Space-Time Evolution of the Marine Depocenters at the Pelotas Basin, Southern Brazilian Continental Margin

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Abstract

This study aims to investigate space and time evolution of the marine sequences at the Pelotas basin - southern Brazilian margin, based on interpretation of about 10.000 Km of multichannel seismic lines.

This work was based on the association of depth to basement map and a series of isopach maps of marine sequences (Lower Cretaceous-Recent). It revealed that the sedimentary distribution pattern changed radically from the Lower Cretaceous to the Oligocene. Through time the main depocenters shifted seawards and backwards again under the influence of a series of processes. The configuration of depocenters was primarily conditioned by basement topographic features, while depocenter segmentation occurred under the influence of dynamic processes.

Since the end of the Oligocene a high sedimentary accumulation rate took place, giving rise to the onset of the Rio Grande Cone. This deposition feature corresponds to the main depocenter at the south Brazilian Margin and its evolution is not related only to thermal-mechanical but also to dynamic processes such as bottom currents.

Introduction

The Pelotas basin originated in the Early Cretaceous by extensional processes during the breakup of Gondwana that culminated in the separation of the South American and African continents (Asmus, 1975). This basin is located at the southernmost segment of the Brazilian passive margin between 28°S and 34°S and covers an area of 210.000 km^2 (Abreu, 1998). This Basin extends from the territorial waters of Uruguay into the Florianópolis Platform in the north, which corresponds to the frontier region between Pelotas and Santos Basin (Fontana, 1996) (Figure 1).

One of the characteristics of the south Brazilian Continental Margin is the ubiquitous thick basaltic wedges (known as seaward-dipping reflectors) that characterize the Pelotas basin as a volcanic margin, thus distinguishing it from other Brazilian marginal basins (Gladczenko *et al*. 1997). The south Brazilian Continental Margin is also segmented by oceanic fracture zones and structural lineaments (e.g. Rio Grande FZ, Porto Alegre Lineament and Chuí Lineament), providing a structurally intricate environment, which influenced the sedimentary evolution of the region (Alves, 1981). For instance, a volcanic high (known as Arco de Torres), associated by the E-W Porto Alegre structural lineament, delimits the northern portion of the Rio Grande Cone (Bassetto *et al.* 2000) (Figure 1).

An anomalous sedimentary thickness (Lower Cretaceous - Recent, Abreu, 1998) was recognized in the Pelotas basin and it may locally reach a thickness of nearly 12 km in the Rio Grande Deep-sea Cone (Gomes, 1993). Asmus (1983) and Fontana (1996) assume that this anomalous sedimentary accumulation has developed mainly due to an intense thermal subsidence and flexural process of the crust. In addition, Bassetto *et al.* (2000) claim that the sediment accumulation has taken place due to an unusual sedimentation rate since the Upper Eocene, developing significant depocenters. However, none of the previous works in the area focused on the sedimentary architecture of the marine sequence of the basin.

In this context, the purpose of this work is to investigate the spatial and temporal evolution of the marine sedimentary depocenters of the Pelotas Basin and to recognize the main factors controlling the sedimentary architecture of the margin. For this purpose, we designed a depth to basement map, as well as a series of isopach maps of the Marine sequence. This work is based on more than 10.000 km of multichannel seismic data. The major source of these data is from the LEPLAC-IV Project which covers an area between 25° S and 37° S. Another data set available concerns about 1500 km of multichannel seismic data surveyed by Petrobras and interpreted by Abreu (1998) (Figure 2).

