THE DEFINITION OF THE BASE OF THE SLOPE ON THE AMAZON DEEP SEA FAN

Izabel King, JECK - Directorate of Hydrography and Navigation (DHN) / Brazilian Navy - izabel@chm.mar.mil.br
Ana Angelica Ligiero, ALBERONI - Directorate of Hydrography and Navigation (DHN) / Brazilian Navy - ana.angelica@chm.mar.mil.br
Luiz Carlos, TORRES - Fundação de Estudos do Mar - torres.luizcarlos@gmail.com

Abstract

According to UNCLOS Article 76 and to CLCS/11 the first step to define the extended continental shelf is the identification of the base of the slope. In this paper the authors present some possibilities to define the base of the slope in the Amazon Deep Sea Fan area, where the classical definition of Heezen et al.(1959) is not applicable.

The Amazon Fan is a unique physiographic feature of the Brazilian Continental Margin. The huge sediment accumulation coming from the continent triggered an intense progradation of the margin. The continental shelf is the widest one and there are no typical continental slope and rise, instead, there is a continuous slope from the shelf break to the Demerara Abyssal Plain, rarely interrupted by locally erosive or constructive features.

In this context one possibility to define the base of the slope is analyzing the geological processes throughout the Upper, Middle and Lower Fan, in order to identify similarities and differences on the slope/rise sedimentary processes.

This paper represents solely the authors' points of view and does not necessarily reflect the Brazilian Government views.

1. Introduction

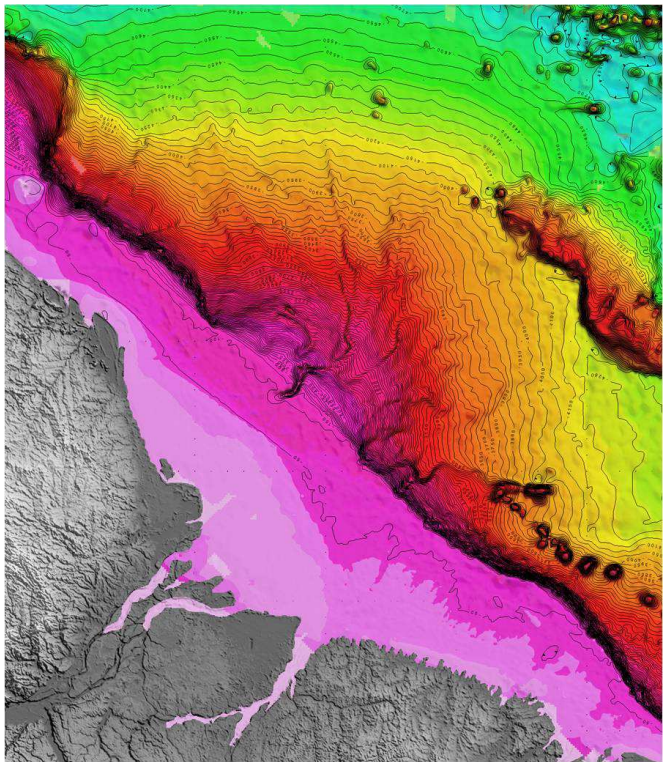

Figure 1- Bathymetric map of Amazon Fan.

The Amazon Fan is a unique physiographic feature of the Brazilian Continental Margin, associated with a complex geology. It is one of the largest fans in the world, reaching 700 km offshore from the shelf break. It is a natural prolongation of the Brazilian Continental Margin, covering approximately 375.000 km^2 of area, and approximately 700.000 km^3 of volume.

The physiography of this region was formed by intense terrigenous sedimentation with restricted areas of carbonate deposition on the continental shelf. As a consequence of the predominance of the terrigenous sedimentation, the continental shelf is broad, reaching up to 350km width in front of the wide Amazon gulf.

The continental shelf and rise are affected by the anomalous high sedimentation of the Amazon Cone and are

an undivided ensemble, starting at the shelf break down to depths of approximately 4,800 m at the boundary with the Demerara Abyssal Plain (Fig. 1).

The cone was classically divided by Damuth, 1973, Damuth et al., 1983 and Damuth et al., 1988, in three distinctive portions: upper, middle and lower cone (Fig. 2).

The upper cone is characterized by the presence of the Amazon Canyon, with up to 500 m of relative relief. There are also present local bathymetric irregularities associated to mud diapirs, extensive areas of slump, slide and debris flow scars, dip slopes and the meandering channel-levee systems associated with a low and continuous gradient of the ocean floor similar to a flood plain in a subaerial environment.

