SEISMIC EXPRESSION OF KEY GEOLOGICAL FEATURES IN THE EAST NATUNA BASIN

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INTRODUCTION

The East Natuna Basin is located in the southern tip of the South China Sea. It is separated from the West Natuna Basin by a basement high called the Natuna Arch (Figure 1). The Bunguran Trough bounds the eastern side of East Natuna Basin from Sarawak Basin, offshore East Malaysia. The northern part of the East Natuna Basin has similar geological setting with the Nam Con Son Basin, offshore Vietnam.

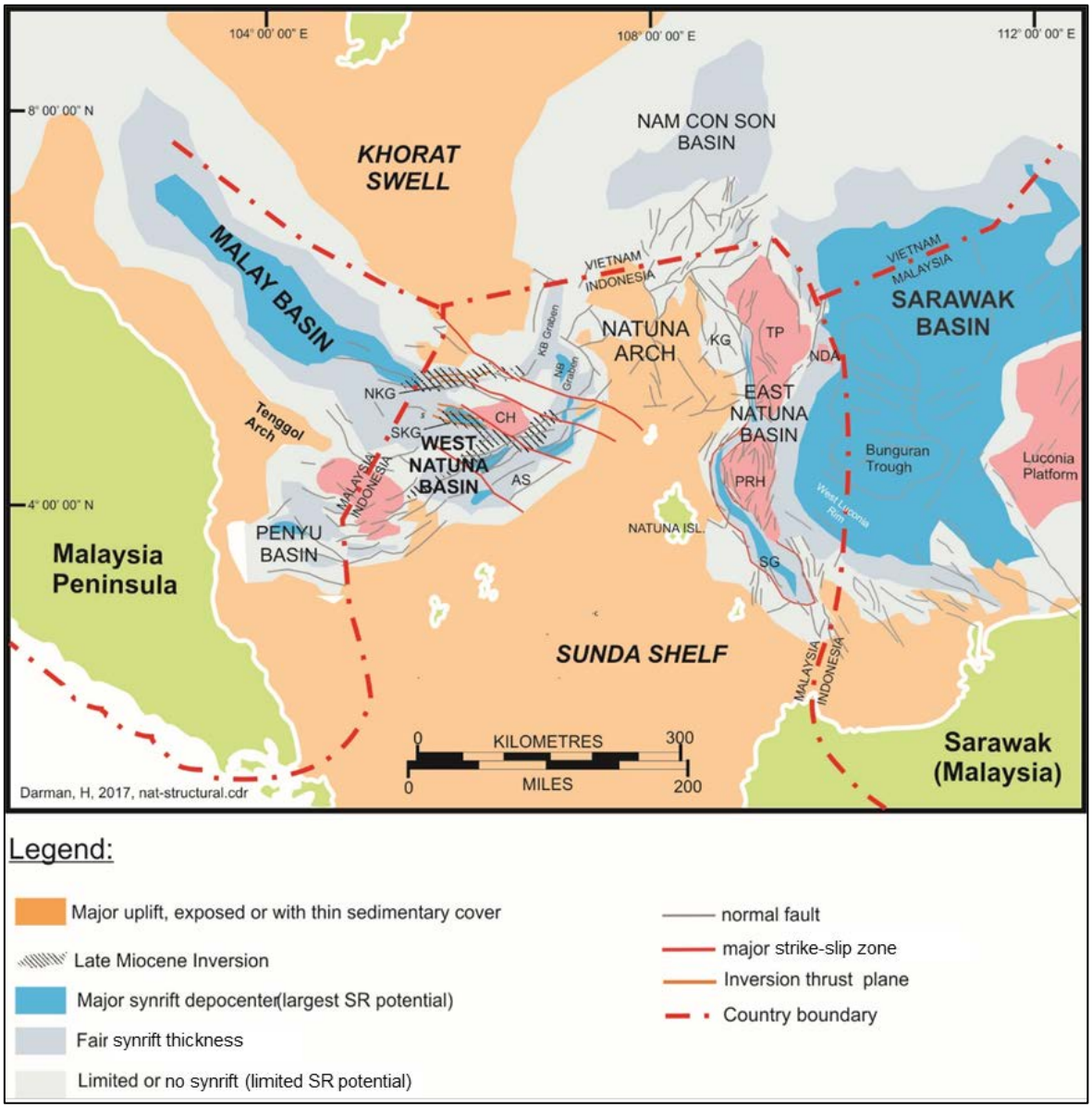


Figure 1: *Regional tectonic framework of the Natuna Region. Natuna Arch with Natuna Island in the middle of the map separates the West and East Natuna Basins. The West Natuna Basin is a southern extension of the Malay Basin in Malaysia, which separates the Natuna Arch from the Khorat Swell. Several Late Miocene inversion features occur in the West Natuna Basin but not in the east. The East Natuna Basin could be considered as the west flank of the greater Sarawak Basin. AS = Anambas Sub-basin, CH = Central High, KG = Komodo Graben, PRH = Penyu-Ranai High, SG = Sokang Graben, SKG = South Kakap Graben, NDA = Natuna D-Alpha, NKG = North Kakap Graben, TP = Terumbu Platform.*

Petroleum exploration activity in this area is relatively low in comparison to it is in the West Natuna Basin. In 1973, Agip discovered Natuna D-Alpha gas field in the East Natuna Basin. The field contains more than 200TCF of gas, but unfortunately, the gas has 71% CO_2 (Dunn & Kozar, 1996). Recently, Premier Oil successfully tested the synrift play in the north of the region by drilling Kuda Laut-1 (2014) and then followed it up in the same year with drilling Singa Laut-1. The results also proved equivalent synrift play in the north within Vietnamese waters. A younger clastic play in the south of the East Natuna Basin was already proven earlier in 2012, by Black Platinum Energy (BPE) as a result of the Dara-3 and 4 drilling campaign.

This article presents a summary of seismic sections published in the area with interesting geological features such as carbonate build-ups, synrift fault blocks and relatively simple anticlinal features at younger intervals. Other potential hydrocarbon accumulations are also discussed here.

DATA

In 1973, Ben-Avraham wrote a dissertation discussing the structural framework of the Sunda Shelf. It was based on regional seismic lines across country borders in the southern part of South China Sea or also called the Natuna Sea region (Figure 2). The seismic data was acquired by Woods Hole Oceanographic Institution, USA. These lines have a spacing of more than 100km, but it is such data that is nowadays not easy to be acquired due to political and procedural issues between the bordering countries.