Seismic Interpretation

Structural significance of the depth to basement map of the Pelotas basin

The depth to basement map the Pelotas basin reveals a rather irregular morphology (Figure 3). The map shows a strip with a lower depth of the acoustic basement aligned in a NE-SW direction (spectrum from blue to dark blue) which characterizes the Continental Margin Province. The area of the highest basement depth corresponds to the offshore area of the basin, in which the Rio Grande Cone has developed (south area of the 32°S latitude). The major structural highs are located particularly at the northeastern of the Pelotas Basin and they seem to be associated to the E-W structural lineaments. The northernmost volcanic high corresponds to the Dorsal de São Paulo (dark-blue spectrum at the 28°S latitude) aligned with the Rio Grande Fracture Zone. Another volcanic high (*Arco de Torres*) is apparently associated to the Porto Alegre lineament at the

31°S latitude, but it has a NW-SE direction. The southernmost lineament (Chuí Lineament) at the 35°S latitude has no structural high associated to it.

The main depocenters of the Lower Cretaceous-Recent Marine Sequence of the Pelotas basin

The isopach map of the post-rift marine sedimentary sequence of the basin (Figure 4) shows a strip along the coast with an increased thickness aligned in a NE-SW direction (spectrum from yellow to pink), illustrating the thicker sedimentary column, which is characteristic of the Continental Margin Province. This strip presents a distinct thickness between the north and south portion at the 30°S latitude. To the north of 30°S latitude the major depocenter has a thickness of 4.0-4.5 km (spectrum from yellow to red). To the south, there is a major depocenter with a thickness of nearly 7 km in which the Rio Grande Cone was developed. This depocenter, the major one along the south Brazilian margin, is shaped like a swelling fan that extends offshore and gradually decreases in thickness towards the Continental Rise (spectrum from green to dark blue).

A series of isopach maps of individual sequences of the post-rift sedimentary cover of the basin was also created. Based on the seismic resolution of Leplac seismic lines, four seismic sequences were identified and mapped in the area. Dating of these sequences was constrained by the chronostratigraphic interpretation of the data set published by Abreu (1998). The four mapped seismic sequences are: (Figure 5):

- **Seismic sequence 1** – (from the acoustic basement to the top of the Maastrichtian)
- **Seismic sequence 2** – (from the top of the Maastrichtian to the top of the Upper Eocene)
- **Seismic sequence 3** – (from the top of the Upper Eocene to the top of the Oligocene)
- **Seismic sequence 4** - (from the top of the Oligocene to the present sea-bottom)

The isopach map of the **sequence 1** (from the basement to the Maastrichtian) shows that a major depocenter (thickness of 3.9 km) developed continually along the coast. To the south of the Chuí lineament this depocenter extends to offshore while to the north its extension is confined at the Continental Margin and its limits are quite irregular featuring reentrance and protuberance (Figure 6).

The isopach map of the **sequence 2** (from the Maastrichtian to the Upper Eocene) reveals a very heterogeneous pattern of the sedimentary distribution illustrated by isolated depocenters (D1, D2 and D3). The depocenter (D1), which features the greater thickness (1.6 km), is located close to the coast and has a noticeable connection with the depocenter D2 (thickness of 800 m). While the depocenter D3 (thickness of 700 m) is located offshore and is completely isolated from the others (Figure 7).

The isopach map of the **sequence 3** (from the Upper Eocene to the Oligocene) shows a similar distribution of the depocenter as the one of sequence 2, with three major depocenters (P1, P2 and P3) distributed heterogeneously over the margin (Figure 8).

The isopach map of the **sequence 4** (from the Oligocene to the Recent) presents a major depocenter distributed homogeneously with a thickness varying from 1.8 to 3.0 km (Figure 9).

Main geologic processes and features controlling the depocenter configurations of the Pelotas basin

The major depocenter of sequence 1 developed closer to the margin, and represents a continuous prograding sequence.

