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Seismic geomorphology of channels in X-Block, Penyu Basin

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Abstract: Penyu Basin is a complex, intracratonic basin, situated on the northern Sunda Shelf. This basin formed during Oligocene, and geological setting of this area is a typical Southeast Asian Tertiary rift system. An oil discovery has been made in X-Block of Penyu Basin. However, it was relinquished in 2006 due to the non-commercial oil discovery. X-Block consists of mostly monoclinal structures that do not seem to provide an efficient trapping mechanism because of the very low reliefs. Three wells have been drilled in X-Block and tested primarily on the structural traps, mainly the basement drape structures. This research aims to analyze the stratigraphic traps, focusing on channel features. This is done with the aid from seismic geomorphology. This method helps examine buried landforms by using seismic data as a tool. By seismic geomorphology study, several channel features can be recognized. Most of the channels can be found in upper and middle part of the seismic section. As going deeper to the bottom section, only lineaments of faults are visible. In the upper part of the seismic section, straight and long channel features can be observed and as moving downwards, the channel sinuosity increases resulting in meandering channel. From this seismic geomorphology study, it confirms that there are channel systems in X-Block of Penyu Basin.

Keywords: Penyu Basin, stratigraphic traps, channel-fill trap, seismic geomorphology, channel features

INTRODUCTION

Penyu Basin is an intra-cratonic basin located offshore, east of Peninsular Malaysia. Sediments in this basin were derived from the area of shallow pre-Tertiary basement to the west, generally less than 1 km thick. This research focuses on the X-Block, ca. 890 km^2, located at north-east of Penyu Basin (Figure 1).

In the early 1990's, four-fold seismo- lithostratigraphic subdivision of Penyu Basin were identified (Figure 2). The formations, in ascending order are: Penyu, Terengganu, Pari and Pilong Formation. This study targets to delineate the channels in Terengganu up to Pilong Formation. Penyu Formation consists of interbedded sandstone and shale, deposited in alluvial and lacustrine environments. During Late Oligocene, Penyu Basin subsided to about the sea level and was affected by marine incursions. This is evidenced by palynomorph assemblages in the formation, which indicates an increasing marine influence, as the basin evolved. In Miocene, Terengganu and Pari formations were deposited in alluvial and coastal plain settings. Both formations consist of mudstone/shale interbedded with fine- to coarse-grain sandstone. The Pilong Formation (youngest strata) was deposited at nearshore to shallow marine environment, and it comprises of sandstone and mudstone/shale.

Three wells (i.e R-1, R-2 and R-3) have been drilled in this area to test the basement drape structures. Oil has been discovered in R-1, but no hydrocarbon was found at R-2 and R-3. These wells were drilled on structural targets, but the reservoirs encountered were possibly laterally discontinuous. The aim of this geomorphic

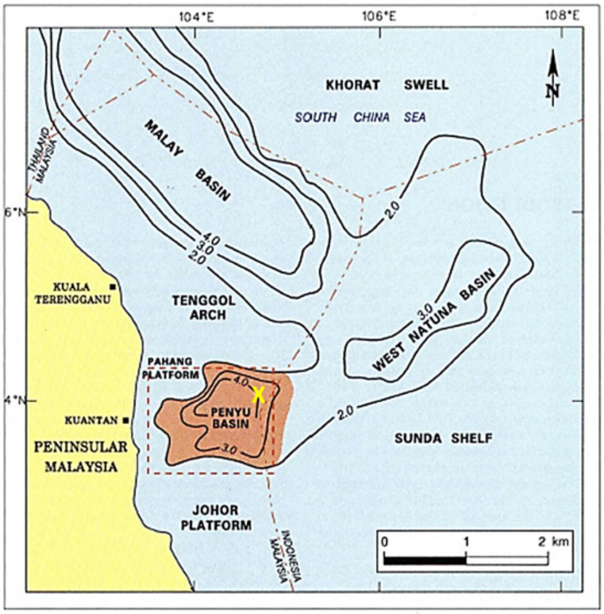

Figure 1: Location of Penyu Basin (Madon & Anuar, 1999) and X-Block (marked by yellow X) (modified from ASCOPE, 1981).

