Kathleen M. Marsaglia, California State University Northridge
10. Debra A. Willard, Climate Research & Development Program, USGS
11. Kara Bogus, IODP liaison, Texas A&M University
12. Christian Gorini, Universté Pierre et Marie Curie - Paris VI, France
13. Sebastien Migeon, Universté Pierre et Marie Curie, Observatoire Océanologique de Villefranche-sur-Mer (OOV-UPMC), France
14. Daniel Praeg, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - OGS, Italy
15. Cleverson Guizan Silva, **workshop co-convenor,** Universidade Federal Fluminense,
16. Antonio Tadeu dos Reis, **workshop co-convenor**, Universidade do Estado do Rio de Janeiro,
17. Márcio Gurgel, Universidade de São Paulo, USP
18. Luigi Jovane, University of São Paulo
19. João Marcelo Ketzer, Professor, Pontifícia Universidade Católica do Rio Grande do Sul, PUC-RS
20. Camila Ribas, INPA
21. Jorge Picanço de Figueiredo, OGPar
22. Juliano Stica, Petrobras
23. Emilson Soares, Petrobras
24. Cristian Nolan, Petrobras
25. Rodrigo Jorge Perovano, UFF/MAG
26. Alberto Machado Cruz, UFF/UPMC – Doutorando
27. Allan Sandes, UFF – Doutorando
28. Wout Salenbien, Duke Univesrsity – Doutorando

7. Workshop Funding

The workshop was jointly funded by the United States Science Support Program (USSSP), CAPES—Edital PAEP, and UPMC.

8. Workshop Outcomes

The workshop participants determined that the research goals and objectives were best addressed by preparing and submitting two separate IODP proposals (each proposal is described briefly below):

- *Proposal 1 – Deep drilling of the Amazon continental margin: The evolution of Cenozoic climate and biodiversity (**pre-proposal submitted and approved**).*

- *Proposal 2 – Sediment Failures on the Amazon Margin: causes and significance on the margin evolution (**in preparation**).*

Deep drilling of the Amazon continental margin: The evolution of Cenozoic climate and biodiversity (**pre-proposal submitted and approved**)

This pre-proposal focuses on the workshop's first theme: Cenozoic tectonic, climatic, and biotic evolution of the Amazon region and origins of the transcontinental Amazon River and of the Amazon Fan. This theme addressed questions that are critical to documenting the history of biodiversity of the rain forest and the changes in surface environment that contributed to its species origins and extinctions; including Andean surface uplift, subsidence and sedimentation of the Andean foreland, the formation of a transcontinental Amazon and Amazon Fan, and Cenozoic terrestrial paleoclimate.

Despite decades of research, many outstanding questions remain about the initiation and evolution of tropical floras and the patterns of tropical biodiversity through time. Research has been hampered by the nearly complete lack of continuous sedimentary records. IODP drilling will be the first to sample the entire late Cenozoic sequence accurately dated by marine biostratigraphy with the main purpose of recovering a record of the evolution of rain forest biota, climate, and paleo-environment.

As detailed in our recently approved pre-proposal (Attachment 1), scientific drilling related to this theme will address the Cenozoic climatic and biotic evolution of the Amazon rain forest, the origins of the transcontinental Amazon River, and the paleoceanographic history of the western equatorial Atlantic; and will answer questions about the record of Cenozoic climate of the Amazon, the role of ocean forcing in Cenozoic climate change, and the relationship between evolution of rain forest taxa and long-term environmental forcing (including Atlantic opening, Andean uplift, and Amazon drainage)?