During the interval Maastrichtian - Upper Eocene (sequence 2), the deeper basin was also an area of important sedimentation but deposition took place as segmented depocenters (depocenters D1, D2 and D3). Depocenter D3 is isolated due to a noticeable topographic high. This basement high was probably a result of a syn-depositional crustal uplift generating normal faults that remained active until the Oligocene (figure 7 and 10). Depocenters of sequence 3 presents much the same configuration, where depocenter P3 is isolated from the proximal margin due to the syn-depositional local crustal uplift (Figure 8 and 10). So this topographic high in all probability controlled the distribution and depocenters segmentation of both sequences 2 and 3. Therefore, from the Maastrichtian to the Oligocene, the major depocenters of the basin seem to have been displaced towards the offshore area. On the other hand, depocenters D2 and P2 (sequences 2 and 3, respectively) are apparently continuous from the Continental Margin to the offshore area. It seems then that the topographic high described above did not act as an obstruction to sediment flux. One can infer that either the uplift was not elevated enough to obstruct the sediment bypass or possibly that there was no uplift at all at this portion of the margin.

During the interval Oligocene to the Recent (sequence 4), the main depocenter corresponds to the Rio Grande Cone - a thick fan-like sedimentary wedge. Sediment accumulation rate was extremely high during this time interval. An estimation of accumulation rates were calculated for the four sequences identified in this work. According to Damuth (1973, *apud* Gorini *et al*. 1984), accumulation rate during deposition of the sequence 4 is as high as rates for the Amazon Cone (100 meters/million years). The particularly high accumulation rates in this time interval of the South Brazilian Continental Margin may probably be related to the severe thermal subsidence and flexural process of the crust, which became intensified since the Miocene.

An isopach map of the Mid Miocene-Recent sequence helps to determine the real extension of the Rio Grande Cone (Figure 11). This map shows a fan-shaped sedimentary feature extending towards the Continental Rise, whose deposition is active since the Miocene. The limits of the cone, as suggested by the isopach map, are not located as far as those indicated by Basseto *et al*. (2000). Actually, the southern outer limit of the Cone seems to have undergone noticeable erosion. The sudden seaward reduction in the sediment thickness is probably related to the action of bottom currents, which erodes internal reflectors, as depicted by dip lines along the Rio Grande Cone (Figure 9 and 12). The northern limit of the

Cone, on the contrary, is structurally controlled by the presence of the Arco de Torres, which acts as a barrier to sediment flux (Figure 9 and 13).

Conclusions

Previous studies related the sedimentary evolution of the southern Brazilian margin (depocenter location and configuration) mainly to basin subsidence under the influence of structural highs.

In our work, mapping of a series of seismic sequences revealed a varying impact of structural highs through time. Besides, isopach maps of identified sequences show rather segmented depocenters from the Eo-cretaceous to the Recent. Depocenter segmentation is probably conditioned by superimposed geological processes such as bottom currents. As an example, the upper units of the Rio Grande Cone are definitely related to the action of bottom currents, which are responsible not only for the sedimentary features recognizable on seismic data, but also for partially defining its limits by erosion.

Finally, our work represents an initial approach to the sedimentary architecture of the southern Brazilian margin. Further study is essential to assess the relation of dynamic processes with the depocenter evolution through time and space.

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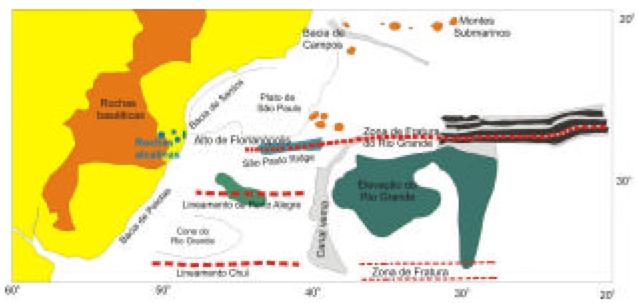

Figure 1: Synthetic map showing the main features of the southern Brazilian Continental margin: crustal discontinuities aligned in an EW direction; volcanic highs (Dorsal de São Paulo and Arco de Torres); Rio Grande deep-sea Cone and Rio Grande Rise (Figure modified from Gamboa *et al*., 1981)