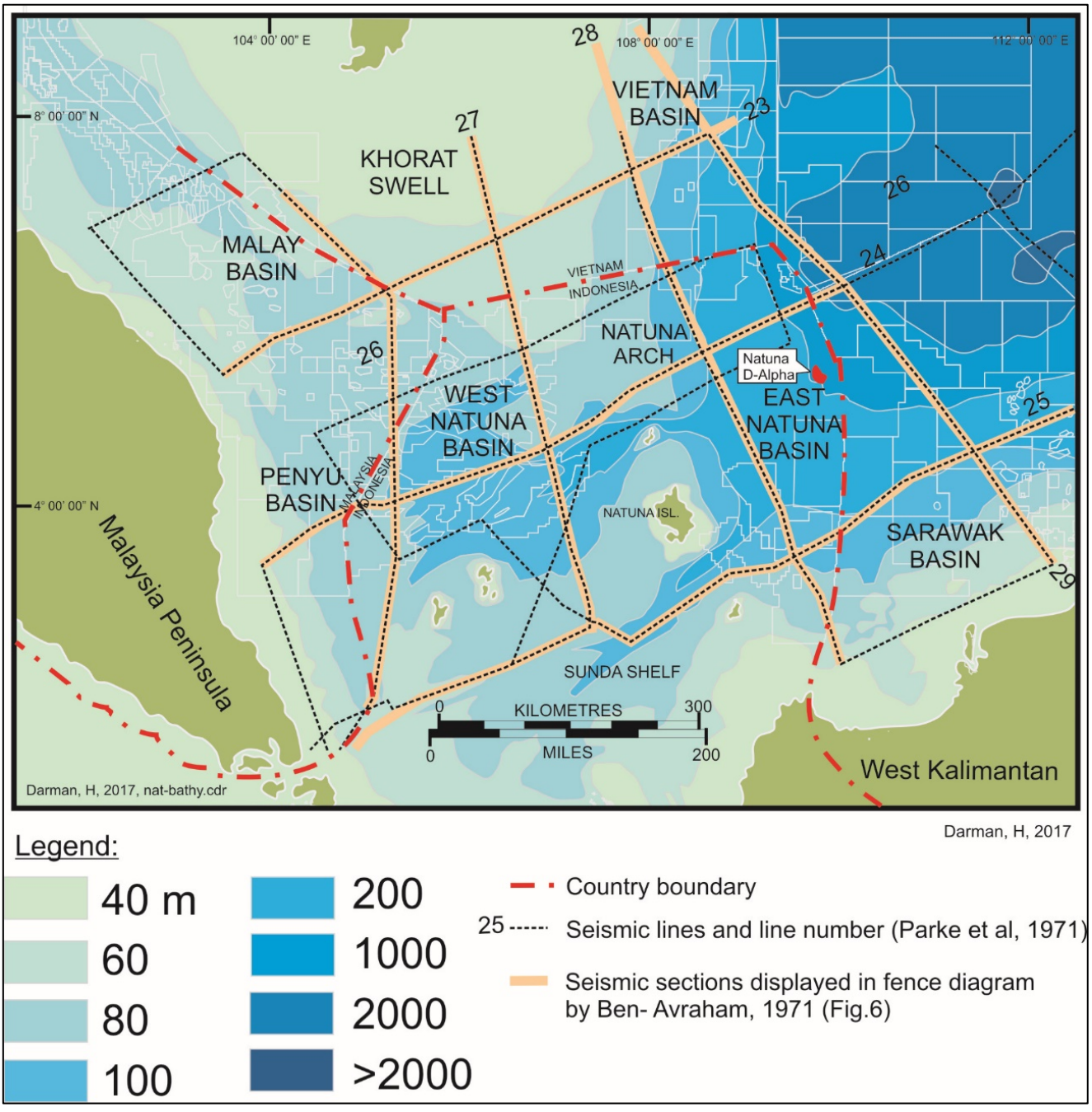


Figure 2: *The bathymetric map of the Natuna region, which includes location of regional 2D seismic lines in Parke et al. (1971) and also the political boundaries of Malaysia, Vietnam and Indonesia.*

In 1995, Nopec acquired in the region a multiclient seismic data set of 8,405km, called SEAS95 seismic survey (Figure 3). Similar to the Woods Hole Oceanographic Institution survey, Nopec data set also went across country borders of Indonesia, Malaysia and Vietnam. The survey was acquired with a 4,500-6,000m streamer using record lengths of 8 and 12 seconds (s). The newer technology provided much clearer image. These seismic data provide ties to key wells in the region. Unfortunately, not much was published from these data sets.

PGS is probably the last seismic company which actively acquired seismic data in the region. They acquired East Natuna 2D in 2009 and Natuna D-Alpha 3D in 2010. The East Natuna 2D survey totals 8,028km, acquired with a 7,950m streamer and record lengths of 8-9s. The Natuna D-Alpha 3D seismic covers 725 sqkm, acquired with a 5,100m streamer using record length of 7,168m (Figure 3). More data sets with pretty dense coverage of the area are available from Patra Nusa. These data were acquired by previous operators in their own concessions, therefore the parameters and quality vary between vintages. Combining seismic lines to produce good quality sections may not be a straight forward exercise with these data.

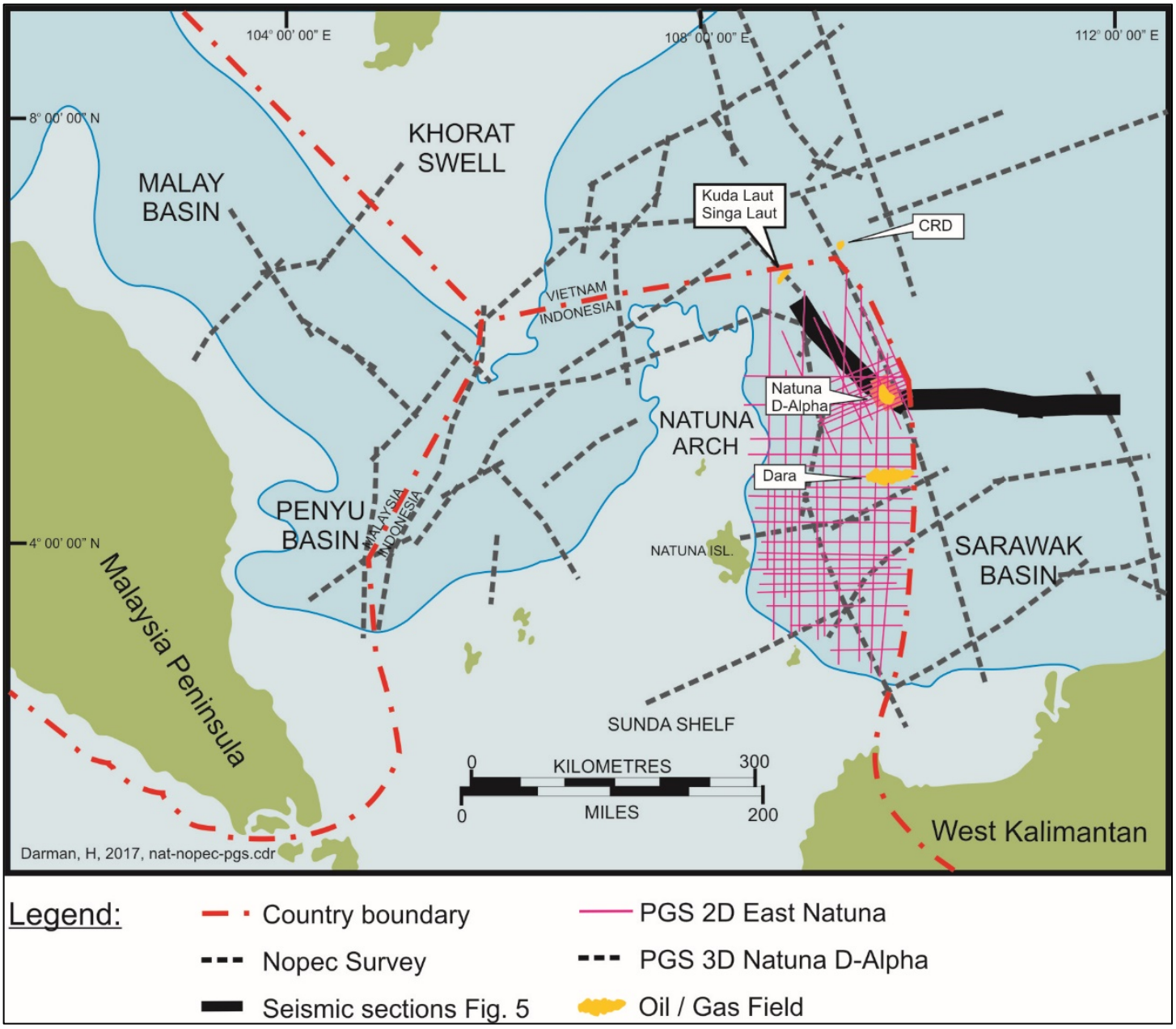


Figure 3: *Location map of multiclient seismic data in Natuna region. TGS by Nopec acquired cross border 2D seismic lines in 1995, which tie key wells in the region. PGS acquired 2D seismic lines in East Natuna in 1998 and then they shot 3D seismic in West Natuna (2009) and another survey that covers the Natuna D-Alpha carbonate field in 2010.*

REGIONAL GEOLOGY

The Natuna region is subdivided into West and East Natuna Basins by the Natuna Arch (Figure 1). A small part of the arch is exposed on the Natuna Island, dominated by Jurassic – Cretaceous metamorphic rocks, covered by an Early Miocene clastic unit in the north (BEICIP-Pertamina, 1982). A granite intrusion occurs in the east of the island and is dated as 73Ma, Campanian, Late Cretaceous (documented by Ben-Avraham, 1973). The West Natuna Basin is the southern extension of the Malay Basin in Malaysia, which separates the Natuna Arch from the Khorat Swell (Figure 1). A number of inverted structures have developed in the area. The oldest sediment sections were accumulated within rift systems of Late Eocene age. The reservoir objectives in this basin usually are Oligocene to Miocene clastics (Figure 4). The East Natuna Basin can be considered as the western flank of the greater Sarawak Basin (Figure 1). Komodo Graben and Sokang Trough (Sokang Graben) separate the Terumbu Platform – Paus-Ranai Ridge from the Natuna Arch. The main depocenter in the Sarawak Basin, located to the east of the East Natuna Basin, is called the Bunguran Trough.