In the middle cone, although the canyon and its distributaries are still present, the channel-levee systems are abundant. These channels are identified through their talwegs and parallel sediment deposits (channel-levees). The middle portion of the Amazon Cone is strongly influenced by these channel-levee systems.

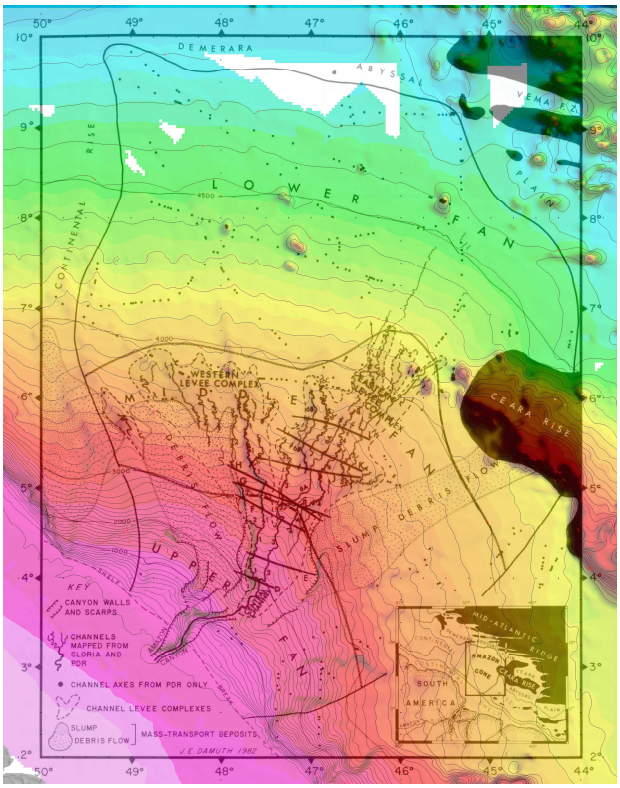

Figure 2 - Amazon Fan division according Damuth integrated to the batymetric map.

Towards the lower cone region the channel-levee systems gradually decrease in height and width, after unloading their sediments throughout their courses.

At the lower portion of the Amazon Cone the gradient is even lower that in the middle portion. The seafloor is rather regular and smooth, depicting very small erosive channels. The presence of quartz sand turbidites is abundant, originated from submarine slides coming from the upper portions of the cone and depositing as sheet flows that extend seaward into the Demerara Abyssal Plain.

In a general way, the processes in the Fan are continuous from the shelf break to the deep ocean floor.

Recently, new studies of the Amazon region made possible mapping in detail the huge areas where Mass Transport Deposits occur (MTD). Those detailed studies have shown that mass-transport deposits have been recurrent elements in the "Foz do Amazonas" Basin from the Middle-Miocene to Recent. In regions located to the NW and SE of the Amazon Deep-sea Fan, mass movement processes remobilized thick siliciclastic series (up to 1,000 m) as huge megaslide deposits over areas up to 90,000 km^2 (Silva et al., 2010).

2. Defining the base of the slope

According to UNCLOS Article 76 and to the Scientific and Technical Guidelines (CLCS/11) the first step to define the extended continental shelf is the identification of the base of the slope. In a situation like in the Amazon Fan, where the classic morphological description of slope and rise are not applicable, where could the base of the slope be defined?

The first approach could be a simple and morphological one: trying to find some regional break in gradient. If we analyse the bathymetric map of this region (Fig.1) it becomes clear, by

the contours lines, that the fan surface is smooth and continuous and there is not an abrupt and regional break in gradient and by the consecutive bathymetric profiles (Fig.3). The statement may be corroborated by the consecutive bathymetric measured profiles recently acquired by the Brazilian continental shelf project - LEPLAC. Although, the presence of canyons, channel levees and mass transports in isolated parts of the fan produce some local changes in the gradient over these locations.

