SEISMIC EXPRESSION OF PALEOGENE TALANGAKAR FORMATION – ASRI & SUNDA BASINS, JAVA SEA, INDONESIA

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INTRODUCTION

The Asri and Sunda Basin are located offshore Southeast Sumatra under the SE Sumatera Production Sharing Contract (PSC). Currently, Pertamina Hulu Energi OSES operates in the Asri and Sunda Basins, known as Southeast Sumatra (SES) Block (Figure 1). As one of Indonesian prime oil and gas producing area in the past 50 years, these basins have produced cumulatively more than 1,500 MMBOE with an average of 90,000 BOPD. Both Asri and Sunda Basins are part of a series of Cenozoic half grabens developed on the Asian continental margin, that have occupied a retro-arc setting since early Neogene times.

Hydrocarbon exploration activities in the offshore southeastern Sumatra began with a signed agreement of Contract Sharing between IIAPCO (Independent Indonesian American Petroleum Company) and Pertamina on 6 September 1968.

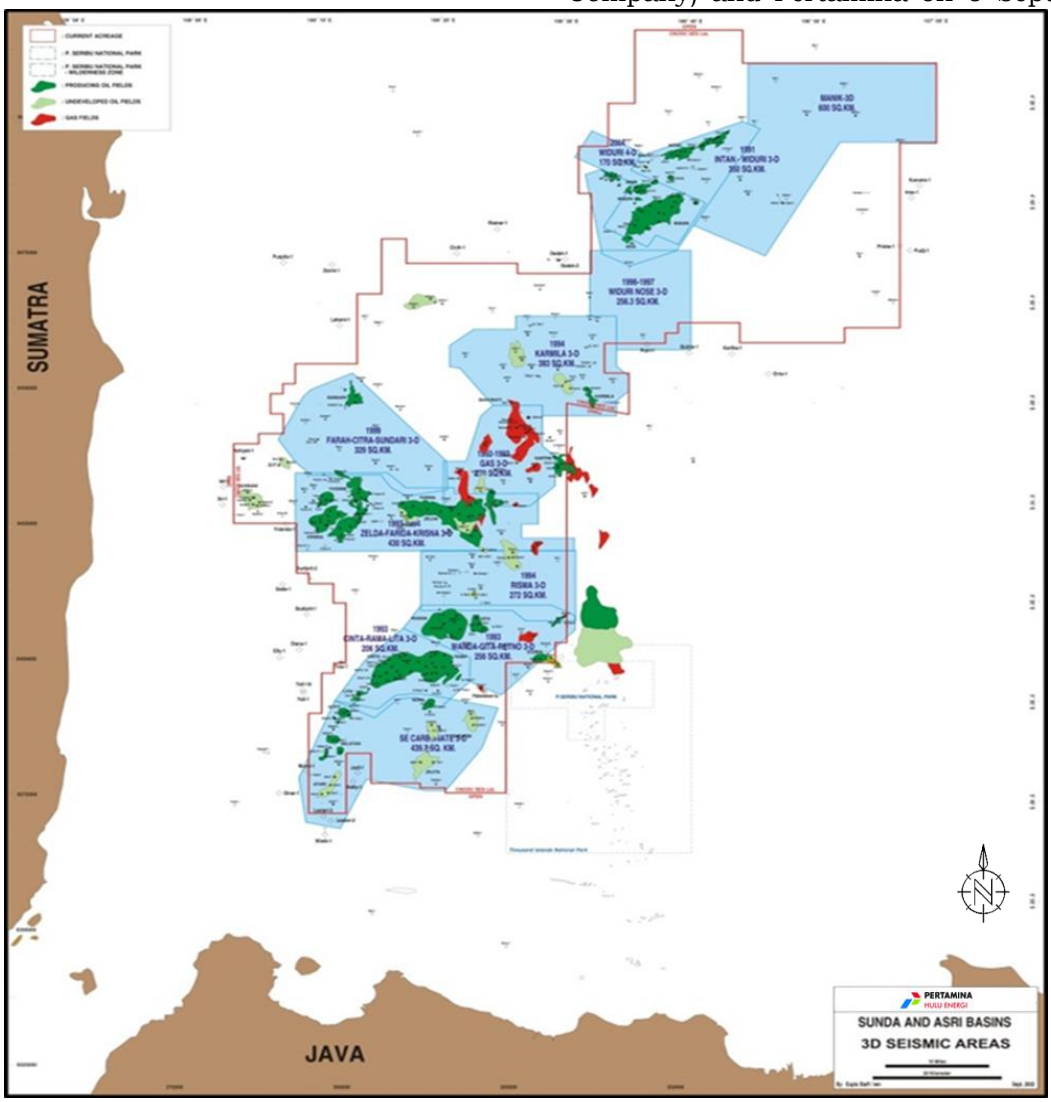


Figure 1: *Current working area map*

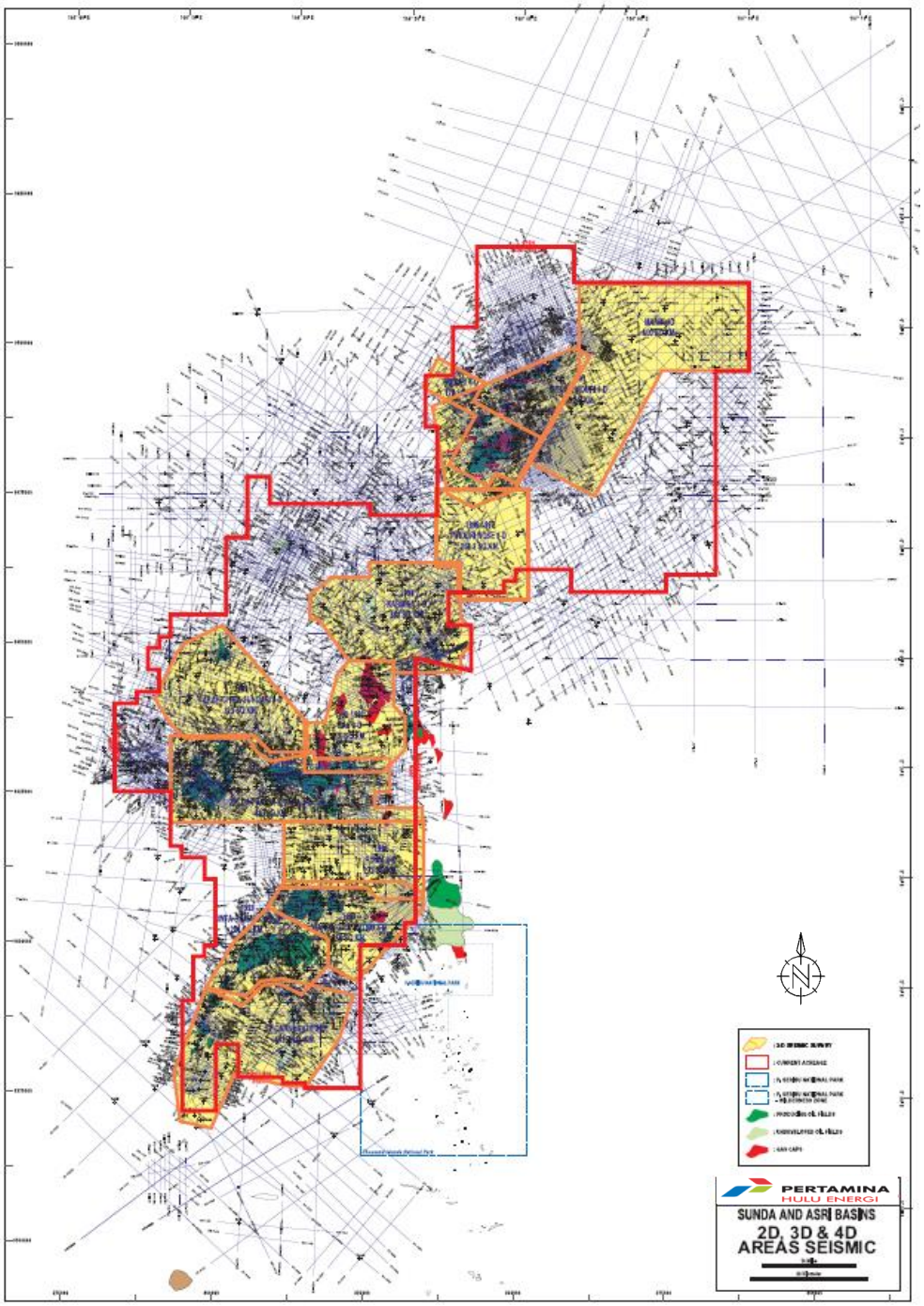


Figure 2: *Map showing 2D and 3D seismic coverage.*

The contract area included the offshore areas east of Sumatra and south of Bangka - Belitung Islands, covering an area of 124,000 km^2. After the final relinquishment in 2008, the current PSC boundary covers an area of 5,851 km^2.

