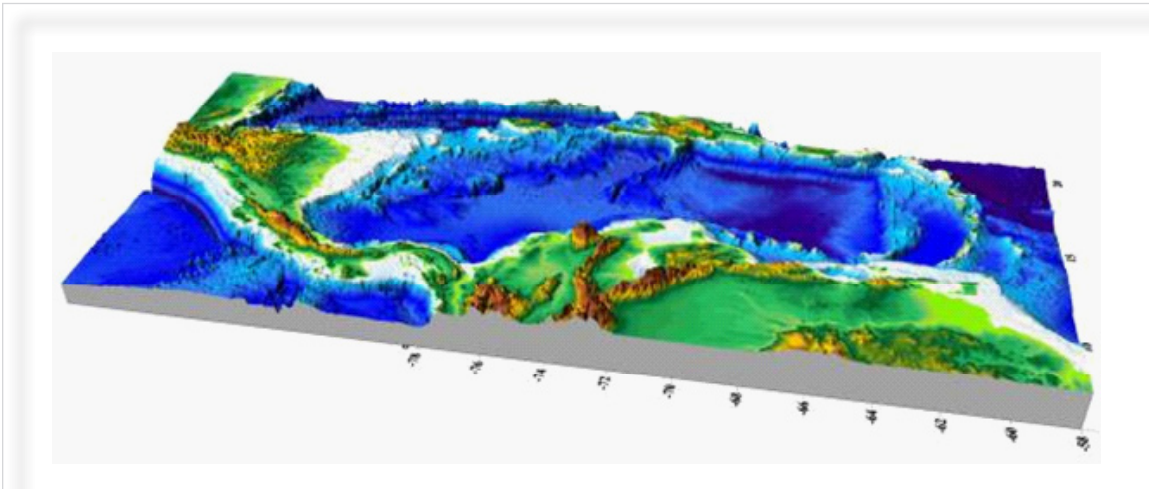


CARIBBEAN BASINS, TECTONICS AND HYDROCARBONS PHASE III

Appendix A



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Scope of Work for CBTH-Phase III

The goal of the proposed, three-year, Caribbean Basins, Tectonics, and Hydrocarbons – Phase III (CBTH) project (September, 2011 – August, 2014, at the University of Houston) is to continue and expand upon the research activities and focus of the Caribbean Basins, Tectonics, and Hydrocarbons (CBTH) project, Phases I and II (September, 2005 – August, 2011) that were begun when the Principal Investigator, Paul Mann, was employed at the University of Texas at Austin. The main goal of CBTH-PHASE III will be to continue to provide our industry sponsors with a fully integrated, web-based, digital surface and subsurface synthesis of a hydrocarbon-rich, study area that includes on- and offshore areas of the circum-Caribbean, the Gulf of Mexico region, the Caribbean region, the equatorial Atlantic area of Suriname, French Guyana, northern Brazil, and the Andean foreland basins (*Figure 1*). We will work on key hydrocarbon-rich or frontier areas within this region that include: on- and offshore Colombia, Venezuela, Trinidad and Tobago, the Leeward Antilles, the Barbados accretionary prism, the offshore Gulf of Mexico, the offshore Nicaraguan Rise, the Yucatan basin, the Greater Antilles area, and the Bahamas platform. CBTH Phase-III will build on previous mapping work by Mann and co-PI Dr. Alejandro Escalona as part of CBTH over the past six years, as well as previous and ongoing work by others in the region. An expanded focus of the CBTH-Phase III study will be basin and flexural modeling and more detailed plate tectonic reconstructions using PaleoGIS software.