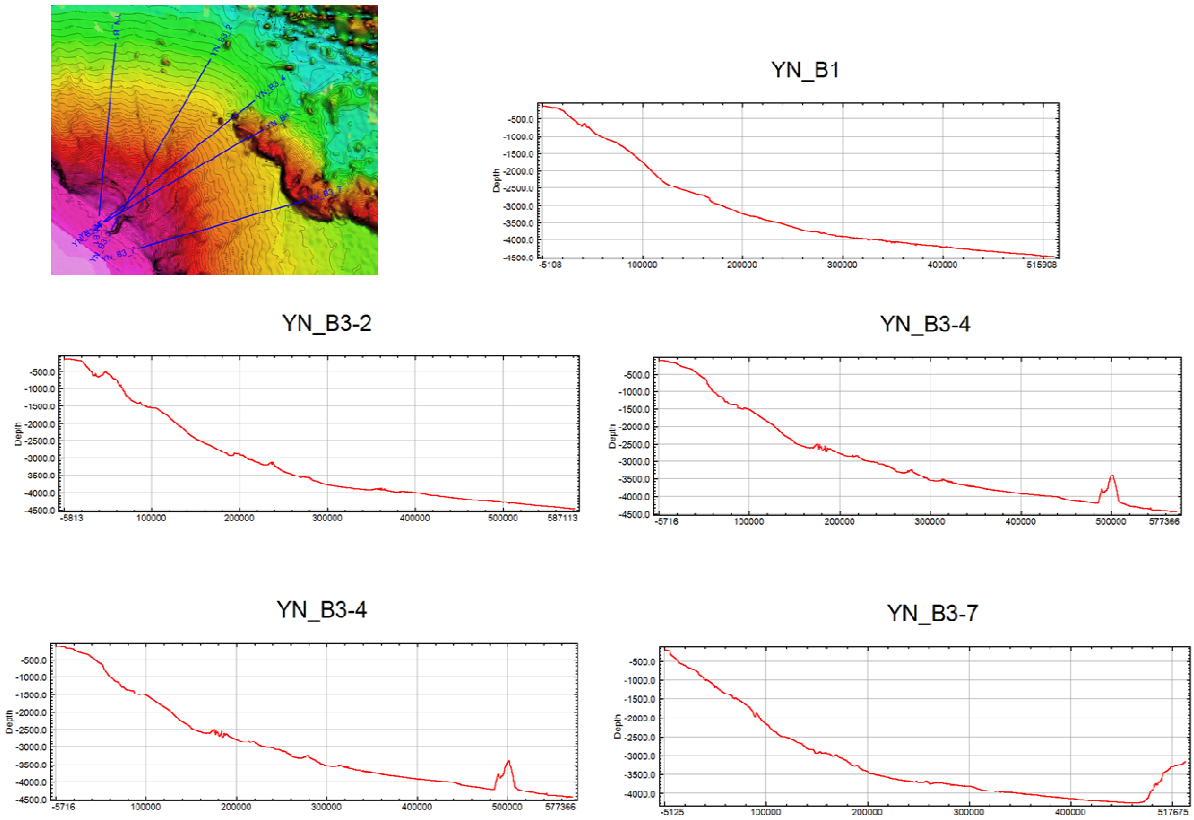

Figure 3-Bathymetric profiles in the Amazon Fan.

The curvature map of Amazon (figure 4), indicates the same smooth characteristic. The left image shows the view from the top, the right image shows a 3D viewing from NE. The red indicates concavity the blue convexity and the white planar. The yellow row indicates the Amazon Fan region. It is visible that the continuity of the convexity and concavity in both sides of the fan are interrupted due to the peculiarity of this huge sedimentary feature.

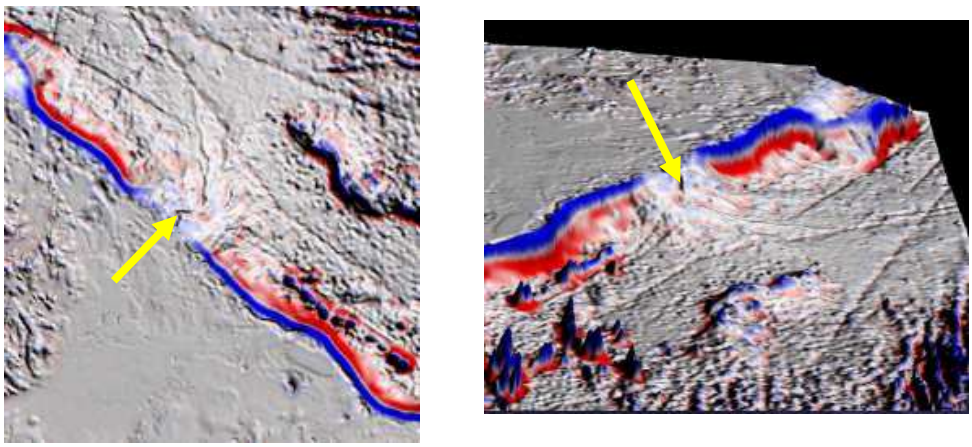

Figure 4- Curvature map of the Amazon Fan.

Therefore, based on current data, this approach seams not be appropriate to be applied in the Amazon Fan.