Stratigraphy of the East Natuna Basin use similar formation names to those in the West Natuna Basin, with Upper Gabus Formation as the oldest sediment section and Muda Formation as the youngest. Miocene carbonates in the East Natuna Basin are well-developed, similar to those in the Central Luconia province (Figure 4). A seismic line, which was acquired by Nopec, tied the East Natuna Basin to the Central Luconia province through Bunguran Trough (Figure 5). The Muda Formation in East Natuna is well-correlated to Cycle VI in Sarawak Basin and Central Luconia province. The Miocene carbonates developed in places but the correlation through Bunguran Trough lacks well control.

Ben-Avraham (1973) has drawn a 3D fence diagram based on the seismic data available for his study (Figure 6). Country political borders were drawn on this diagram and key structures were annotated. The Natuna Arch with Natuna Island as part of the arch separates the West and East Natuna Basin.

GEOLOGICAL FEATURES ON SEISMIC

A number of significant geological features were recorded on seismic images. Selected good quality seismic sections, especially those related to oil and gas potential in the area were published. Some common features of them are discussed below.

Carbonate Build-ups

The Natuna D-Alpha Field, discovered by Agip in 1973, made the area famous for its carbonate reservoir potential. The discovery well was AL-1X, drilled to a total depth of 4,189m in the Lower Miocene Arang Formation. The well encountered 1,520m of single gas column to base limestone (Figure 7). The carbonate build-up developed over a local basement high. A 3D seismic section (Figure 8) clearly shows reefal build-up features. The slope carbonates on the right of the section are indicated by red arrows.

The regional section in Figure 5 also shows other carbonate build-ups, most of which were tested by wells. Unfortunately, apart from AL-1X with gas discovery and AP-1X with oil and gas content, most wells are dry. In Bunguran Trough the carbonates could not grow due to higher rate of subsidence and higher clastic input into the basin. Central Luconia province is another area which is rich of carbonate build-ups in Sarawak, Malaysia. It is well known for its large gas potential.

Synrift Fault Blocks

A synrift fault system occurs in the north of the East Natuna Basin and extends to the Nam Con Son Basin in Vietnam (Figure 1). An N-S oriented regional 2D seismic line acquired by PGS (Figure 9) shows a synrift basin developed between basement highs. Created accommodation space was filled with an Eocene to Oligocene clastic system with possible lacustrine shales at the lower part of the section. Potential tallus deposits developed at the flank of the synrift graben. Anticlinal features on the west of the synrift sediment fill show that the boundary fault has been inverted. Both clastic and carbonate units occur in the post rift interval.

The Kuda Laut and Singa Laut fault blocks were the last discoveries in Tuna PSC, East Natuna Basin (Figure 3). Premier Oil discovered Kuda Laut oil and gas field in April 2014, followed by Singa Laut gas field in June 2014. Both wells targeted Oligocene clastic reservoir equivalent to the Gabus Formation (Figure 10). There are still untested fault blocks in the area such as Cacing Laut and Gajah Laut Utara. The NW dipping faults in the area are more prominent as indicated by their fault throws which are larger than the SE dipping faults. Both Kuda Laut/Singa Laut complex and Cacing Laut/Gajah Laut Utara complex are located on basement highs.

The detailed section of Kuda Laut / Singa Laut complex shows an anticlinal component within the Kuda Laut structure (Figure 11). The anticline indicates an inverted structure, and potentially there are hydrocarbon indicators in the section. The Singa Laut structure is located on the west of an eastward tilted fault block.

Premier published a 3D view of the top Oligocene structural map which shows Singa Laut, Gajah Laut Utara structural highs and other similar features in Vietnam. Silver Sillago in Block 07/03, Vietnam was tested dry in March 2014 by Premier (Figure 12). The Ca Rong Do (CRD) structure which is also known as the 'Red Emperor' was a discovery by Talisman in 2009. This structure contains oil and gas in Miocene and Oligocene clastic intervals. Belut Laut and Gajah Laut Utara remain as untested structural highs.