Proponents:

- Paul A. Baker, Duke University, USA*, geochemistry, paleoclimate*
- Cleverson G. Silva, Univ. Federal Fluminense, Brazil*, marine geology*
- Catherine A. Rigsby, East Carolina University, USA, *sedimentology*
- Tadeu Dos Reis, Univ. do Estado RJ, Brazil, *seismic stratigraphy*
- Sherilyn C. Fritz, Univ. of Nebraska, USA, *phytoliths/diatoms, paleoecology*
- Cristiano Chiessi, Universidade de São Paulo, Brazil, *paleoceanography*
- David Hodell, University of Cambridge, UK, *paleoceanography*
- Enno Schefuss, Universität Bremen, Germany, *organic geochemistry*
- Debra A. Willard, US Geological Survey, USA, *palynology*
- Stephen J. Burns, University of Massachusetts, USA, *geochemistry*

Sediment Failures on the Amazon Margin: causes and significance on the margin evolution (**in preparation** for October 2014 submission deadline).

This pre-proposal will focus on workshop's second and third themes: Amazon margin gravity tectonics on long and short time-scales and on the microbial activity, gas hydrates, fluid flow, and diagenesis related to this gravity tectonics.

Spectacular examples of gravity tectonic deformation and huge submarine landslides at once shaped this portion of the Brazilian margin and created hazards on the sea floor and tsunami dangers across the

Atlantic basin. Gravity-driven deep-water fold-and-thrust belts stand as the most remarkable structures along the margin (Figure 1), deforming both the Neogene Amazon Fan and earlier (Lower Cretaceous-Middle Miocene) marine sequences. Thrust structures, imaged by 2D multichannel seismic profiles, make up a linked extensional-contractional system gliding on weak levels and driven gravitationally by sedimentary loading and steep bathymetry of the slope. Three main structural domains (figure 2) exist between the continental shelf and the continental slope: an upslope extensional domain extending to 500 m water depth, an intermediate translational domain, and a downslope compressional domain located between ca. 900 and 2100 m water depth. This extensional–compressional system deforms the entire marine stratigraphic sequence of the Foz do Amazonas basin, across an area as wide as 190 km by about 300 km along strike, over a total area of ca. 40000 km^2. Extension is characterized by both basinward- and landward-dipping normal faults on the shelf and upper slope. Downdip, compression-induced detachment folds and thrust faults lead to the formation of piggy-back basins. Sliding of the sedimentary section took place along distinct detachment surfaces and at different stages of the margin's evolution (Perovano et al., 2009; Reis et al., 2010). At least three main stratigraphic levels have acted as detachment surfaces (figure 2). The most conspicuous gravitational fold-and-thrust belts along the upper Amazon Fan are active compressional structures detaching on the "Intermediate" décollement surface. Distribution of structural complexity seems to be related to depocenter evolution. Depocenters are more complex in the north part of the basin (where the major depocenters are located), exhibiting evidence of long-lasting deformation from multiple partially-overlapping fronts that resulted in further shortening and modern scarps up to 500 m high. To the south, the system is restricted to pairs of active reverse faults causing no major sea-bottom relief.