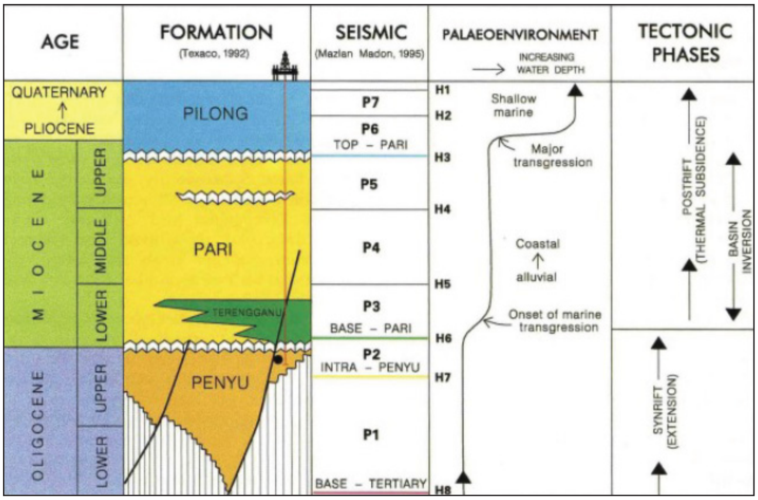

Figure 2: Stratigraphic subdivision of Penyu Basin, which consists of synrift and postrift sequences (Madon & Anuar, 1999).

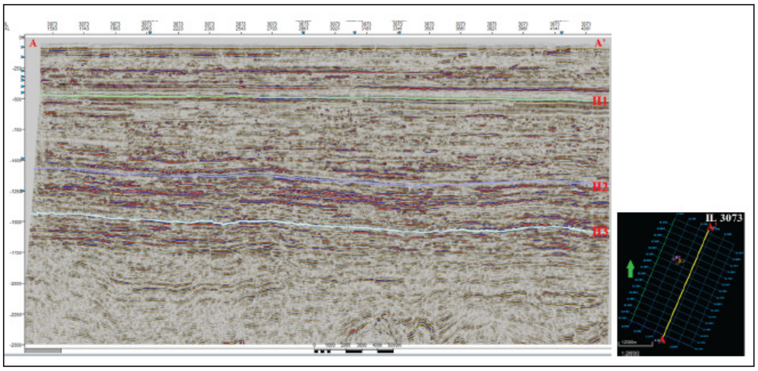

Figure 3: Horizon interpretations at inline 3073.

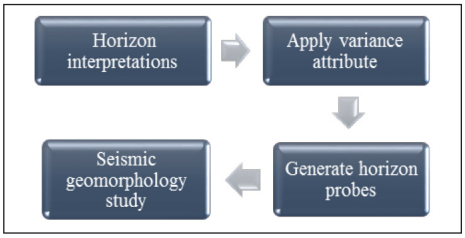

Figure 4: Workflow of study.

study is to delineate the channel systems, to support the stratigraphic distribution of the reservoir beds.

METHODOLOGY

This study is primarily based on horizons interpreted in both 3D inline and crossline, throughout the X-Block. A total of three horizons were interpreted, named as H1 (~-500 ms TWT), H2 (~-1200 ms TWT) and H3 (~1600 ms TWT), as shown in Figure 3. General method used for this study is shown in the flowchart below (Figure 4).