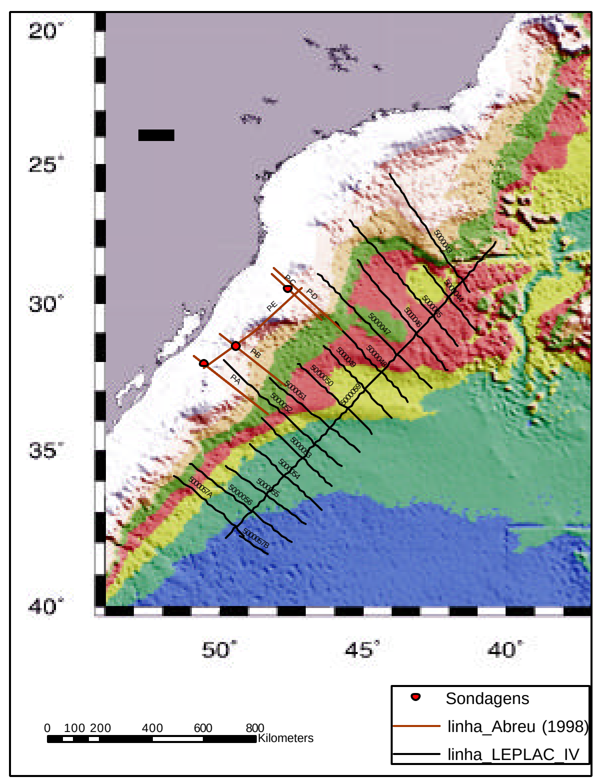

Figure 2: Seismic data base (Abreu, 1998 e LEPLAC-IV) overlapping a bathymetric map

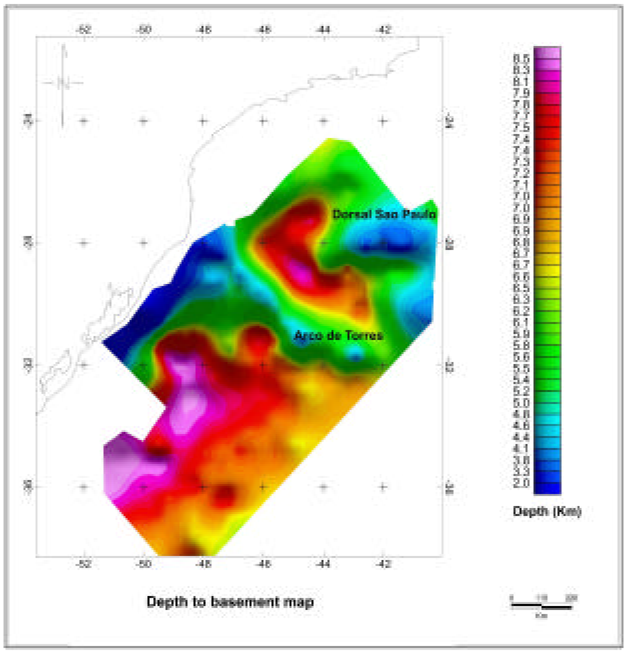

Figure 3: Depth to basement map

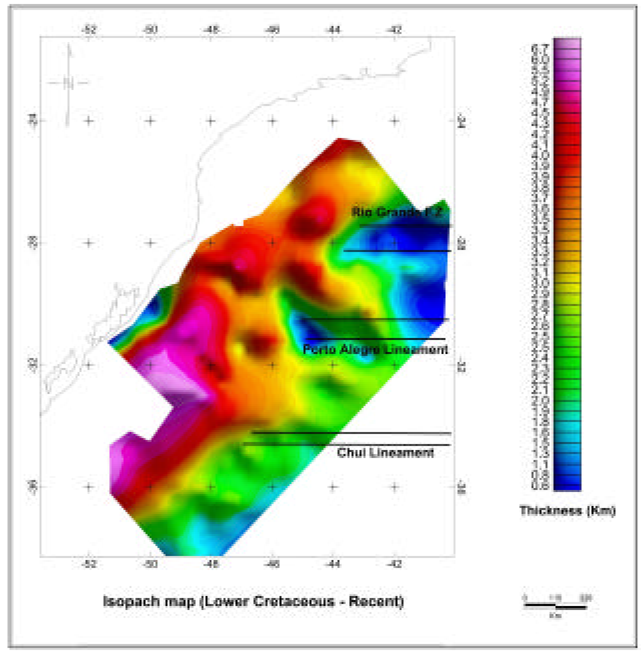

Figure4: Isopach map showing the main depocenters at the Pelotas basin confined by volcanic highs.