Project Management of CBTH-Phase III

As for the previous CBTH Phase of this study (2005-2011), CBTH-Phase III will be a scientific and educational collaboration between research groups at two separate universities: The University of Houston (P. Mann, co-PI) and the University of Stavanger, Norway (A. Escalona, co-PI). P. Mann, a newly appointed professor at the University of Houston will continue to supervise BS, MS and PhD level students and manage GIS and student support staff. UH will act as the main base for the CBTH-Phase III project with 2 students entering the program in August, 2011 and plans to hire one fulltime GIS support person and one fulltime seismic support person. A. Escalona is a co-PI who supervises 5 MS students and GIS and support staff in Norway. Due to the proximity of UH to most CBTH sponsors in Houston, Mann and the UH group will host the annual year-end CBTH meeting in early September of each year of the project. As with CBTH-Phase I and II, the Norway group will use funds from CBTH-phase III sponsors to employ scientists, post-doctoral researchers, graduate students, and undergraduate students to accomplish the goals of the proposed study. We also use sponsor funds to hire key experts including Dr. Ian Norton (UTIG researcher, specialist on PaleoGIS-based plate reconstructions), Dr. Nestor Cardozo (UiS researcher, specialist in basin modeling) and Dr. Pete Emmet (Houston-based consultant, specialist on Central America

and subsurface geology of the Nicaraguan Rise).

Data Sources and Products for CBTH-PHASE Phase III

As for the previous CBTH phases of the project completed at the University of Texas, CBTH-Phase III data sources include 2D seismic data, well data, outcrop data, previous publications on the region, and original seismic and well data provided with permission by the sponsoring companies or government agencies. As we have done over the past 6 years of the study, CBTH Phase III will continue to respect the conditions placed on the use of donated data either by the research staff or by graduate and postdoctoral researchers employed by the project.

The CBTH-Phase III study will integrate the results of our own seismic interpretation and well correlations over the entire region to produce structural, isopach, and paleogeographic maps which will make available to our sponsors in digital format. These data will be integrated with our large GIS database and literature compilation to produce regional and more detailed geologic models and will serve as a basis for modeling and visualization of critical hydrocarbon basins in the area. Proposed work for CBTH-Phase III (2011-2014) will not only focus on the understanding of the regional geology and basin-forming mechanisms of the study area but will also address improved characterization of the many petroleum systems in the study area (e.g. source, reservoir, trap, etc.). In addition, we will continue to expand our database compilation in the key exploration areas of Suriname, French Guyana, the northern equatorial margin of Brazil, the Andean foreland areas of southern Colombia and Ecuador, and in the Mexican sector of the Gulf of Mexico (*Fig. 1*). The level of detail for these studies will largely depend on the amount of new data we can access for the project.

Deliverables for CBTH-Phase III

The focus areas and deliverables for each year of the project will be discussed during each annual meeting with sponsors and will be subject to changes depending on the availability of new data. Deliverables provided by the CBTH-PHASE III project will include: (1) an integrated and user-friendly GIS database which is updated regularly and accessible through our secure website; (2) plate tectonic and paleogeographic models built in PaleoGIS and also updated as new data is accessed; (3) a series of structural and stratigraphic maps of key seismic surfaces in the region; (4) our original interpretations of seismic data and well data; (5) modeling results using the most complete compilations of available data; (6) all student and researcher oral and poster presentations from international meetings including the AAPG annual meeting held in the US and the EAGE

meeting in Europe; and (7) access by sponsors to the secure, online CBTH-Phase III database where all project information can be downloaded. In addition to these web-based products, we will continue to provide sponsors with an annual atlas and DVD's containing the same annual deliverables that are also accessible from our website. Our yearend meeting in September of each year of the project will involve oral presentations by all members of the UT group along with Alejandro Escalona from UiS and students and postdocs working on the study in Norway.

Special Projects to be delivered for CBTH-PHASE III

Our work is largely driven by the data that is made available to us through the efforts, generosity, and specific exploration priorities of our sponsors. Given our discussions with sponsors at our last year-end meeting, we propose the following thematic studies in this area (pending availability of data from sponsors, companies, or governmental agencies):

1. **Tectonics and sedimentation in the Trinidad area.** In the Trinidad area, CBTH-Phase III will focus on several areas of study:

(a) Understanding the distribution and limits of tectonic terranes and how these contrasting basement blocks control overlying source rock families and the structural styles in overlying hydrocarbon-bearing basins. A key problem is the complex, three-way intersection of disparate tectonostratigraphic terranes in Trinidad that includes the Barbados accretionary prism, the South American passive margin, and the Caribbean arc (Tobago terrane). We are using deep penetration seismic data combined with earthquake information to better understand the deeper structure underlying the entire region.