Variance attribute, which is an edge method is used to image the discontinuities of seismic data, which can be related to the stratigraphic lateral distribution. This attribute measures similarity of waveforms or traces adjacent over the given lateral and/or vertical windows. By that, variance attribute is a very effective tool for delineation of channel edges in both horizon slices and vertical seismic profiles. Based on the interpreted horizons, horizon probes are generated respectively to better examine any geological features. Seismic geomorphology refers to the extraction of geomorphic insights using predominantly three- dimensional seismic data, which facilitates the study of the subsurface using plan view images (Posamentier *et al*., 2007). The key in seismic geomorphology is to look for and recognize any geologically or geomorphologically meaningful patterns in plan and section views. Such patterns can take the form of fluvial or deep channels, slumps and slides or any other depositional elements as well as other geologically significant features. By using this method, seismic patterns are interpreted to determine geomorphology of a formation. This is similar to using satellite and aerial photos to portray the earth's surface (Koson *et al*., 2014). Besides, this method can also be used primarily in viewing, mapping subsurface geological features, as well as interpreting structures and stratigraphy away from well controls.

RESULTS AND DISCUSSIONS

A wide channel outline can be clearly observed in the seismic profile (Figure 5a). Horizon probe in Figure 5b, at 60 ms above H1 and 5 ms thickness, shows a relatively straight channel feature with approximately 1.5 km channel width. This channel is visually obvious and continuous as it can be seen in several vertical offsets, as the probe is moved. Several channel features can also be observed in seismic profile at the random line (Figure 6a). The channels are associated with horizon probe at 40

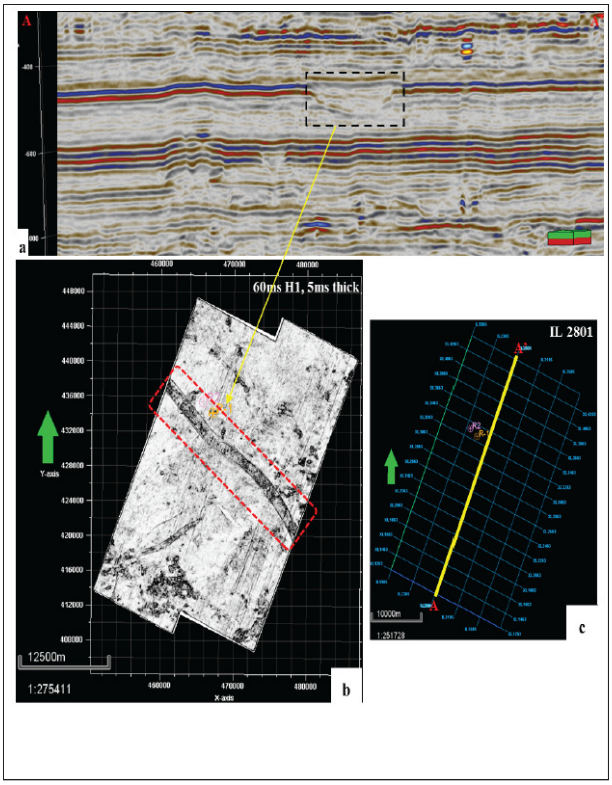

Figure 5: (a) Seismic profile at inline 2801, (b) Horizon probe at 60 ms above H1, and (c) Position of the inline.

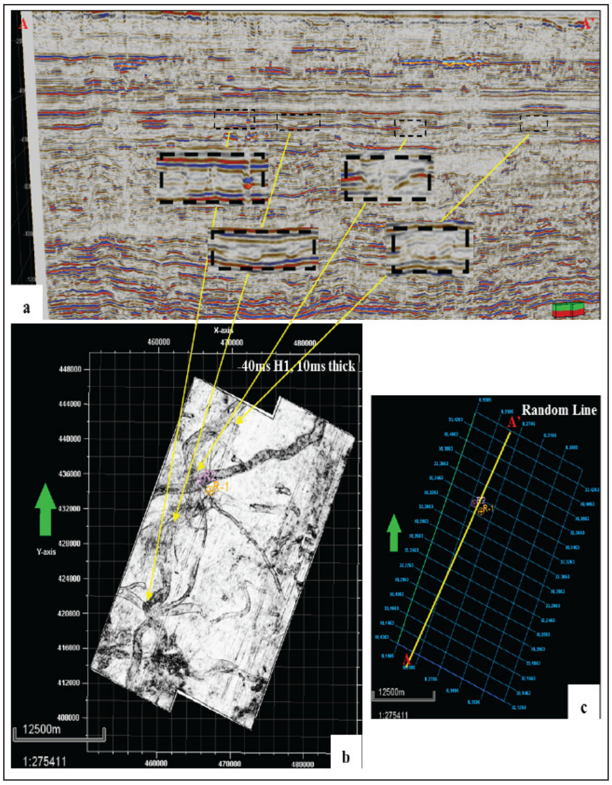

Figure 6: (a) Seismic profile at random line, (b) Horizon probe at 40 ms below H1, and (c) Position of the random line.

