Mygdalys Salazar graduated as a geophysical engineer and spent eight years working for the Venezuelan national oil company. Realizing the importance of improving her knowledge in other areas of earth science, she completed two master programs, one in The University of Texas at Austin. Her advisors are Dr. Lorena Moscardelli and Dr. Lesli Wood.

The impact of shelf margin geometry and tectonics on shelf-to-sink sediment dynamics and resultant basin fill architectures: Study of the shelf-to-sink system of the northern Taranaki Basin, New Zealand

PROJECT SUMMARY

The processes affecting sediment transport from the shelf edge to the continental slope and deeper abyssal regions of a basin are not simple. Traditional depositional models are basically applied in 2D, assuming that most sediment transport occurs from proximal to distal locations along a transect perpendicular to the stratigraphic dip direction (Posamentier and Vail, 1988; Posamentier and Allen, 1999; Johannessen and Steel, 2005). Furthermore, sequence stratigraphic models, whose role is to predict sediment architecture, distribution and type, overemphasize the role of relative sea level fluctuations to explain sediment delivery processes into deep-water settings (Vail et al., 1977; Mitchum et al., 1977; Posamentier et al., 1988). World-wide examples show that shelf-to-sink configurations might be influenced by a variety of geological factors not acting in the dip direction, including variations in bathymetry due to tectonics, shelf margin geometry and alongshore currents. Recently, the availability of extensive 3D seismic datasets has allowed researchers to obtain a real three-dimensional perspective of the shelf-edge region architectures and a better understanding of these processes.

This work intends to pursue a detailed seismic geomorphological study of shelf edge architectures within the Miocene-to-Recent succession of the northern Taranaki Basin, New Zealand. The purpose is to understand the relationships between clinoform nature and the variables that influence the shelf margin region, including ocean processes, sea level fluctuations, sediment supply and tectonics. Basin dynamics make this area interesting in that we will be able to evaluate the effect of different tectonic episodes in clinoform development and the relative controls of different transport mechanisms.

I will address the following general questions: What are the main geomorphological differences between the clinoform architectures observed within the different tectonic stages in the Taranaki area? To what degree are these differences controlled by changes in tectonism, sediment supply, relative sea level fluctuations or current-controlled processes? How does the nature of clinoform development relate to sediment escape into deep-water regions? What seismic criteria can be used to identify and characterize different types of depositional elements and sediment transport mechanisms operating in the shelf margin region? Can these same criteria be used in other types of worldwide continental margins?

I will interpret 1,700 sq-km of 3D seismic data and 4,000 km of 2D seismic profiles offshore northern Taranaki Basin to document in detail the architectural complexities that exist in its Miocene-to-Recent shelf-break region. Structural and isopach mapping will help us to understand the evolution of the shelf margin and depocenter migration. Seismic attribute extractions will allow the visualization of stratigraphic patterns and depositional systems, which will be very helpful in recognizing the processes

acting in the shelf edge at specific times. These observations will provide the input to stratigraphic forward modeling of the margin evolution and its response to various inputs to reveal the nature of depositional processes operating on this region. Finally, I will compare the results with similar observations in the eastern offshore regions of Trinidad, where there is also extensive seismic coverage. The improvement in the understanding of architectures in these types of progradational systems will help us to design better predictive models.

INTRODUCTION

Although the amount of sediment that ultimately ends up in the deep basin is influenced by the source area and the fluvial systems that feed the shoreline, it is the deltaic and shelf repositories that ultimately feed the slope and deep water environments. When sediments reach the boundary between subaerial and marine processes, they typically store in deltas and shelf sand systems, where they are acted upon by marine processes to affect the nature and the distribution of sediments at shelf-edge locations. This research will focus on the shelf to slope to basin plain portions of the source-to-sink system.