(b) The southern Gulf of Paria region straddles the political boundary between Trinidad and Venezuela. On both sides of the border, hydrocarbons are produced from siliciclastic reservoirs that are generally younger than Oligocene. The production area of light to heavy oils form a linear oil trend aligned with major north-dipping thrusts in the region. The CBTH-Phase III project will reconstruct the geological and structural evolution of the southern Gulf of Paria to better understand the distribution of large, mature oil fields such as Pedernales in Venezuela and Brighton and Soldado in Trinidad. The CBTH-Phase III project will build a regional-tectonic framework integrating geologic information from both Venezuela and Trinidad. Our project continues to enjoy a good working relationship with governmental ministries and private companies in both countries along with international graduate students working on the

study from the region.

(c) The pre-Middle Miocene history of Trinidad and its offshore region has always been problematic due to problems in seismic imaging of highly deformed rocks underlying the Middle Miocene unconformity found both on- and offshore Trinidad. We are working with the Trinidad Ministry of Energy who is providing key seismic lines tied to wells that will assist in the effort of improving imaging and interpretation of pre-Middle Miocene events.

2. **Suriname and French Guyana.** We will pursue collaborations with the Suriname and French Guyana energy ministries and universities in order to improve our database and access more subsurface data. Because some of our sponsors are actively exploring along this margin, we would hope to gain access to subsurface data in the deep basin and the southeastern part of the shelf. Basin modeling would be conducted using available subsurface data combined with reconstruction of major tectonic and eustatic events that have affected the margin. We have an important new synthesis paper on the petroleum geology of the Guyana margin using well and reflection data that is appearing in a forthcoming issue of AAPG Bulletin. Our goal is to provide our sponsors with a regional structural and stratigraphic synthesis of the entire margin from Trinidad to northern Brazil.

3. **Study of the northern Brazilian margin.** We propose data compilation and establishment of academic relations with Brazilian universities and Petrobras in order to gain access to subsurface information for the offshore equatorial basins of northern Brazil. Our goal is to provide the sponsors with a regional framework for the complex, Cretaceous transtensional margin formed during the opening of the Central Atlantic Ocean that is now blanketed by a passive margin. This margin remains the last remaining frontier area of Brazil's Atlantic margin. Our experience in Trinidad and Guyana will allow us to attempt regional stratigraphic comparisons for this source-rock-rich coast of northeastern South America. We also are refining the plate opening and strike-slip model for the Mesozoic opening of the area using PaleoGIS which would act as a framework for all paleogeography data compiled for the area. To our knowledge, there has never been a previous effort to integrate subsurface data from Trinidad to northern Brazil.

4. **Northern Andean foreland basin study.** We will develop a series of projects from Venezuela to Ecuador that will aim to provide the basis for a regional and synoptic study of the Northern Andean foreland basin that has been tectonically influenced in part by the Caribbean "Great Arc" collision that we studied in previous years in the area of Venezuela and Trinidad and Tobago. From our more recent work on onland basins in Colombia, we are also recognizing that