ms below H1, with 10 ms thickness (Figure 6b). From the probe, these channels are quite long and they overlap one another. As the probe is moved to 250 ms below H1, a very extensive channel (Figure 7b), measured at 2.8 km channel width can be observed. The seismic profile in Figure 7a also shows a big channel outline. From the profile, the inside of this channel is dominated by low amplitude responses.

Several high amplitude channel features can be identified on the seismic profile in Figure 8a. From the horizon probe at 10 ms downwards, vertical offset from H2 (Figure 8b), a clear medium-sinuosity channel can be seen. There are also several channel features observed in the surrounding area. However, these surrounding channels are not continuous and might overlap with other geological events. From the seismic profile in Figure 9a, a few small channel structures can be detected, and they show high amplitude responses. Horizon probe at -166 ms from H2 (Figure 9b) shows several small meandering, high-sinuosity channels and some of them crisscross each other. This may be due to the channels that were formed at different time intervals, thus forming the indication of stacked channels, on top of one another.

A wide channel feature, with high amplitude can be observed in seismic profile at inline 2769, as shown in Figure 10a. This channel feature is related to the horizon

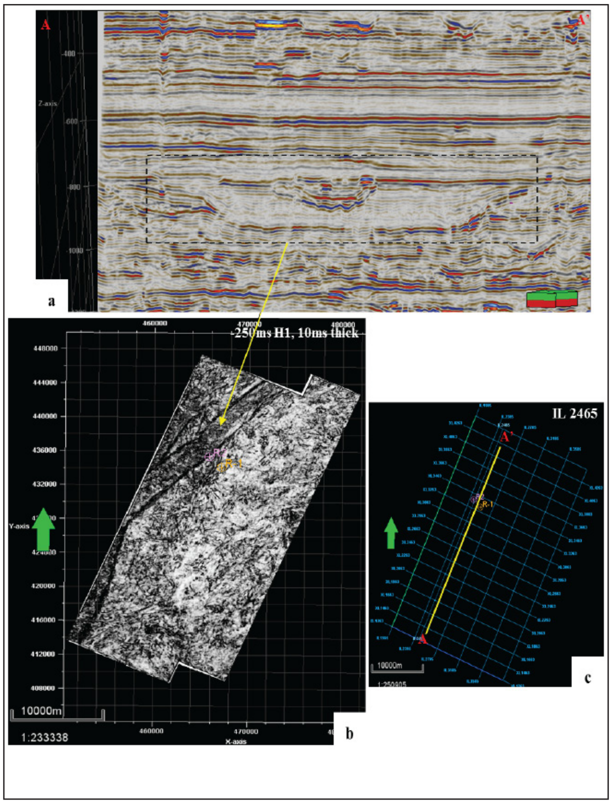

Figure 7: (a) Seismic profile at inline 2465, (b) Horizon probe at 250 ms below H1, and (c) Position of the inline.