Shelf-to-sink configurations are influenced by a variety of geological factors including relative sea level fluctuations, tectonism, sedimentation rates, and current-controlled processes. The tectonic and structural configuration of a given marine basin might influence the bathymetry of the outer-shelf region and the tortuosity of sedimentary pathways that bypass sediments from the shelf region. Tectonic pulses can also trigger variations in sediment supply by increasing the surface area of potential sedimentary sources that will eventually influence stacking patterns and depositional styles on the basin (e.g. Miall, 1986; 1991; Williams, 1993). Similarly, marine currents can mobilize huge amounts of sediments along strike without requiring the presence of incised valleys or canyons in the shelf-break region (Martinsen and Helland-Hansen, 1995; Boyd et al., 2008; Georgiopoulou et al., 2011). The influence that tectonic pulses and alongshore processes have on the transport and redistribution of sediments in continental margins tend to be underestimated by models that overemphasize the role of relative sea level fluctuations. The availability of extensive 3D seismic datasets and bathymetric information has allowed researchers to obtain a real three-dimensional understanding of the shelf-edge region that, when integrated with more detailed information from well logs, biostratigraphic analyses and core information, can help unravel the relationships between tectonics, eustacy and sediment supply (e.g. Moscardelli et al., in review; Kertznus and Kneller, 2009; Moscardelli et al., 2006; Posamentier and Kolla, 2003). In this work, I will take full advantage of a extensive subsurface 3D dataset located in the northern Taranaki Basin (New Zealand) to document in detail the architectural complexities that exist in the Miocene-to-Recent shelf-break region. The observations will provide the input to stratigraphic forward computer modeling of the margin evolution and its response to various inputs of slope, sediment volumes, wave and tidal energies and accommodation distributions to reveal the nature of depositional processes operating on the region. The end results will be compared and contrasted with learnings from previous works in offshore eastern Trinidad (Moscardelli et al., in review).

Available Dataset

The Taranaki Basin has been subject of intense oil and gas exploration since 1955. A rich historical database of observations exists to help understand the area. The available dataset for this study is located in the northern region of the basin and it includes a 3D seismic volume, 2D seismic profiles, and well information (Figure 1C). The 3D seismic volume (Pogo 3D) was acquired in 2005 and covers an area of 1,700 sq-km. These data represent a primary tool for studying the margin architecture, and spatial and temporal variations in clinoform character. Because of its fine spatial detail, 3D seismic allows geophysical attribute analyses and visualization options not afforded to researchers working only with 2D seismic. Moreover, the higher frequency content on the 3D seismic volume (dominant frequency of 40 Hz compared to an average of 25 Hz for the 2D seismic profiles) allows a better resolution of structural and stratigraphic features. Four thousand kilometers of time-migrated 2D seismic reflection profiles, located in the offshore area of the Taranaki Peninsula, are also available (Figure 1B). Geophysical logs, foraminiferal, lithological and velocity information from seven exploratory wells will be also incorporated into the study.

Regional Geology

The Taranaki Basin is a Cretaceous-Tertiary age sedimentary basin that covers a total area of 330,000 sq-km along the western coast of New Zealand (Figure 1). The north-south oriented Taranaki Fault defines the eastern boundary of the basin. The ridges of New Zealand's South Island define its southern boundary whereas the basin merges with the New Caledonian Basin towards the northwest (Figure 1A). The study area is located on the continental shelf, northwest of the Taranaki Peninsula (Figure 1B).

The Taranaki Basin has a very complex tectonic history that started in the Late Cretaceous during a rifting event (King and Thrasher, 1996). This study focuses in the Neogene regressive succession of the basin, whose origin is associated with the collision between the Pacific and Australian plates. It is

composed of two phases of continental margin progradation: a Miocene retro-arc succession (Wai-iti Group), and a Pliocene-to-Recent back-arc succession (Rotokare Group) (King and Thrasher, 1996).

OBJECTIVES AND SCOPE

The objective of this study is to pursue a detailed seismic geomorphological study of shelf edge architectures within the Miocene to Recent section of the Taranaki Basin, in order to investigate and document the evolution of the basin's continental margin in this time frame. This will allow a better understanding of the relationships between clinoform nature and the variables that influence the shelf margin region: ocean processes, sea level variability, sediment inputs and tectonics. Since the Taranaki Basin is considered a dynamic basin, in that subsidence and sediment supply were not constant through time, but the response to fault activity and evolving topography, we intend to contrast the stratigraphic signatures of variable eustasy and variable tectonic activity. Observed variations in margin architecture within the Taranaki Basin will be compared with studies from other continental margins to try to identify the degree and manner in which these variables affect sediment transfer from the shelf to the slope in a diversity of tectonic settings, and to identify which variables show local versus universal behaviors.