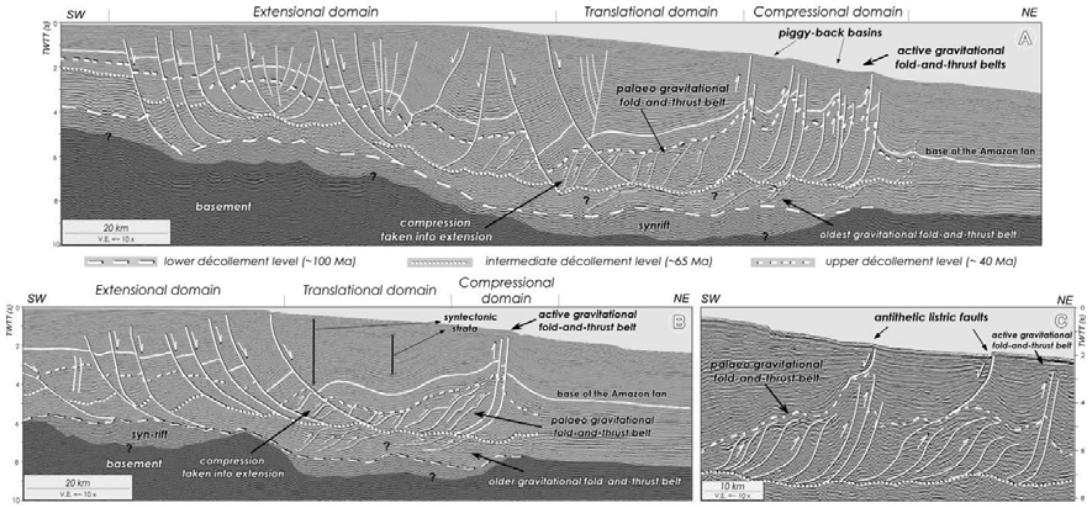

Figure 2. Interpreted dip seismic lines of the linked extensional–compressional system gliding over basal décollements illustrating variable structural complexities across (a) the NW and (b) the SE Structural Compartments of the Foz do Amazonas basin. (c) A portion of a seismic line showing antithetic normal growth faults that detach over an upper décollement level of local extent. (Reis et al., 2010)

Much shorter timescale gravity tectonism in the form of widespread submarine landslides is also present on the Foz do Amazonas margin. Some of these slides may have themselves been triggered by the longer timescale gravity tectonic deformation (Araújo et al., 2009; Silva et al. 2010). While some large late Quaternary-age slides on the Amazon Fan have previously drawn attention (e.g. Damuth and Embley 1981; Piper et al. 1997; Maslin et al. 2005), slides many times larger have recently been mapped in regions to the immediate southeast (Para-Maranhao (PM) megaslide complex) and northwest of the Amazon Fan (Amapa megaslide (AM) complex) (Araújo et al., 2009; Silva et al. 2010). The estimated

volume of the PM megaslide was 60,000 km^3 while individual slides within the AM complex were perhaps 20,000 km^3. By comparison, the main Storegga slide, often cited as one of the largest known from the late Quaternary record, had a much smaller volume of 3,000 km^3 (Ha idason et al. 2005) yet was associated with tsunami deposits with runup as great as 20 meters around the North Sea. The tsunamogenic potential of the AM/PM megaslides must have been considerably larger. Silva and co-workers (2010) mapped the basal detachment surface of both megaslides and suggested that the detachment surface was an impermeable unit that allowed the buildup of fluid overpressure and promoted gravitational collapse. Although they speculated on the age of the megaslides, these have not been drilled and directly dated.

This research theme generated the following research questions which we hope to be able to answer with scientific drilling:

- The dramatic differences of structural complexity between north and south compartments suggests a key question to the overall understanding of the sedimentary and tectonic evolution of the margin: What is the nature and provenance of the sediments that preceded the Amazon Fan?
- High sedimentation rates and the presence of impermeable layers are necessary for creation of fluid overpressure and these conditions appear to have occurred on the Amazon margin prior to Amazon Fan deposition. The occurrence of multiple detachment levels also indicates that these conditions were attained repeatedly through time, reactivating structures after the onset of the Amazon Fan sedimentation (Reis et al., 2010; Perovano et al., 2009). What is the lithological nature and age of the multiple décollement levels?
- Which mechanisms generated overpressure conditions at these levels: hydrocarbon generation, compaction and fluid expulsion, clay mineral transformation and dehydration?
- Which are the ages of the superimposed mass transport deposits on the Para-Maranhão and Amapá Megaslides Complexes? Can we associate the ages of megaslide deposits with deformation on the compressional front? Were these megaslide events related to global sea-level changes? Are these events triggered by gas hydrates dissociation or do they trigger gas hydrates dissociation? Did these events cause basin-wide tsunamis?

Questions about microbial activity, gas hydrates, fluid flow, and diagenesis related to this gravity tectonics address both scientific and practical interest. Rapid burial of fine-grained, organic-rich sediment creates an ideal environment for microbial activity, methane hydrate formation and dissociation, hydrocarbon maturation, overpressuring and fluid flow, and sediment diagenesis. Combined with slope instability the potential exists for large releases of methane gas to the ocean and atmosphere, representing a potential climate change hazard.