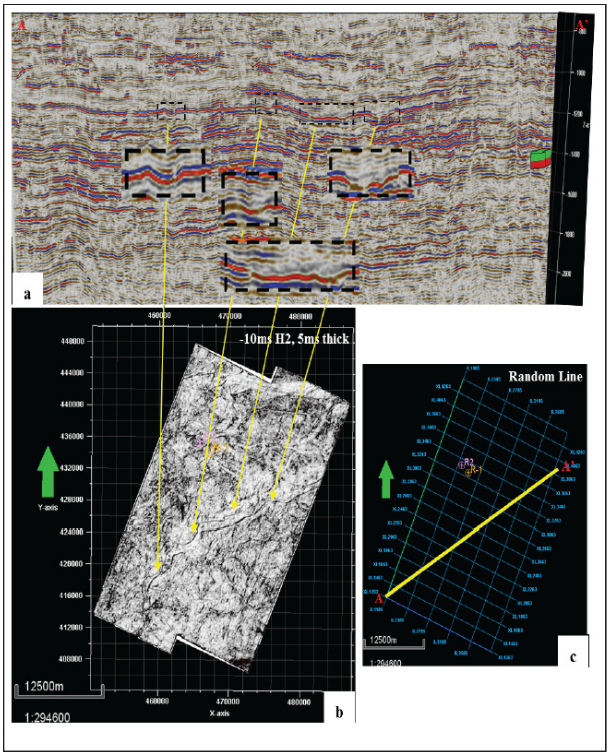

Figure 8: (a) Seismic profile at random line, (b) Horizon probe at 10 ms below H2, and (c) Position of the random line.

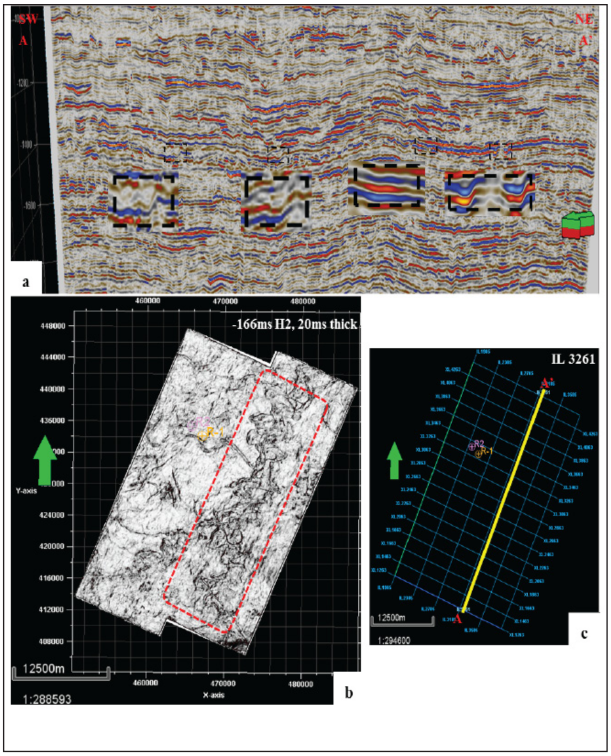

Figure 9: (a) Seismic profile at inline 3261, (b) Horizon probe at 166 ms below H2, and (c) Position of the inline.

probe at 28 ms upwards from H3 (Figure 10b). From the probe, a meander channel, almost the same result as previous probes can be detected. Besides, the edges of this low-sinuosity meandering channel are very clear and it is obvious that the channel is continuous across the study area. No other channel feature can be seen in the surrounding area of the probe. As the probe is moved further downwards from H3, for example at -255 ms from H3 (Figure 11), no more channel features can be observed. Only lineaments (highlighted by red box in Figure 11) are apparent in the probe, which might represent the faults. This is supported by numerous small faults seen in the basement on seismic section (example in Figure 12). This lack of channels in deeper strata reflects a different depositional environment.

CONCLUSIONS

Seismic geomorphology study in X-Block reveals several types of channel features, ranging from relatively straight to meandering channels with different levels of sinuosity. Numerous channel profiles can also be seen throughout the 3D seismic data in the study area. The shape of channels in seismic profiles are clear and wide, with some showing high amplitude responses. These channels are found in upper and middle part of the seismic sections. The deeper, older section only enables the delineation of faults and fracture zones from displacement of synrift systems.