Hypotheses

1) If irregularities affecting the bathymetry of continental margins (e.g. relative lows and highs) are associated with the lateral discontinuity of structural elements (e.g. relay ramps, horst and graben structures, growth-fault sediment traps, etc), then:
   - we should be able to locate areas of sediment bypass versus areas of sediment accumulation along the margin by identifying these structural variations along strike
   - sedimentary pathways influenced by underlying structures will not necessarily transport sediments perpendicular to the shelf break due to the irregular character of some of these structural elements
2) If changes in tectonic regime and variations on the location and nature of sedimentary sources through time have the capacity to alter the geometric configuration of continental margins and these variations are not only temporal (changes on the vertical succession), but also affect the configuration of the margin along strike at any given time, then by performing a detailed seismic geomorphological study, we should be able to:
   - record along-strike variations affecting clinoform architectures and stratigraphic stacking patterns
   - identify regions of sediment accumulation versus bypass in the continental margin and predict the occurrence of deep-water deposits
3) If variation in clinoform geometries (foreset declivity) respond to sediment composition and fabric as suggested by several authors (e.g. Adams et al., 1998; Orton and Reading, 1993; Adams and Schlager, 2000), then foreset declivities within the fine-grained siliciclastic clinoforms of the Taranaki Basin should have values within the ranges defined by these previous authors.

METHODOLOGY

To address the problem and test my hypotheses I will map 9 and 6 seismic units for the Rotokare and Wai-iti geoups, respectively (Figures 2 and 3). Lithological, biostratigraphic, well log information from seven wells will be integrated to the seismic in order to get the chronostratigraphic framework and paleoenvironments of the seismic units (Figure 2). Time-depth conversion will be possible using velocity surveys from four of the wells, calibrated through synthetic seismograms.

Structural and isopach mapping of these units will help us to understand the distribution and migration of depocenters through time as well as the associated evolution of the margin. Seismic attribute extractions will allow the visualization of stratigraphic features (shape, dimension and type) and their associated depositional systems, which will be very helpful in recognizing the processes acting in the shelf edge at specific times. Visualization techniques such as 3D perspective views, strata and time slices, interval attributes and the use of opacity and lightening will also be applied to identify the presence of these depositional elements and its evolution through time. Seismic interpretation and attribute analyses will be done on seismic workstations using Landmark Seisworks, OpenVision, and GeoProbe softwares.

The characterization of clinoform morphologies using geometrical criteria proposed by several authors (Adams and Schlager, 2000; O'Grady et al., 2000) will allow us to find potential correlations between clinoform geometrical parameters (e.g. foreset declivity, height and length, progradational-to-aggradational ratio) and variations in sedimentation rate, transport regimes, and relative sea level within the Giant Foresets Formation (Rotokare Group). The observations will provide the input to a 2D stratigraphic computer forward modeling of the margin evolution using the software STRATA (Flemings and Jordan, 1989). The response of the model to various inputs will reveal the nature of depositional processes operating on the region, and the end results will provide useful constraints on the tectonic evolution of the basin as well as better estimates of sediment supply, transport conditions, and the possibility of transport in directions non-perpendicular to the shelf break. Finally, I will compare the results with similar observations in the eastern offshore regions of Trinidad and in the Gulf of Mexico, where there is also extensive seismic coverage (Moscardelli et al., in review). The improvement in the understanding of architectures in these progradational systems will help design better predictive models with wide applicability.