Drilling on ODP Exp 155 highlighted the significance of: (1) diagenetic reactions linked to terrestrial and marine organic matter (Burns, 1997, 1998; Ruttenberg and Goni, 1997), (2) lignin concentrations and isotopic composition of organic carbon confirming marine and terrestrial contributions (Goni, 1997), (3) the presence of aldose at depth (Keil et al., 1997) that provides usable fuel for a deep-seated microbial community (Cragg et al., 1997), and (4) the accumulation of methane gas with potential for gas hydrate formation (Arning et al, 2013). But Leg 155 drilling targeted only the shallow levels of the distal fan and understanding stratigraphic architecture of the distal fan was the prime motivation. Thus, greater burial depths including the most interesting sites targeting BSRs, fault zones and decollements, cold seeps, zones of likely fluid flow and diagenesis, and deep microbial habitats were not drilled. A new set of goals, coupled with 15 years of advances in analytical techniques and basic scientific knowledge, put us on a path to address the following research questions with targeted scientific drilling on the Amazon margin:

- What lithological and diagenetic changes occur at the thrust belts? What are the pressure conditions at the compressional fronts? How does faulting affect fluid flow, fluid chemistry, diagenesis, heat flow, and distribution of gas hydrates?
- How does microbial community structure and activity change with depth in response to different chemical, thermal, organic and mineralogical conditions? In the past two decades, large advances have been made in studying the deep-seated microbial community, including results from gene expression, enzyme production and single cell genomics. With these advances in molecular techniques, that are now routinely part of IODP, we can investigate the spatial distribution of Bacteria and Archaea within Amazon Fan sediments and the links between microbial activity and changes in sediment properties.
- Do individual faults actively transport fluids and gas to the seafloor or to subsurface hydrate deposits? If transport along fault zones is sporadic, this can be constrained through systematic variations in pore water chemical profiles across such faults.
- The widespread distribution of BSRs and known presence of methanogenic cements and chemosynthetic communities (Petrobras 2002) suggest many questions such as: what is the predicted hydrate stability zone across the Amazon Fan? Where do hydrates currently exist? How do sedimentological factors control their formation? How does fluid flow along fault zones affect their formation? What is the relative importance of biogenic versus thermogenic sources of gas? New drilling could also provide evidence for large, past hydrate dissociation events in Fan sediments.

As will be further elucidated in our pre-proposal on these themes, drilling of the key gravity-driven deep-water fold-and-thrust belts on the Amazon margin will allow us to determine the global relevance of mass transport deposits on the Amazon margin and the relationship of these deposits to the gravitational tectonics of the Amazon Submarine Fan, sea level changes and dissociation of gas hydrates; to characterize the rates of frontal compressive deformation, displacement of thrust faults, sedimentation in basins piggy-back, and related BATs; to characterize the origin and the migration of fluids: gas hydrates, microbial life, over-pressure; to determine the interaction between sediment deformation and fluids in larger submarine fan; and to understand the importance of large submarine fans in carbon storage and carbon flux.

Proponents:

- Cleverson Guizan Silva – UFF
- Antonio Tadeu dos Reis – UERJ
- Marcelo Ketzer – PUC-RS
- Luigi Jovane - IOUSP
- Márcio Gurgel – USP
- Rodrigo Jorge Perovano – UFF/MAG
- Alberto Machado da Cruz – UFF/UPMC
- Christian Gorini – UPMC - França
- Sébastien Migeon - UPMC, OOV - França
- Daniel Praeg – OGS – Italia
- Roger Flood – Univ. Stony Brooks, EUA
- Paul Baker – Duke University, EUA

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IODP Proposal Cover Sheet

Amazon margin drilling

2 - Pre a

Title	Deep drilling of the Amazon continental margin: The evolution of Cenozoic climate and biodiversity		
Proponents	P. Baker, C. Silva, C. Rigsby, T. Reis, S. Fritz, C. Chiessi, E. Schefuss, D. Hodell, D. Willard, S. Burns,		
Keywords	Amazon, paleoclimate, biodiversity, tropical, paleoceanography	Area	Amazon continental margin