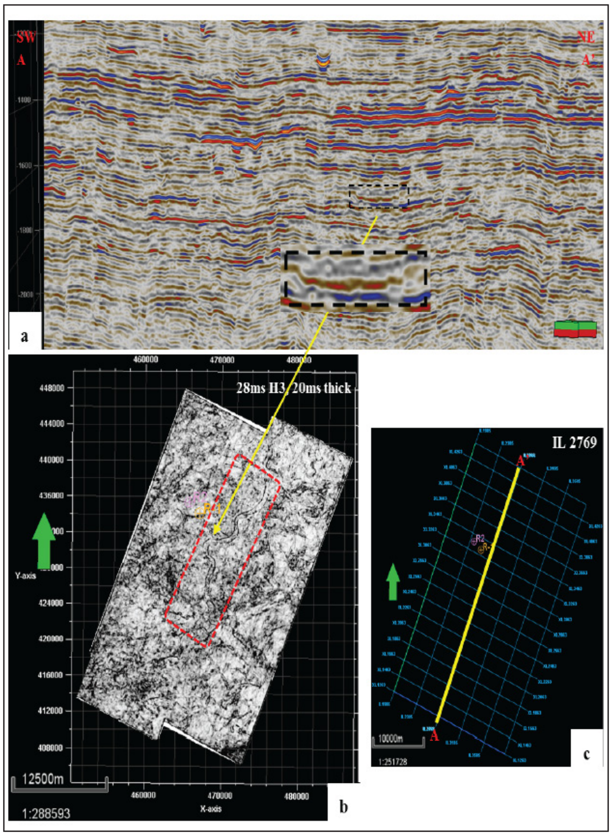

Figure 10: (a) Seismic profile at inline 2769 (b) Horizon probe at 28 ms above H3 (c) Position of the inline.

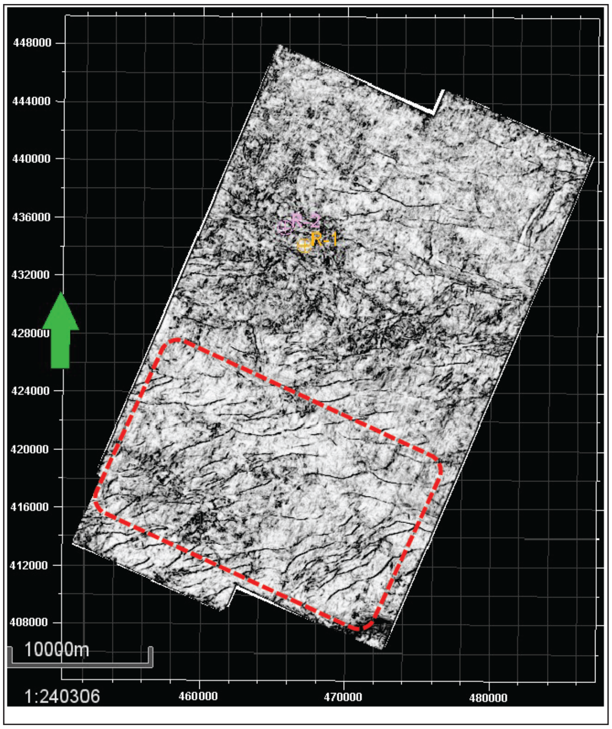

Figure 11: Horizon probe at 225 ms below H3.

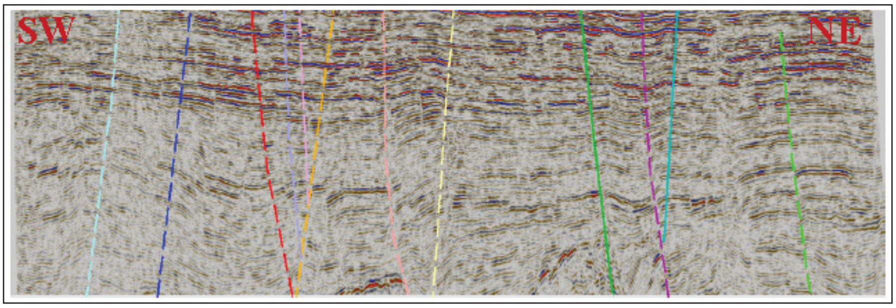

Figure 12: Some of the faults seen in basement area, example taken from inline 2869.

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