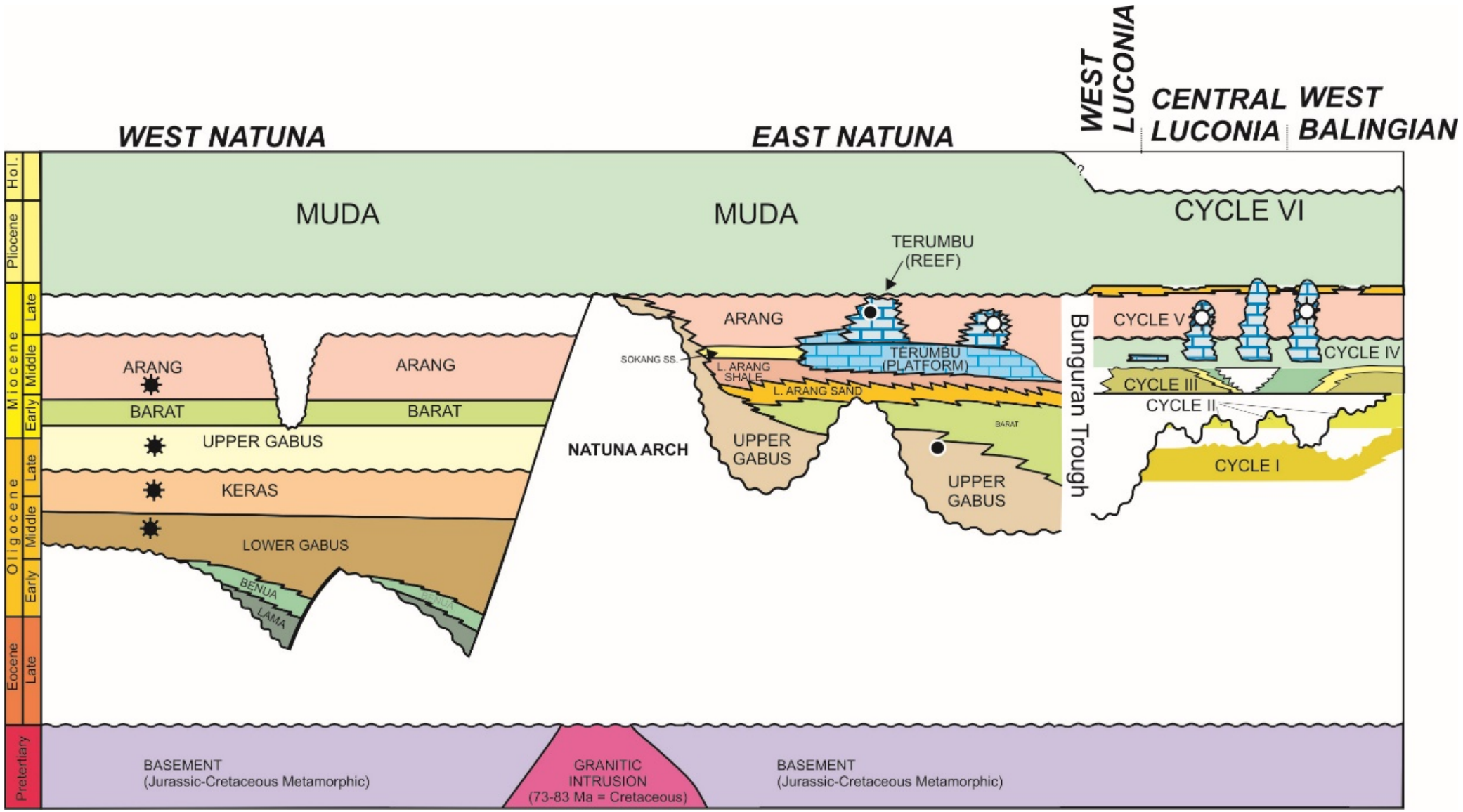


Figure 4: *Chronostratigraphic chart of the Natuna and Luconia region in Sarawak (Malaysia). This panel shows the differences between West and East Natuna, which are separated by the Natuna Arch. Carbonates in East Natuna and Central Luconia developed approximately at the same time but were separated by Bunguran Trough in West Luconia. The clastic system was dominant in Bunguran Trough so that the carbonates could not develop here. Modified from Caughey et al. (1995) by Murti & Minarwan (2000). Luconia and Balingian are based on Hazerbroek et al. (1994).*

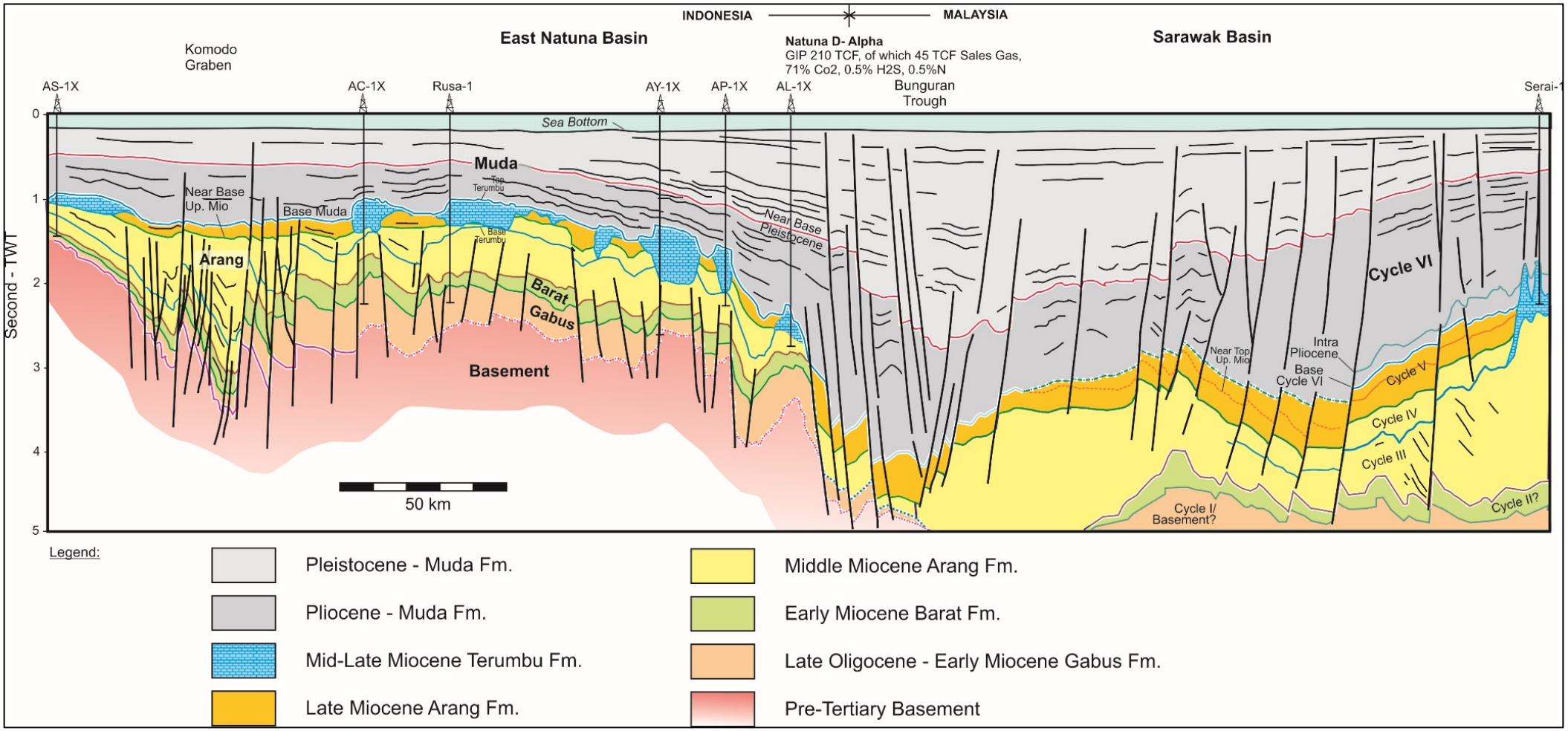


Figure 5: *A geoseismic section that correlates the East Natuna Basin and the western tip of the Central Luconia Basin. In this line, the Natuna D-Alpha giant gas field is tied to a couple of wells in the west and to Serai-1 well in Central Luconia. The section gives further detail to the chronostratigraphic correlation in Figure 4, especially on the correlation of the Muda Formation to Cycle VI and the Arang Formation to Cycle V and IV in Sarawak. Bunguran Trough in Sarawak Basin separates the East Natuna and Central Luconia. Unfortunately, correlation in the deeper part of the trough is weak due to lack of well control.*