the Andean foreland basins have a more complex evolutionary history that is also strongly influenced by the interaction of the Andean margin with subducting oceanic plateaus, arcs, young oceanic plates, and thickened oceanic ridges of Pacific origin. We currently have two projects focused on the northern (UT) and southern (UiS) Llanos foreland basin of Colombia and have made considerable progress in our understanding of this foreland system. The proposed CBTH-Phase III Andean foreland study area will include the Barinas and Llanos basins (Colombia and Venezuela), the Putumayo basin (Colombia), and the Oriente basin (Ecuador). We have one new MS student arriving at the University of Houston in August, 2011, to begin a study of the Putamayo basin, an area he has worked on with a company for the past 2 years. All these oil and gas-rich basins once formed part of a large and interconnected Cretaceous seaway that contains world class source rocks and evolved into a foreland setting during tectonic events of the late Cenozoic. The basins in these regions, particularly in Ecuador, are among the richest hydrocarbon basins in South America, yet they have not placed into the type of regional tectonic framework that we propose for the CBTH-Phase III study. A main focus of the CBTH-Phase III project is to expand our GIS and reference compilations for all these foreland areas, seek opportunities to access subsurface data, and build regional maps of key tectonosequences that will form the basis of the CBTH-Phase III regional framework. We have found that these data-driven types of activities are of great benefit to our sponsors and can be done at relatively modest costs given that our compilation effort is carried out by undergraduate, graduate, and post-doctoral students.

5. **Structure and stratigraphy of the Nicaraguan Rise.** Regional mapping and correlation is key to understanding the plate evolution of this vast, underexplored submarine carbonate bank, its underlying tectonic terranes, and how these terranes control the overlying source and reservoir units. We have made considerable progress in our regional study given that most of the data we are using was collected in the 1970s and has limited depth penetration especially in submarine carbonate environments. We have supplemented these vintage data with a complete compilation of all exploration well logs available in the Honduran and Colombian sectors where possible with data available from modern, deeper penetration seismic surveys. We have also integrated both data and drilling results from the publicly available, high resolution, stratigraphic wells completed by the Deep Sea Drilling Project (DSDP) and the Ocean Drilling Project (ODP). For this study, we plan to continue our collaboration with ANH in Colombia and build collaborations with ministries in Honduras and Jamaica. Our goal is to produce regional subsurface maps that encompass the various sectors of the Nicaraguan Rise and then use these maps to constrain our PaleoGIS plate reconstructions for the area. These PaleoGIS

reconstructions can then form the basis of updated paleogeographic maps. We are planning trips to visit with ministers and governmental officials in Jamaica and Nicaragua who control extensive areas of the Nicaraguan Rise. Nicaragua has expressed interest in sending two of their young geologists to the University of Houston to work on their offshore data as part of MS studies.

6. **Mexican sector of the Gulf of Mexico.** About half of the Gulf of Mexico falls within Mexican waters (*Fig. 1*). Our goals in this area include linking the onland geologic history of Mexico with the offshore depositional record on the shelves, slopes and deep basins of the Mexican sector of the Gulf of Mexico. Our plan is to assemble publicly available seismic and well data and use a SEG-Y conversion program to supplement our seismic database with lines we have found in the published literature and in unpublished thesis studies. While these data constitute a small fraction of the studies and modern geophysical data widely available for the US-controlled part of the Gulf of Mexico, we have found sufficient data sources for a major new synthesis of the Mexican sector. Depending on data availability, we may expand this study of the Mexican GOM into the adjacent US sector of the deepwater GOM.
7. **Onland basins of Colombia and regional effects of Panama indenter.** Colombia experienced the collision of the Great Arc of the Caribbean in the late Cretaceous and Paleogene and was again subjected by a superimposed collision by the Panama arc “indenter” in late Miocene times. Using ANH seismic and well data, we have several projects in Colombia that include the Lower and Middle Magdalena basins, the offshore Sinu accretionary prism, and the Llanos foreland basin. Our proposed CBTH-Phase III work for this area includes incorporation of the many recent surficial stratigraphic and structural studies by other groups into our subsurface mapping effort. One main goal of this study is to constrain the presence of the Great Arc in the subsurface of northwestern Colombia, its regional structural effects, and the later structures superimposed on the region by the Miocene Panama collisional event. This later, superimposed Panama event appears to have a major impact on the subsidence and uplift history of hydrocarbon-bearing basins in the region.
8. **Basin modeling of selected basins.** Previous research in which Mann and Escalona have completed and published have shown the importance of basin modeling for understanding the evolution of the petroleum system. In particular, basin modeling has shown the importance of temperature variations from underlying and contrasting tectonic terranes including thinned continental crust, accreted arcs, and basins overlying actively subducting slabs such as in the Trinidad, Leeward Antilles, offshore Venezuela and

northwestern Colombia areas. In the CBTH-Phase III project, we will use basin modeling to evaluate the effects of basin subsidence, deformation, heat flow on source rock maturity and reservoir rock quality. All these effects will influence hydrocarbon potential. All basin models are based on our integrated database.