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Abstract

The major objectives of the proposed drilling project are to determine the evolution of climate, hydrology, and biodiversity of the Amazon basin and to determine the sea-surface temperature history of the equatorial Atlantic that forces the climate on the adjacent continent. We propose to recover sediments from a single deep IODP drill hole located north of the Amazon Fan on the upper continental slope of the Atlantic equatorial margin of South America (primary site location at 4.93N, 50.27W, 400 m water depth, 1600 m total hole depth). Here, we have identified a nearly continuous, high accumulation rate sequence that spans the latest Cretaceous to present without major unconformities. This site will be part of an IODP-ICDP drilling transect across the Amazon basin~~the~~ plan is to also drill complete Cenozoic sequences on land in four sedimentary basins (Acre, Solimoes, Amazonas, and Marajo). The offshore site has three major advantages over continental sites~~ne~~early continuous sediment accumulation, marine biostratigraphy, and paleoceanographic archives. Continental sites will record regional variation (of climate and biodiversity) across the entire basin. Provenance studies along the transect will establish timing of west-to-east hydrological connectivity (the age of the trans-continental Amazon) and perhaps the timing of Andean uplift. Key measurements that must be done on core materials to achieve these objectives include biostratigraphy, pollen and phytolith analysis, geochemical analysis of marine and terrestrial organic biomarkers, isotopic and minor element analysis of marine carbonates, environmental magnetic studies, and a suite of geochemical and mineralogical provenance analyses.

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2 - Pre a

Scientific Objectives

1. Use paleofloral data from terrestrial sediments in our well-dated marine sediment core to reconstruct the history of plant diversity of the Amazon basin region throughout the entire Cenozoic. Test the hypothesis that plant diversity parallels global temperature.
2. Use organic geochemistry to reconstruct terrestrial climate throughout the Cenozoic. Test the hypothesis (from Soden and Held) that wet regions became yet wetter during past thermal optima.
3. Use organic geochemistry and shell isotopic and chemical composition to reconstruct paleoceanographic conditions (primarily SST and BWT) in the western equatorial Atlantic throughout the Cenozoic. Test the influence of SST forcing on the climate of the adjacent Amazon basin, specifically the hypothesis that lower N-S equatorial SST gradients in the Atlantic bring about wet conditions in the Amazon.
4. Use provenance measures to determine the timing of trans-Amazon hydrologic connectivity. Test the many alternative hypotheses concerning the origins of the trans-Amazon drainage.
5. Characterize the Cretaceous/Tertiary boundary changes in the tropics. Was there complete floral turnover at the boundary?

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

None

Proposed Sites

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
AM-2A	5.37246561795, -50.6569510857	520	1940	0	1940	Alternate stratigraphic reference core. This 1940m sedimentary sequence spans the Cenozoic and crosses the K/T boundary. It will provide a record of the Cenozoic climatic and biotic evolution of the Amazon rain forest, the origins of the transcontinental Amazon River and Amazon Fan, and the paleoceanographic history of the western equatorial Atlantic. It will also serve as a reference hole for the planned gravity tectonics and gas hydrates drilling leg on the Amazon Fan, and provide marine biostratigraphic control for correlation with terrestrial drill sites.
AM-1A	4.93200804577, -50.2727365183	400	1600	0	1600	Primary stratigraphic reference core. The 1600m sedimentary sequence spans the Cenozoic and crosses the K/T boundary. It will provide a record of the Cenozoic climatic and biotic

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-	-	-	-	-	-	evolution of the Amazon rain forest, the origins of the transcontinental Amazon River and Amazon Fan, and the paleoceanographic history of the western equatorial Atlantic. It will also serve as a reference hole for the planned gravity tectonics and gas hydrates drilling leg on the Amazon Fan, and provide marine biostratigraphic control for correlation with terrestrial drill sites.

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