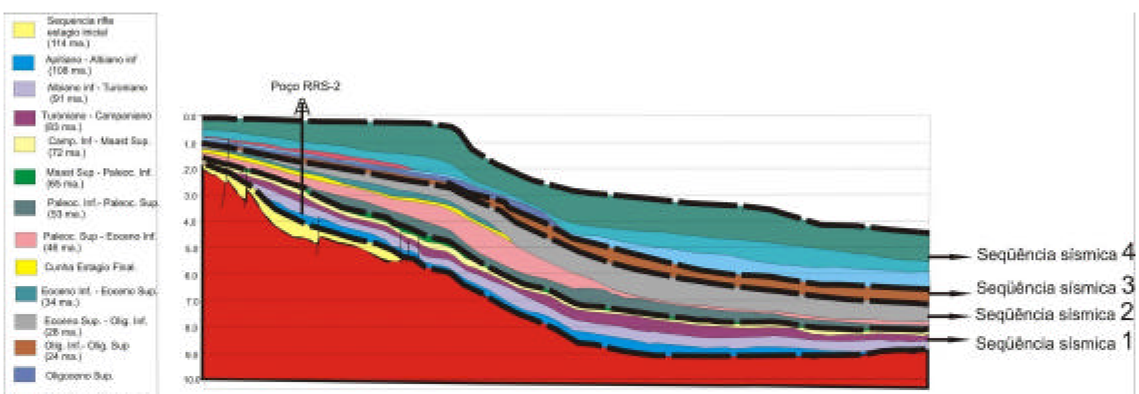

Figure 5: Dotted lines represent limits of the four sequences identified and mapped in the present work (modified from Abreu, 1998).

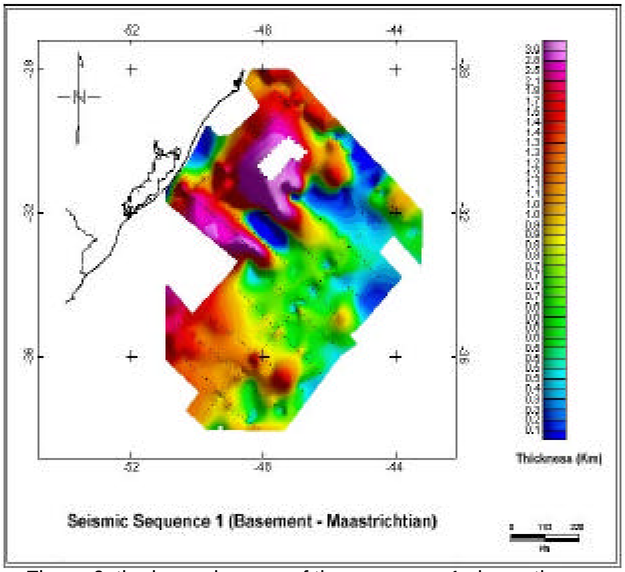

Figure 6: the isopach maps of the sequence 1 shows the major depocenter close to the margin.