9. **PaleoGIS plate reconstructions encompassing a wider area.** Building on the widely accepted Pacific-derived origin of the Caribbean plate, we will expand the reconstructions and paleogeographic maps to include from the offshore equatorial basins of northern Brazil to the Andean foreland basins of Colombia and Ecuador and explore tectonic and stratigraphic linkages to the central and south Atlantic opening. We will develop a full set of movies based on the Paleogeographic database and reconstructions between Jurassic to recent. A particularly time-consuming effort is to fully integrate the data points in our GIS database with the reconstructed maps in order to ground truth the plate model. This plate model serves as the main template for the paleogeographic maps and for the sponsors to visualize a regional framework. Because the generation of the plate tectonic model is time consuming, we propose to deliver the Paleogeographic compatible geodatabase at the end of Year 3 of the CBTH-Phase III project.
10. **Geochemistry of hydrocarbons of the northern margin of South America and the Caribbean.** Our goal is to integrate existing geochemical studies of hydrocarbons in the region with our subsurface mapping and basin analysis. This type of study can reveal how certain types of basins (foreland, rift, strike-slip, etc.) and their source rocks have produced certain geographic and tectonostratigraphic clusters of “hydrocarbon families”. We would like to collaborate with sponsors, governmental agencies, and other groups to compile geochemical data and use these geochemical data to better constrain petroleum systems.
11. **GIS-based research, models, and products.** CBTH-Phase III will continue to use the power of GIS technology to both deliver information quickly to our sponsors along with simplifying data management especially to those sponsors who may not routinely work with GIS applications. In addition to Paleogeographic reconstructions, paleogeographic data will be provided to sponsors in geodatabase format. With support from a fulltime GIS support person to be hired, CBTH-Phase III will continue to provide novel and useful GIS-based research and projects along with assisting sponsors in data management as needed.
12. **Cross-section restorations and flexural modeling.** Cross-section restorations and flexural modeling in 2D and 3D will be another research topic we will apply to key, hydrocarbon-rich areas in the CBTH-Phase

III study area (*Fig. 1*). The main goal of this activity is to quantitatively evaluate the effect of tectonic and sediment loading during mountain uplift. Since the CBTH-Phase III study area contains so many examples of deep basins adjacent to high mountains, the linkages between mountain uplift and basin subsidence is a widespread problem in the region. This type of modeling will lead to important predictions about the stratigraphy of the basin and its paleogeography that can be in turn compared to the data we have in our database.

Cost of CBTH-Phase III.

The total cost of the three-year CBTH-Phase III is \$180,000 per sponsor. We will require a three-year financial commitment from all CBTH-Phase III sponsors with a minimum annual fee of \$60,000 US due by August 15 of each year starting with year one of the project in September, 2011. If sponsor payments are not received by August 31, 2011, we will consider these companies “late buy-ins” who will be charged 150% of the annual \$60,000 US rate.