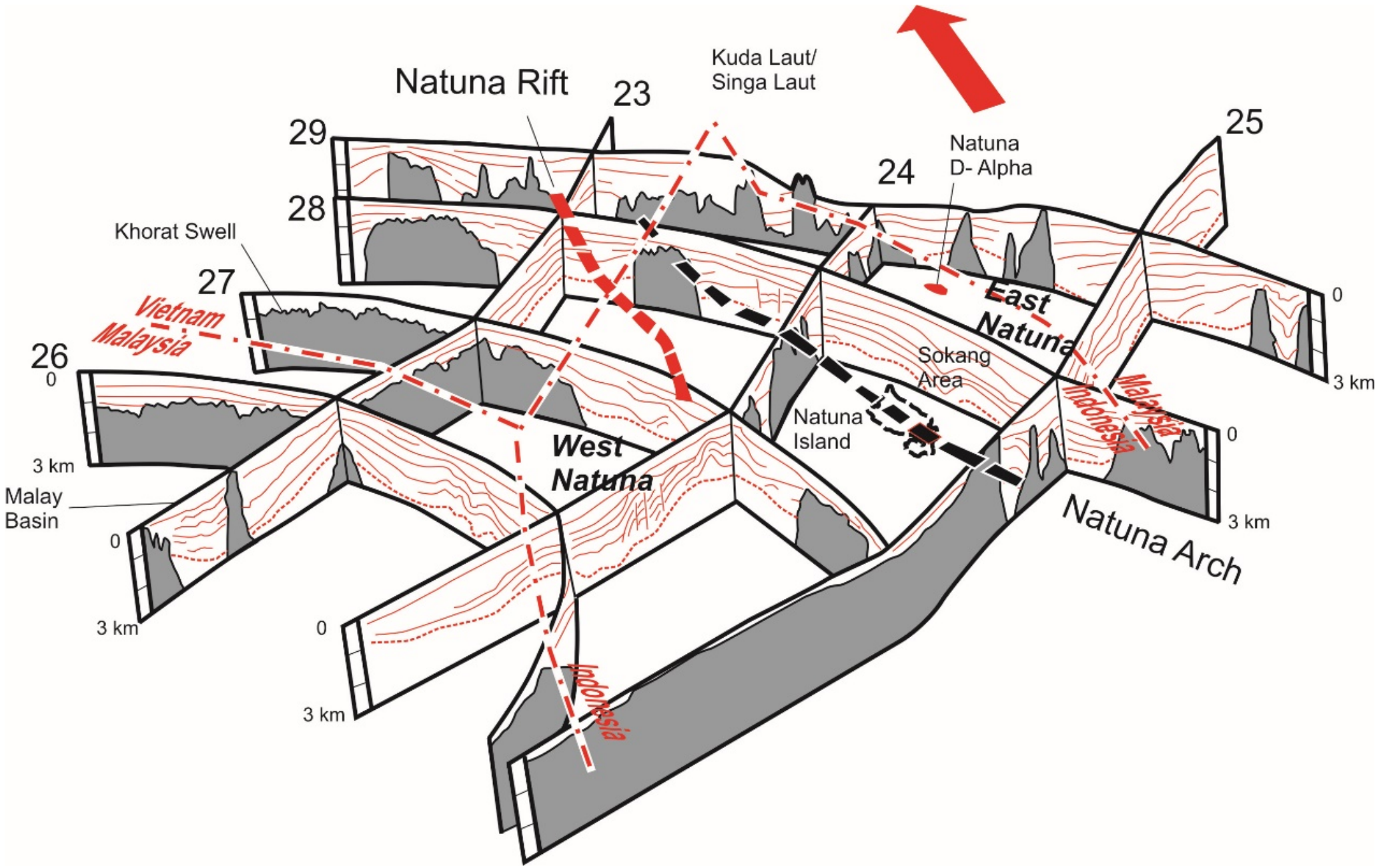


Figure 6: *A fence diagram of the Natuna region, which was modified after Ben-Avraham (1973), provides a regional framework of the region. The grey area is the basement highs and the sedimentary beds were traced on the sections. Natuna Rift in the west of Natuna Arch separates the arch from the Khorat Swell. This section was prepared by using old seismic data and it is probably time to renew the regional picture.*

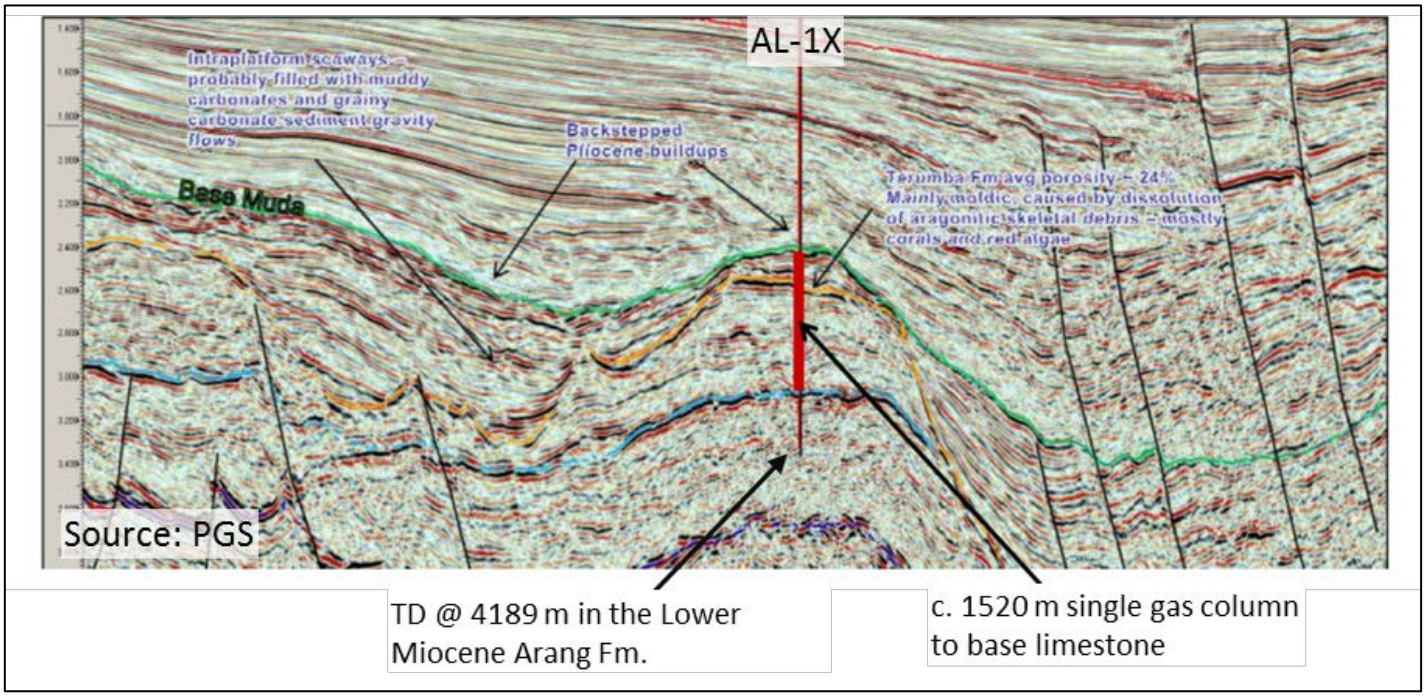


Figure 7: *PGS 2009 seismic line across AL-1X well which penetrated Natuna D-Alpha gas field in west-east orientation. The field has 1,520m of continuous gas column with an average porosity of 24%. The green horizon is the base of Muda Formation and the blue horizon is base Terumbu Formation. PGS indicated back-stepped Pliocene build-ups, intra-platform deposits which probably were filled by shales and reworked materials from the platform.*

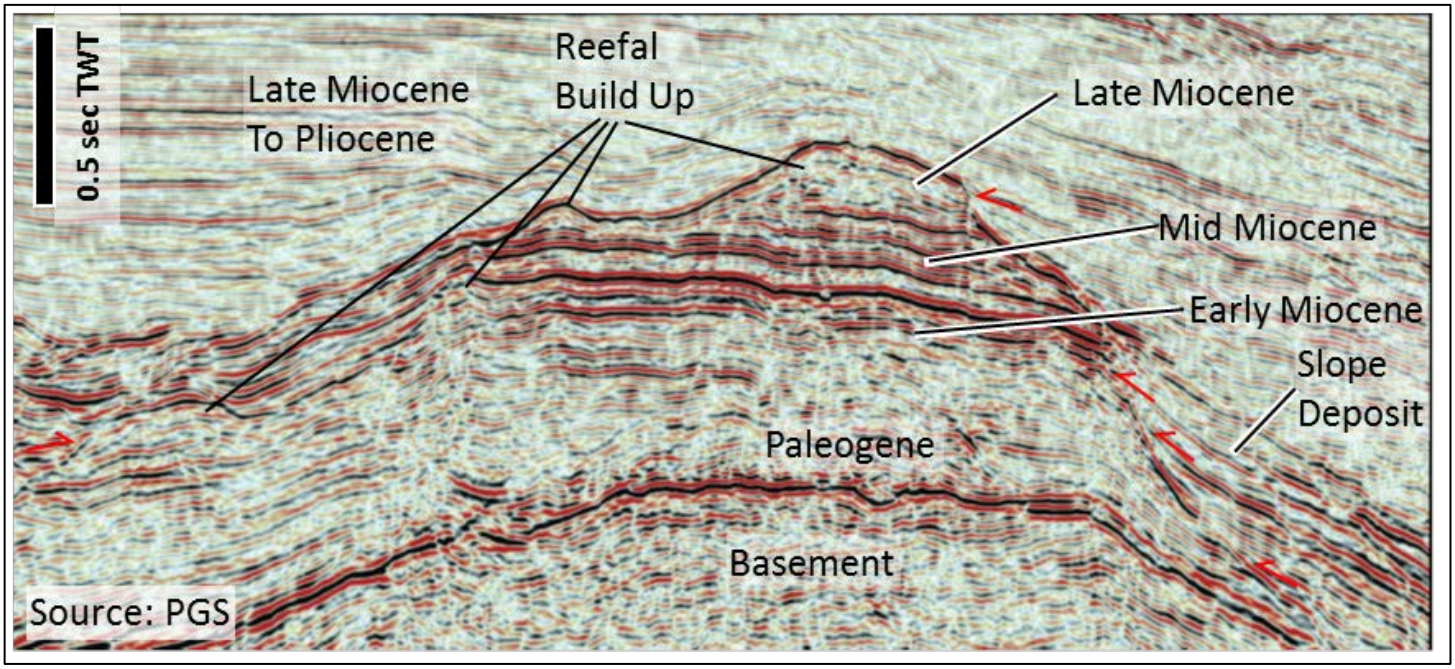


Figure 8: *An approximately West-East oriented PGS 2010 3D seismic image of Natuna D-Alpha field, which shows detailed internal structures of the build-up. An onlap feature occurs on the right side of the build-up, which is interpreted as slope deposit with reworked materials from the reef. At the top, a sequence of reef build-up developed more towards right, which may indicate that the open marine at the time was to the east.*