PRELIMINARY RESULTS

Two different successions in terms of tectonic regime and sediment supply are identified within the regressive phase of the Taranaki Basin stratigraphic infill: the Miocene Wai-iti Gp. and the Plio-Pleistocene Rotokare Gp. Isopach and attribute extraction maps allowed us to observe the character and evolution of their depocenters and depositional environments, and suggest that tectonics and structural configuration of the basin since Miocene were among the main controlling factors defining:

1) Location of sedimentary sources inland, which shows a southward migration associated with the advance of the Australian-Pacific subduction zone and related uplifting

2) Geometry and location of sedimentary pathways in the shelf-break region, which were associated to the location of structural features such as normal fault subsidence and relay ramps (Figure 4)

3) The location and migration of depocenters in the deep-water region

4) Change in depositional conditions from deep water (Wai-iti) to shelfal (Rotokare)

Clinoforms in the Taranaki Basin can be categorized according to their morphology. These results seem to support the idea of a correlation between lithological composition and clinoform morphology. There also seems to be a relationship between clinoform morphology and depositional processes. Preliminary observations suggest that sigmoidal clinoforms within the Rotokare Gp. could have been affected by the redistribution of sediments along the shelf margin due to the action of current-controlled processes.

BROADER IMPLICATIONS

Deep water deposits have acquired increasing importance in terms of petroleum exploration in the last several years. Although the amount of sediment that ultimately ends up in the deep basin is influenced by the source area and fluvial systems, it is the deltaic and shelf repositories that ultimately feed deeper water environments, making this area one of the most important in marine geology and deep-water oil exploration. Since this study intends to better understand how marine processes affect the nature and the distribution of sediments at shelf-edge locations, the results will help in the characterization and determination of reservoir distributions in deep water settings that can be applied in different worldwide regions (e.g. with smaller seismic dataset). Moreover, the results will give us the opportunity to improve our general understanding of the nature of deposition and the processes controlling shelf edge evolution and clinoform architecture development under the influence of different tectonic regimes.

Consequently, results of this research will impact our understanding of:

1.- The relative role that sediment supply, sea level changes and tectonics plays in shelf-break trajectories and sediment transport from the shelf to the slope and deeper-water regions of the basin.

2.- The impact of tectonics in changes in accommodation space, location of sedimentary sources, creation of bathymetric irregularities in the basin and distribution of sedimentary pathways.

3.- Conditions that allow the deposition of high relief clinoforms, and the influence of currents not perpendicular to the basin strike in clinoform architectures.

4.- Feasibility of using 2D stratigraphic modeling to constraint hydrodynamics controls on clinoform morphology and shelf-margin geometry.

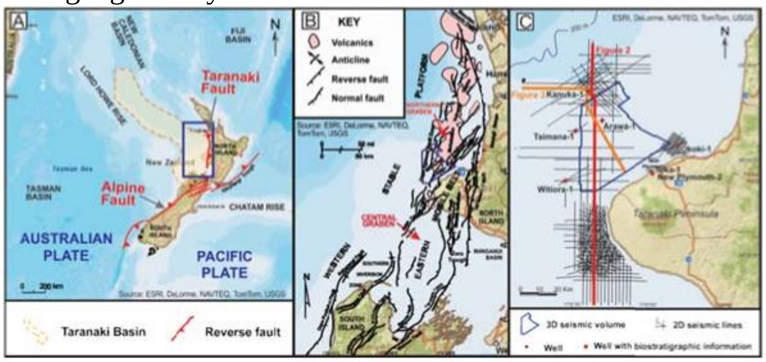

Figure 1: (A) Regional location map (modified from Stagpoole and Nicol, 2008), (B) structural elements in the study area (modified from Giba et al., 2010), and (C) available data (modified from Hansen and Kamp, 2004)