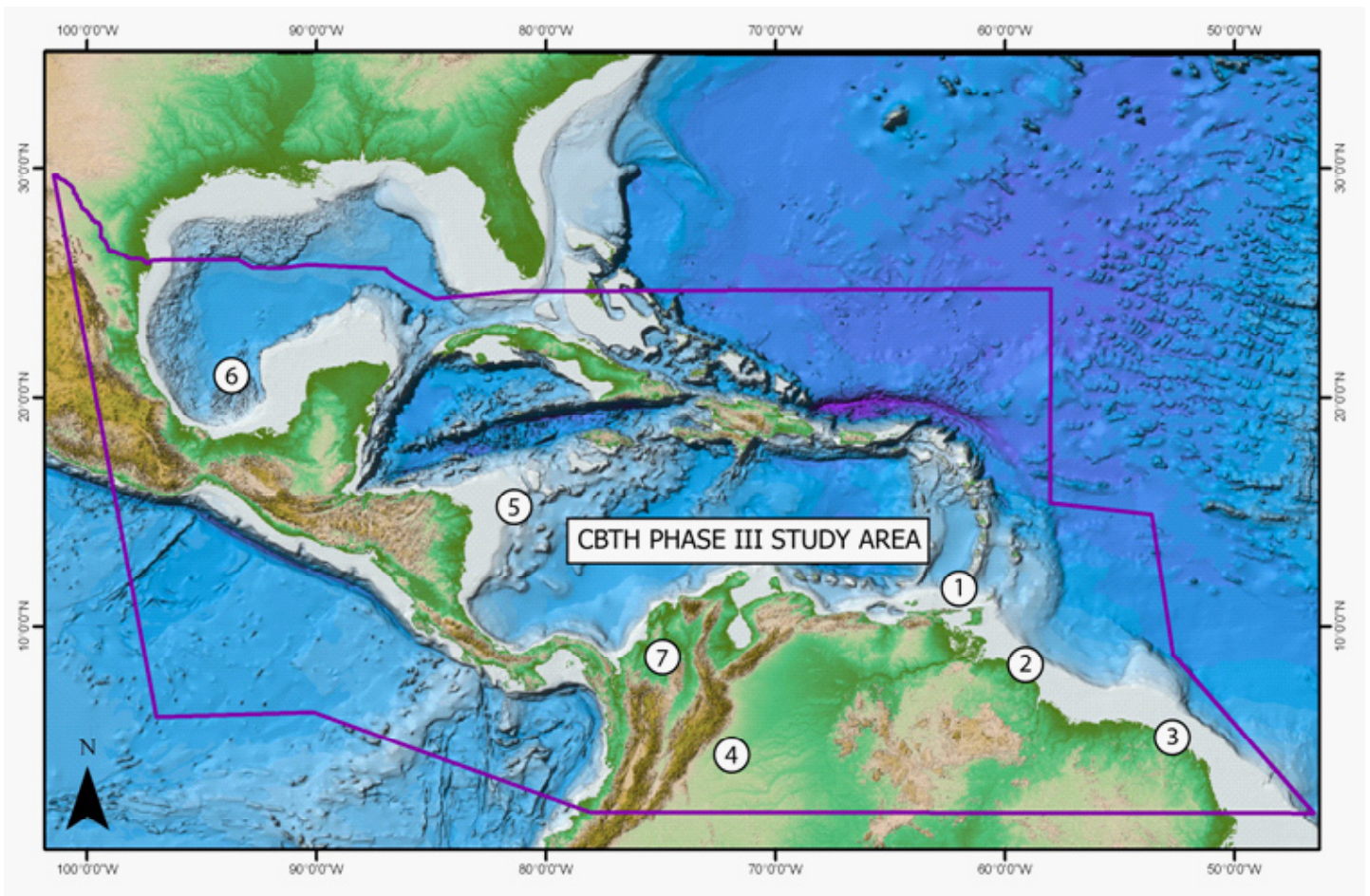


Figure 1. CBTH-Phase III proposed study area is shown in the large boxed area. The CBTH-Phase III area includes the Mexican sector of the Gulf of Mexico, the Caribbean, and northern South America. The southern part of the expanded CBTH-Phase III study area includes the equatorial basins area of northern Brazil and a large area of the northern Andean foreland basins. Numbers on map refer to areas of proposed work described in the text of this proposal: 1 = Trinidad region; 2 = Suriname and French Guyana; 3 = equatorial basins of northern Brazil; 4 = northern Andean foreland basins; 5 = Nicaraguan Rise; 6 = Mexican sector of the Gulf of Mexico; and 7 = onland basins of Colombia.