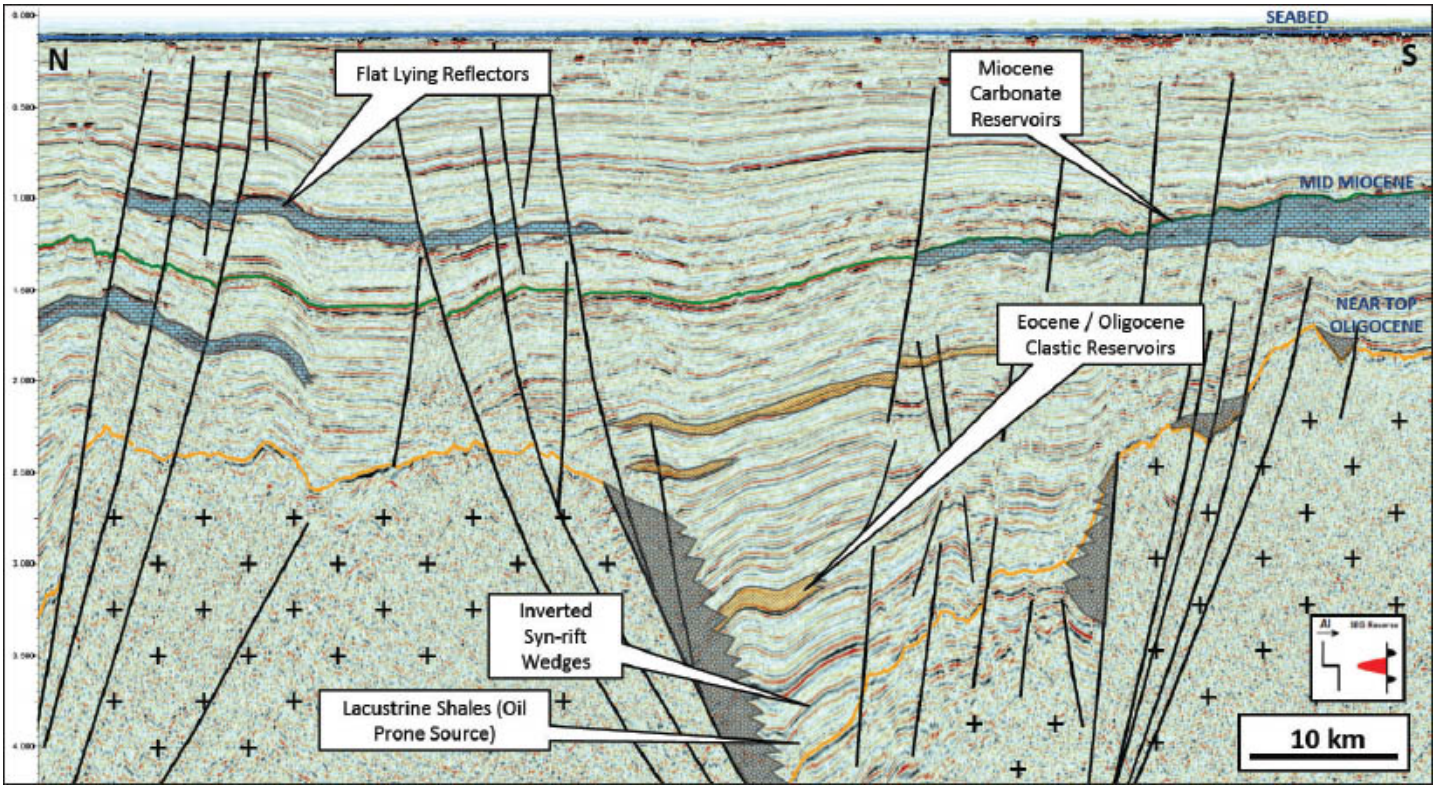


Figure 9: *A north-south seismic section acquired by PGS in 2009 in the northern part of East Natuna Basin, showing synrift system which developed in the lower section > 2.5 second TWT. The synrift deposits contain Paleogene sediments partly deposited in lacustrine environment. The Miocene carbonate units at shallow section are relatively undisturbed by faults. Above the carbonates there are still a number of bright reflectors indicating Pliocene clastic play equivalent to Dara Field further south in the basin.*

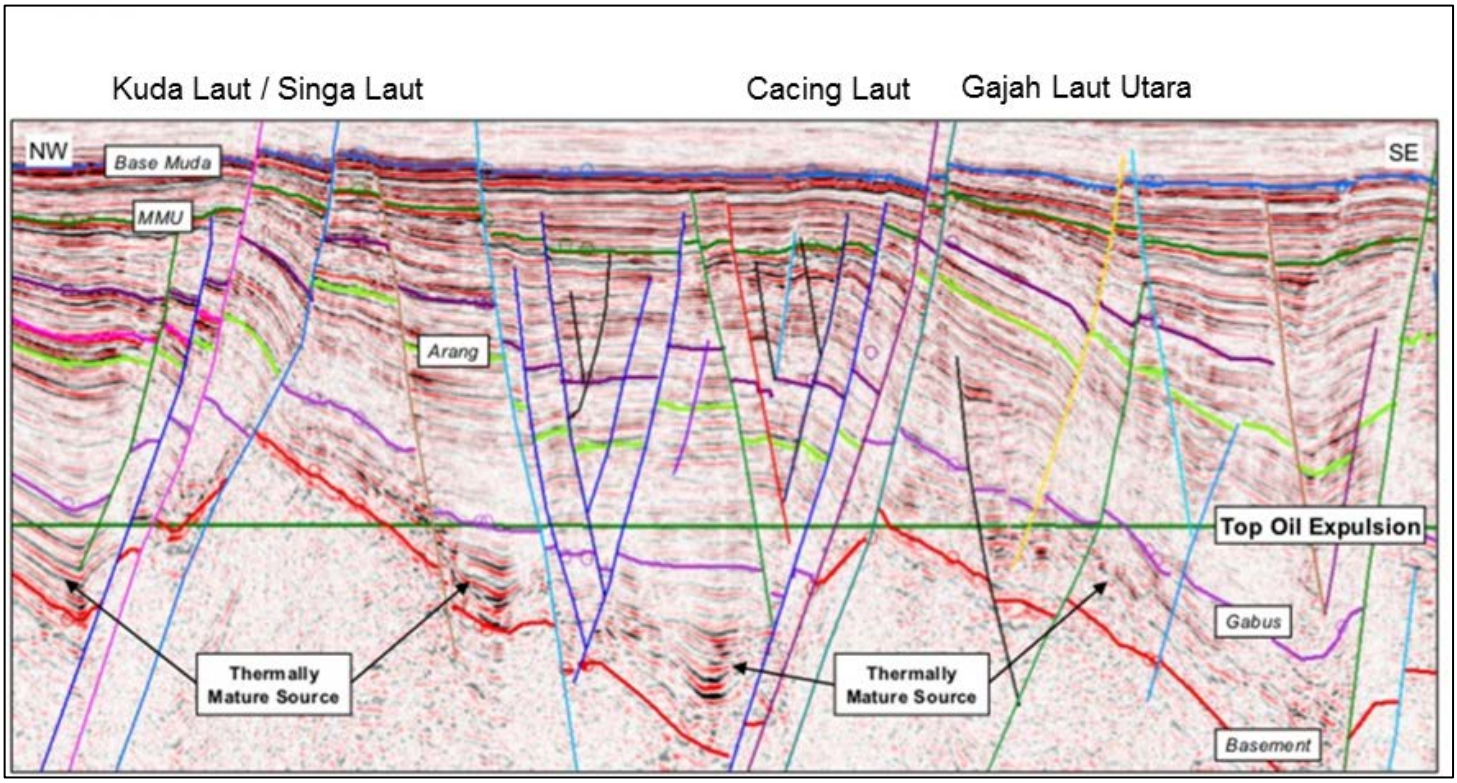


Figure 10: *A NW-SE orientation 2D seismic line in the northern part of East Natuna Basin, published by Premier Oil. This section shows intensive faults in the synrift complex. A number of hydrocarbon accumulations were discovered within these structures. Most of the major faults dip to the NW.*