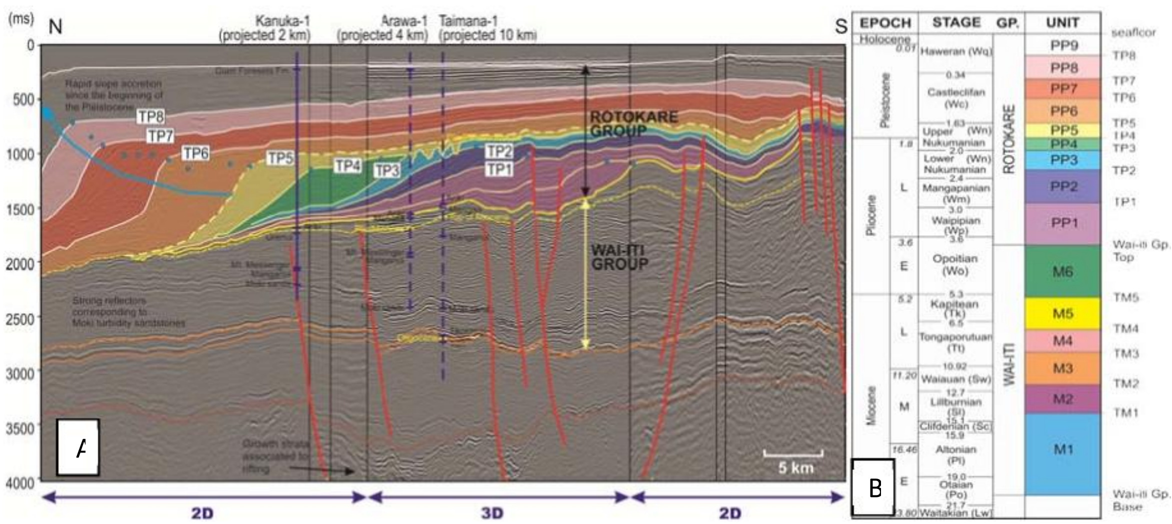

Figure 2: (A) Seismic character of the Rotokare Group (see Figure 1 for location) and (B) cronostratigraphic correlation The section is characterized by well-developed clinoform packages (topset, foreset and bottomset) and discontinuous inclined reflectors (degradational foresets) towards the north.

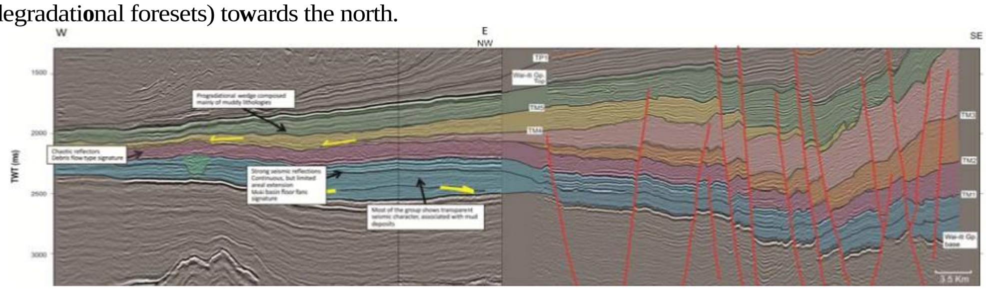

Figure 3: Seismic character of the Wai-iti Group (see Figure 1 for location). The section shows a wedge-like shape, development of foresets and bottomsets, low amplitude reflectors (mud deposition) and limited-extension high amplitude seismic anomalies (basin-floor fans). See Figure 4 for chronostratigraphic correlation.

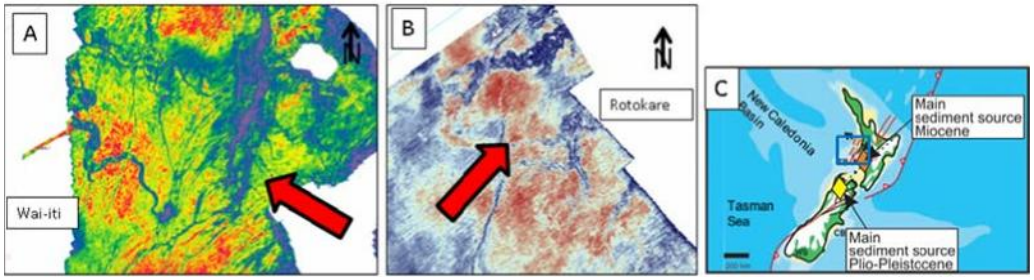

Figure 4: RMS amplitude maps within (A) the Wai-iti Group (top of M1) and (B) Rotokare Group (within PP6). Broad, strong amplitude anomalies are associated with submarine fan systems in Wai-iti, smaller stratigraphic patetrns can be resolved within this fan complex. Channelized features in Rotokare are parallel to the graben, while en echelon faulting seems to be affecing the entrance of tributaries. Red arrows show sediment transport directions, which orientation seems to be controlled by a southward migration of the sedimentary source (C).

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