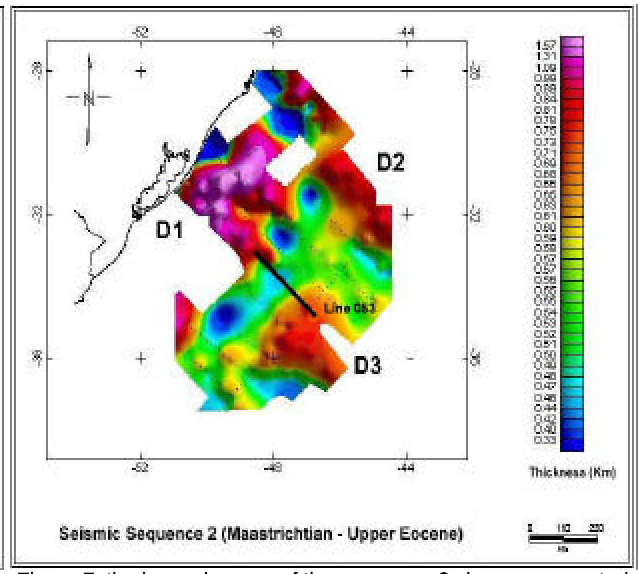

Figure 7: the isopach maps of the sequence 2 shows segmented depocenters. The dip seismic line 053 is highlighted in the picture.

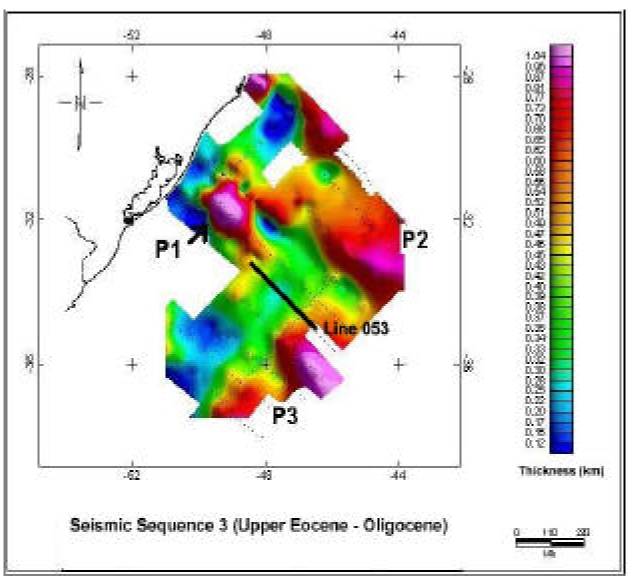

Figure 8: Isopach map of sequence 3 shows segmented depocenters, similarly to sequence 2. The dip seismic line 053 is highlighted in the picture.

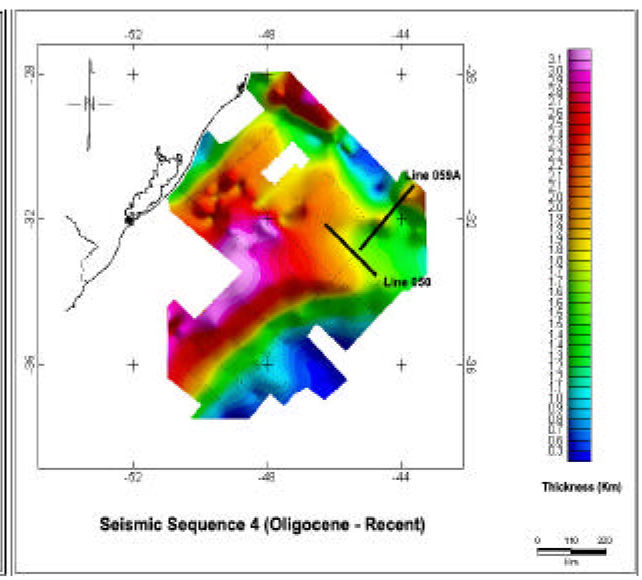

Figure 9: The isopach map of the sequence 4 shows the Rio Grande Cone development. The dip and strike line 050 and 059A respectively are highlighted in the picture.