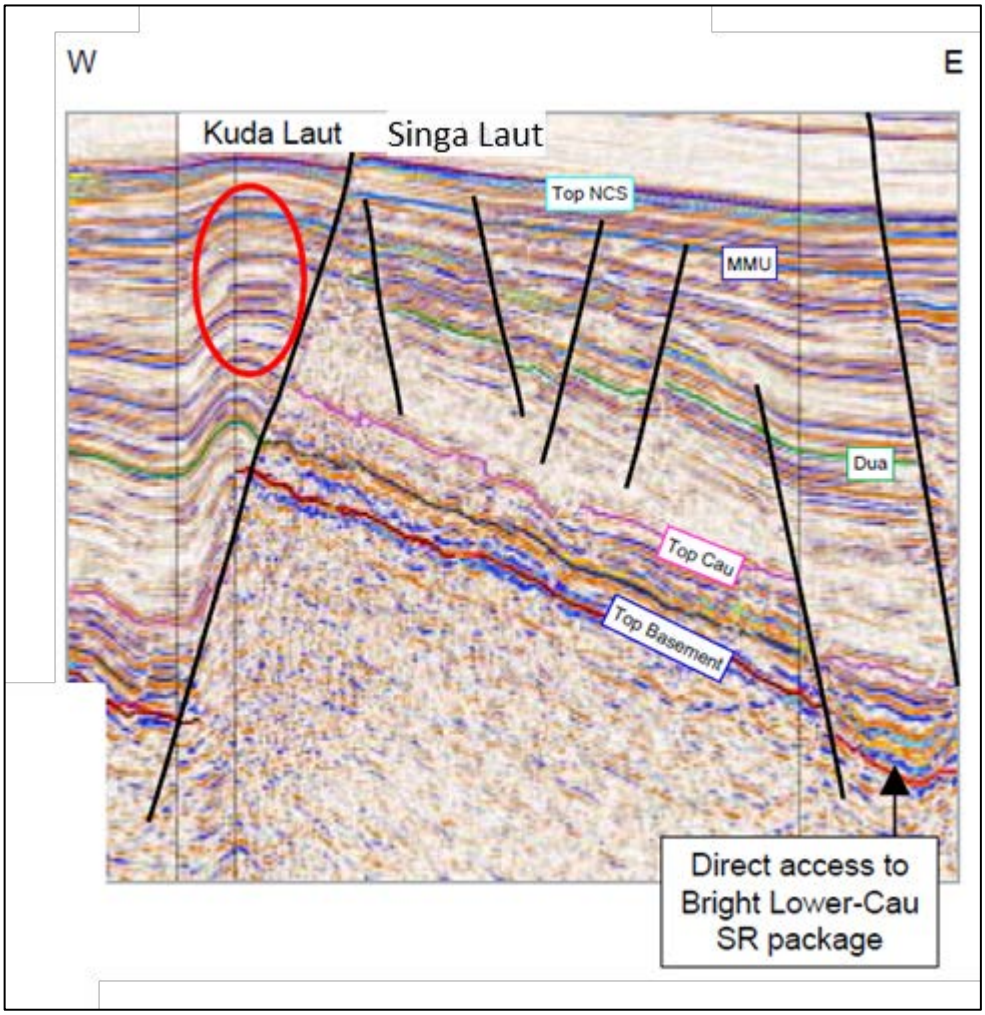


Figure 11: *Another section which shows further detail of Kuda Laut and Singa Laut structures in Tuna PSC, operated by Premier Oil. The anticlinal feature in Kuda Laut is probably of an inverted structure.*

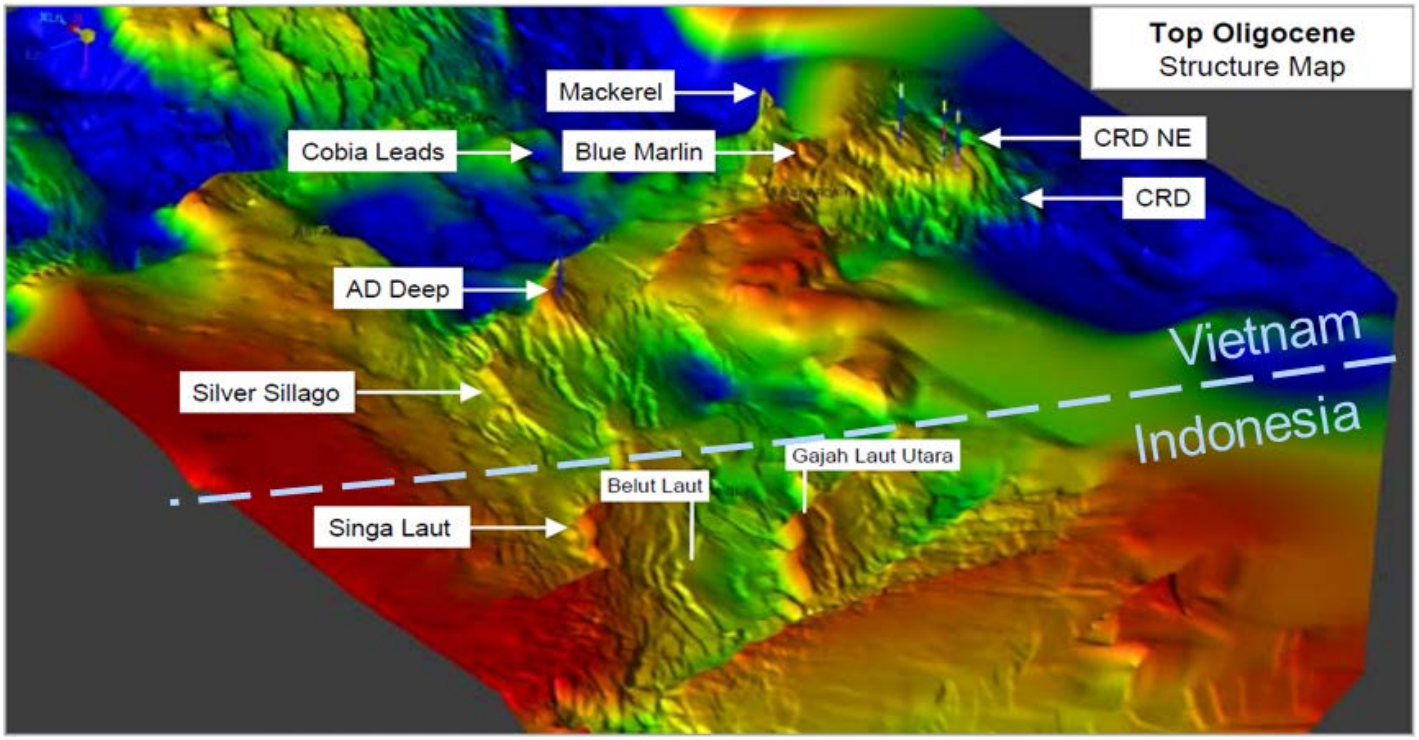


Figure 12: *A 3D view of the top Oligocene structural map published by Premier Oil shows the key structures in the Tuna PSC in Indonesian water and their extension toward Vietnam territory in the north. Note that Silver Sillago structure was tested dry in 2014. CRD is Ca Rong Do (Red Emperor), a structure that contains oil and gas in Miocene and Oligocene intervals, discovered in 2009 by Premier Oil as the operator.*