This paper presents the results of integrated petroleum geosciences framework, its implications for Oligo-Miocene reservoirs and hydrocarbon prospectivity of the basins using near field exploration approaches. A four-fold division comprising rift initiation, rift climax, immediate post rift and late-post rift stages of basin evolution characterize the basin filling. Seismic expression of these kinematic units gives an idea about the linkage of their deposition with different stages of rift evolution. The present study has also identified a new potential play concept in Oligo-Miocene reservoirs.

BASIN OVERVIEW

The Asri & Sunda Basins reservoirs are mainly from the syn-rift deposits. Existing contract area covers an approximately 11,046 km^2 including the Asri, Sunda and Hera basins. Stratigraphic nomenclature is based on basin tectonic evolution, rather than just lithostratigraphic terms (Ralanarko et al., 2012).

Data Coverage and Quality

A total of 80,338 km of 2D seismic acquisition conducted from 1969 until 1996 covered the entire working area. A total of 4,068 km^2 of 3D seismic has been acquired, comprising of 12 vintages conducted from 1991 until 2006. The 3D seismic covers almost all producing fields and area of exploration interest. Advanced 4D seismic acquisition also been applied over the Widuri field with coverage 270 km^2.

The history of seismic data in the Contract Area began in 1969 when a 2D seismic survey as large as 14,400 km was acquired and initially generated ten drillable prospects. To date, about 80,000 km of 2D seismic survey covers the entire Contract Area. Seismic lines with a grid density about 1x1 km have been recorded across more prospective and production areas. This dense grid of 2D seismic surveys of various vintages from 1969 to 1996, acquired as a compromise between the required target and the technology availability at the time of the survey was being conducted. Both 2D and 3D data coverage contract area can be shown in Figure 2.

Since 1990, 3D surveys have been performed across nearly all of the important oil fields within the Contract Area. To date, twelve 3D surveys have been acquired and covering about 4068 km^2 of all prospective production areas. Furthermore, during

2000 and 2004, a 170 km^2 4D seismic survey was acquired over the most significant production area. The list of all survey data was shown in Table 1.

Seismic data covering the contract area are average to good quality. Seismic reflections which represent top formation were noticeable across the survey down to 3.2 sec. TWT, i.e. approximately 8000 ft deep. Some random noise, multiples and artefacts present within the dataset which can be seen in Figures 3 and 4 marked by red circles. Detailed evaluation and comparison of dataset can be shown in Table 2.

No	2D Surveys	Year	Size (km)
1	Multiple surveys	1969-1996	±80,000

No	3D Surveys	Year	Size (km^2)
1	Widuri	1991	350
2	Gas	1992/93	270
3	WGR	1993	256
4	CRL	1993	206
5	Zelda	1993/94	430
6	Karmila	1994	383
7	Risma	1994	272
8	Wid Nose	1996/97	256
9	SE Carbonate	1998	439
10	FCS	1999	329
11	Widuri	2000	170
12	Manik	2006	707
	TOTAL		4,068

No	4D Surveys	Year	Size (km^2)
1	Widuri	2000	100
2	Widuri and North of Lidya	2004	170
	TOTAL		270

***Table 1**. Seismic data availability within the Contract Area*

REGIONAL GEOLOGY

Regional Tectonics

Although the West Java Sea basinal area is currently positioned in a back-arc setting, the rift systems did not form as back-arc basins. Extension direction fault patterns and basin orientation of the West Java Sea basins suggest that the Asri Basin is a pull-apart basin at the southern terminus of a large, regional, dextral strike-slip system; viz. the Malacca and Semangko fault zones, propagating down to the west flank of the Sundaland. Through both Eocene-Oligocene rift phases, the primary extension directions were NE-SW to E-W. Other similar major pull-apart basins are the Palembang and Pematang rifts, located north-west of the Asri Basin & Sunda Basin. Two observations support the interpretations that these basins are not back-arc related; 1) the extension direction for the West Java Sea rifts is