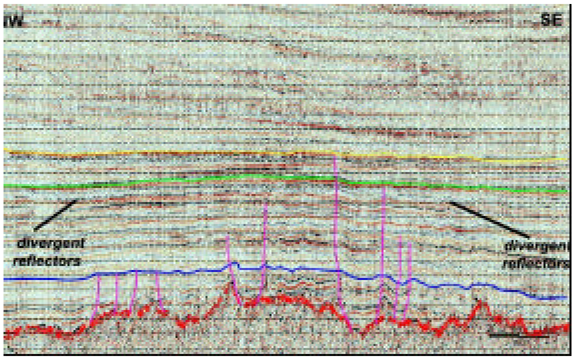

Figure 10: Dip seismic line 053 (Leplac-IV) showing the divergent pattern of the reflector, which indicates crustal syn-depositional uplift. The normal faults were active until the Oligocene (yellow reflector). Vertical scale represented in second.

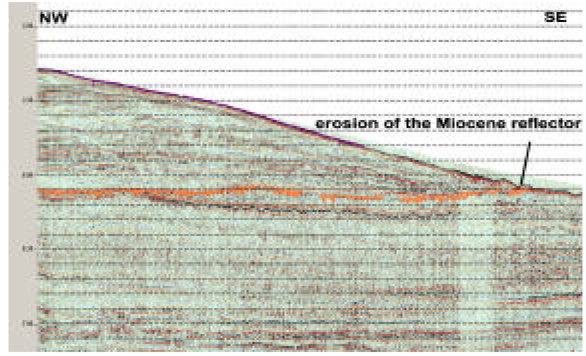

Figure12: Dip seismic line 050 (Leplac-IV) shows a sudden seaward thinning in the sediment thickness of the Rio Grande Cone, probably caused by current bottom. Vertical scale represented in second.

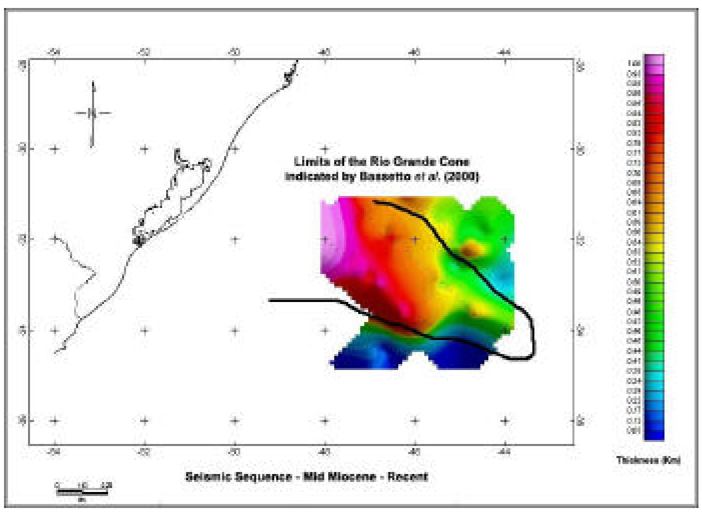

Figure 11: Isopach map (Mid Miocene – Recent) showing outer limits of the Rio Grande Cone, proposed in this work.

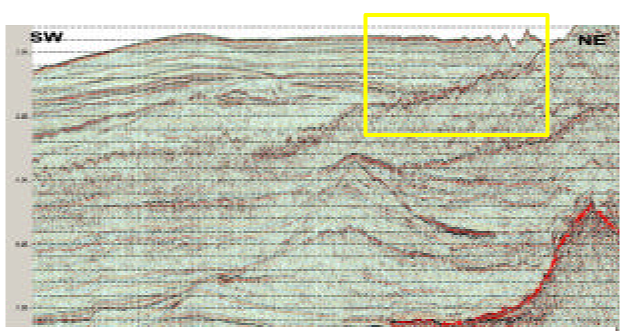

Figure 13: Zoom area in line 059A (Leplac-IV) showing the onlapping termination of sedimentary units of the Rio Grande Cone over the Arco de Torres. Vertical scale represented in second.