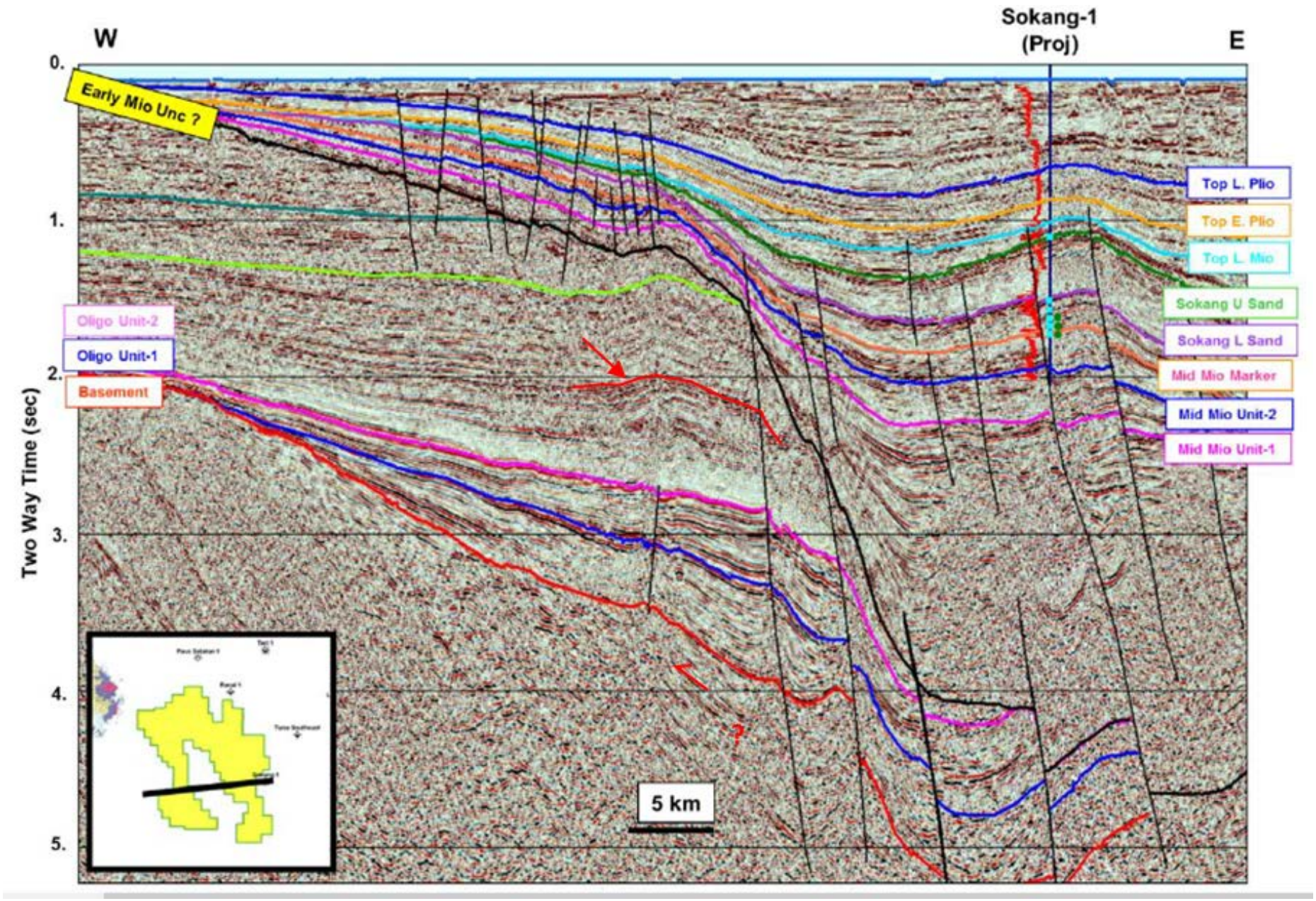


Figure 13: *A west-east seismic section shows faulted anticline structure which was drilled by Sokang-1 well and the west flank of Sokang Graben, in the southern part of East Natuna Basin. The lower part of the graben has significant fault throw and it is reduced by depth. In the shallower section the seismic shows onlap features against the faults (from Raharja et al., 2013).*

Grabens

A graben system developed in the east flank of the Natuna Arch. The northern part of this graben system is called the Komodo Graben and its southern extension is called the Sokang Graben. It seems that the graben system is wider to the south. A seismic section across Sokang-1 well shows the western flank of Sokang Graben and a faulted anticlinal feature (Figure 13). The anticlinal feature was tested by Sokang-1 exploration well. Unfortunately, Sokang-1 is a dry hole.

The ramp on the west of the section in Figure 13 also contains an untested structure. Below the basement horizon, interpreted by Raharja et al. (2013), there are still seismic reflectors which may indicate sediment occurrence below the so called 'basement horizon'.

The Komodo Graben in the north is captured by the regional seismic line as shown in Figure 5. In this part the Komodo Graben looks more like a synrift system with prominent west dipping faults. The fault system is similar to the synrift system discussed earlier. The relationship of the Komodo Graben to the synrift system in the north of the East Natuna Basin needs further study.

CONCLUSION

Despite the availability of significantly good quality seismic data in the East Natuna Basin, understanding of the geology of the East Natuna Basin remains limited. A number of geological syntheses of the area exist, but they are poorly tied to the seismic data. This article shows significant potential in the carbonates with oil (e.g. AP-1X) and in undrilled structural highs in the synrift complex, north of East Natuna Basin (e.g. Cacing Laut, Belut Laut and Gajah Laut Utara).

Deeper sections also contain untested structures such as in the ramp of the Sokang Graben. The section under the 'basement horizon' may also have potential for hydrocarbon accumulations because there are still identified reflectors on seismic. Although not as large as they are in the West Natuna Basin, inversion structures also occur in the north of the East Natuna Basin.

Key geological features are identified by using available seismic data in the East Natuna Basin. Some geological features need further investigation and the area still has interesting features to be evaluated in the future.

REFERENCES

BEICIP-Pertamina, 1982. Geological Map of Eastern Indonesia, G. Maillet – France.

Ben-Avraham, Zvi, 1973. Structural framework of the Sunda Shelf and vicinity, Thesis, Woods Hole, Mass. Woods Hole Oceanographic Institution

Caughey, C.A., Dyer, N.J., Kohar, A., Lestarini, H., Ludwick, W.R., Prijosoesilo, P., Wight., A.W.R., & Wilson, J.N. (eds.), 1995. Seismic Atlas of Indonesian Oil and Gas Fields, Vol II, Java, Kalimantan, Natuna & Irian Jaya, IPA Professional Division, Jakarta.

Dunn, P.A. and Kozar, M.G. 1996. Application of Geoscience Technology in a Geologic Study of the Natuna Gas Field, Natuna Sea, Offshore Indonesia". 25th Annual Convention Proceedings. Indonesian Petroleum Association. 1: 117–130.

Hazerbroek, H.P., Tan, D.N.K., and Swinburn, P., 1994. Tertiary Evolution of the Offshore Sarawak and Sabah Basins, NW Borneo, Abstracts of the American Association of Petroleum Geologists, International Conference & Exhibition, Kuala Lumpur, 21-24 August 1994, AAPG Bulletin, 78.

Murti, N.A. and Minarwan, 2000. Natuna, *In*: An Outline of the Geology of Indonesia, Darman, H. and Sidi, F. H. (eds.), Indonesian Geologists Association Publication

Parke, M.L. Jr., Emery, O., Szymankiewics, R., and Reynolds, L.M., 1971. Structural framework of continental margin in South China Sea, AAPG Bulletin, 55,

Raharja, M., Carmody, S., Cherdasa, J., Haribowo, N., 2013. Dual Paleogene and Neogene Petroleum Systems in East Natuna Basin: identification of a New Exploration Play in the South Sokang Area.