The second approach could be based on the geological processes that occur in this region, considering the item 5.2.1 of CLCS/11, which states - *Bathymetric and geological data provide the evidence to be used in the geomorphological analysis conducted to identify the region defined as the base of the continental slope...*

Considering that the Amazon Fan is a unique feature formed by a huge sedimentation, and the fact that the processes along the Fan are related to down slope process, varying these processes in intensity and frequency, all the Fan could be considered similar to a slope and its base be defined in its limit with the deep ocean floor.

Another possibility is that, with the exception of mud diapirs, the same geological processes present in the Upper Fan are also present in normal continuation down the Middle Fan, with the same intensity and frequency. Also the submarine slides and associated processes are present on both Upper and Middle Fan interrupting old channel-levee systems. In that situation the Upper and Middle Fan could be assumed as analogue to the continental slope of a normal passive continental margin and the base of the slope could be identified in the region between Middle and Lower fan limits.

Also using the geological processes to identify the base of the slope, the analysis of the extension of the mass transport deposits (MDT) is a possibility. This kind of process is related to a gravitational flow, well known as a slope process. The extension of these deposits in the Amazon region were established based on the interpretation of seismic profiles.

There are two other possibilities to apply Art. 76 and CLCS/11 in areas where the classical division between slope and rise is not clear. The first is to consider the use of Evidence to the Contrary to define the Foot of Slope. The second is to consider that although Article 76 and CLCS/11 do not prescribe the use of single approach to be applied in continental areas where the classical boundary between slope and rise are not clear, they present legal support to be invoked in this situation.

Article 76 states - *the continental margin comprises the submerged prolongation of the land mass of the coastal State, and consists of the sea-bed and subsoil of the shelf, the slope and the rise. It does not include the deep ocean floor with its oceanic ridges or the subsoil thereof*; CLCS/11 deals with the cases where a continental rise does not exist or is not developed in several paragraphs, namely 5.4.4, 5.4.5, 6.2.1, and 6.2.2. In such cases, for instance, paragraph 5.4.4 states: *For the purpose of identifying the region defined as the base, the Commission defines the continental slope as the outerportion of the continental margin that extends from the shelf edge to the upper part of the rise or to the deep ocean floor where a rise is not developed.*….. The interpretation of this paragraph could lead to the conclusion that if the rise is not developed, it cannot be departed from the slope. The base of the slope could be located in the proximity of the end of the continental margin, in an area in contact with the deep sea floor.

3. Conclusions

Some possibilities were discussed in this paper on how to define the base of the slope in areas where there is no noticeable break in gradient between slope and rise. Taking into account the example of the Amazon Fan, the morphological approach does not present itself as a suitable solution, while the use of geological evidence seems to be more appropriate to be used to identify the base of the slope.

The interpretation and the definition of the base of the slope should be done based on the best scientific evidences, trying to fit the classical description of slope and rise with the information obtained, in order to make possible the assumption of an analogue to the continental slope.

If there is no distinction between slope and rise the possibility of locating the base of the slope in the proximity of the end of the continental margin could be considered, in an area in contact with the deep sea floor, or even using the of Evidence to the Contrary to define the Foot of Slope.

Bibliography

HEEZEN, B.C.; THARP, M. and EWING, M. The floor of the Oceans, 1: The North Atlantic. New York, The Geological Society of America Special Paper 65, 122 pages, 1959.
DAMUTH J.E. The western equatorial Atlantic: morphology, quaternary sediments and climatic cycles. Tese de Doutorado. New York, Columbia University, 602 p, 1973.
DAMUTH,J.E.; KOLLA,V.; FLOOD,R.D.; KOWSMANN,R.O.; MONTEIRO,M.C; GORINI,M.A.; PALMA,J.J.C. and BELDERSON,R.H. Distributary channel meandering and bifurcation patterns on the Amazon Deep-Sea Fan as revealed by long-range side-scan sonar (GLORIA). Geology, V.11, N.4, P.94-98, 1983.
DAMUTH, J.E.; FLOOD, R.D.; KOWSMANN, R.O.; BELDERSON, R.H. and GORINI, M.A. Anatomy and growth pattern of Amazon deep-sea fan as revealed by long-range side-scan sonar (GLORIA) and high-resolution seismic studies. Am. Assoc. Petrol. Geol., V.72, N.8, P.885-911, 1988.
SILVA, C.G.; ARAÚJO; E.; REIS, A.T.; PEROVANO, R.; GORINI, C.; VENDEVILLE; B.C.; ALBUQUERQUE, N. Megaslides in the Foz do Amazonas Basin, Brazilian Equatorial Margin. In: Mosher, D.C. et al. (eds.), Submarine Mass Movements and Their Consequences Advances in Natural and Technological Hazards Research, V.28, P.581-591, 2010.