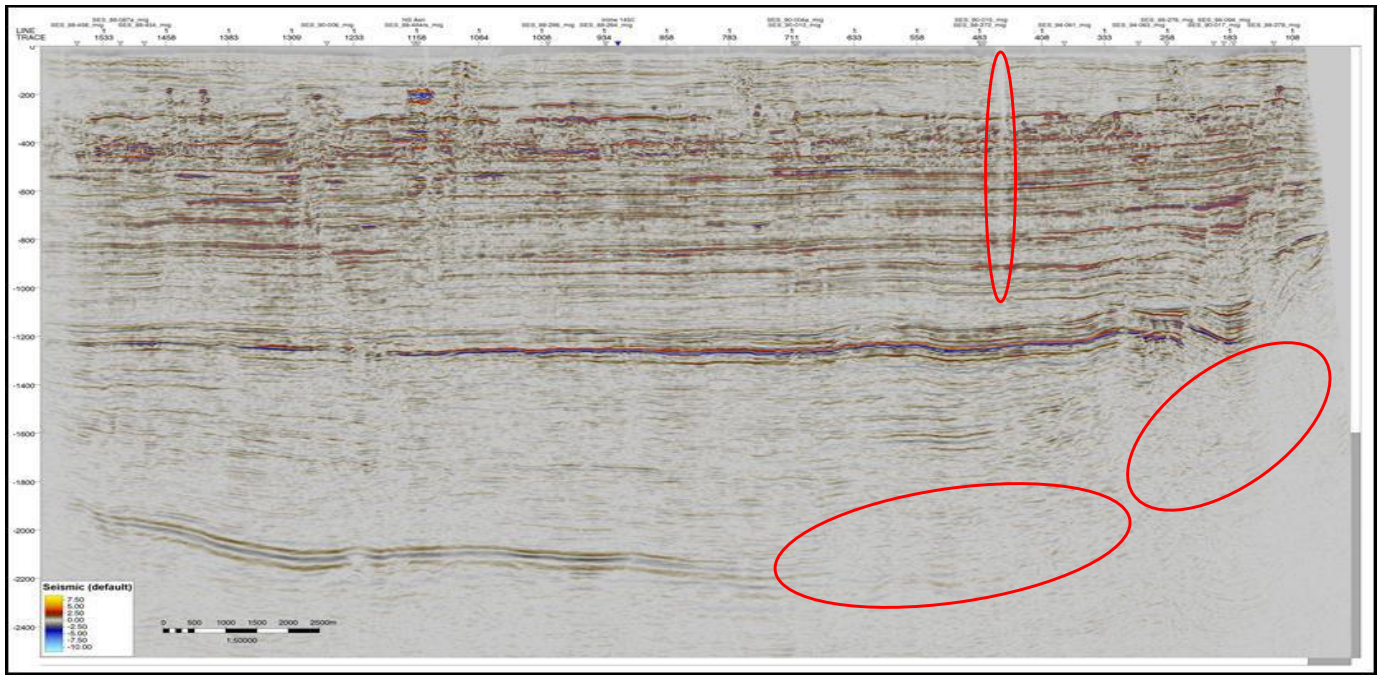


***Figure 3:** Example of average quality seismic section.*

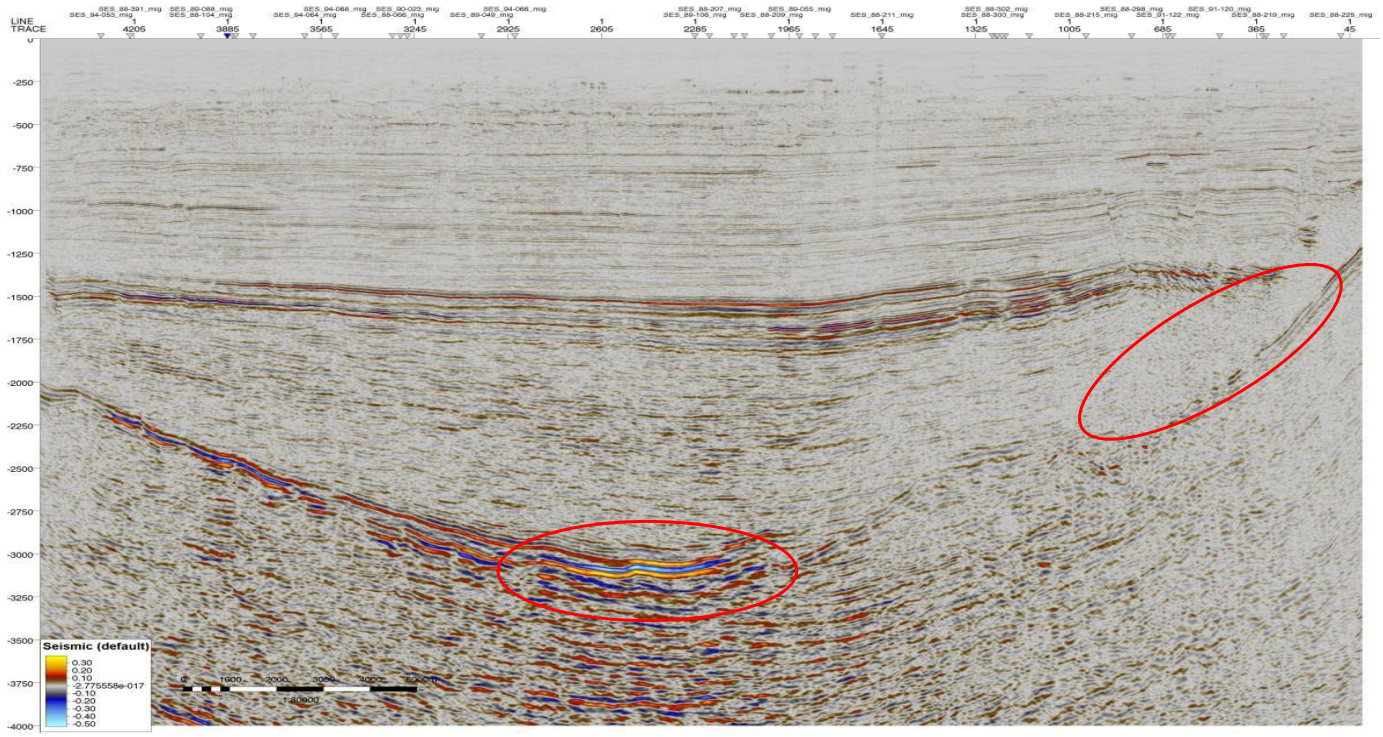


Figure 4: *Example of good quality seismic section.*

nearly perpendicular to the present subduction zone, 2) a thick continental crust is involved (Hamilton, 1979).

There are three major tectonic periods that affected the structural style and depositional systems in the Asri and Sunda Basin: 1) Rift Initiation during pre- to early Oligocene, 2) Syn-Rift during early to late Oligocene, and 3) Post-Rift (Sukanto et al.,

Average Quality	Good Quality
- Seismic data is band limited. Had it been processed with broadband seismic flow, broader bandwidth seismic data would be achieved: sharper events, crisp images, better event definition, continuity, etc. - Water bottom is poorly defined. Reason: lack of near offset during acquisition. - Little possibility of poor (not accurate) static correction had been applied. Water bottom is pretty rugose considering that the shallow to mid reflection are dominated by flat reflectors. - Shallow gas bodies can be seen prominently in the section. However, the resulting multiples reflection are quite strong that still remnant in the deeper section. - Multiples (surface and internal multiple) can be seen in the data. - Between 1200 ms to basement, event definition and continuity are very poor. - Basement continuity is poor. It diminished to the right part. Reason: perhaps due to 2D seismic effect.	- Post basement multiples are still very strong. - Event continuity is poor; basement signal diminishes as we go to the right section. Generally, the right section has dimmer amplitude below 1500 ms. It might be caused by absorption or wrong parameter in amplitude compensation had been applied.

Table 2. *Seismic data comparison*

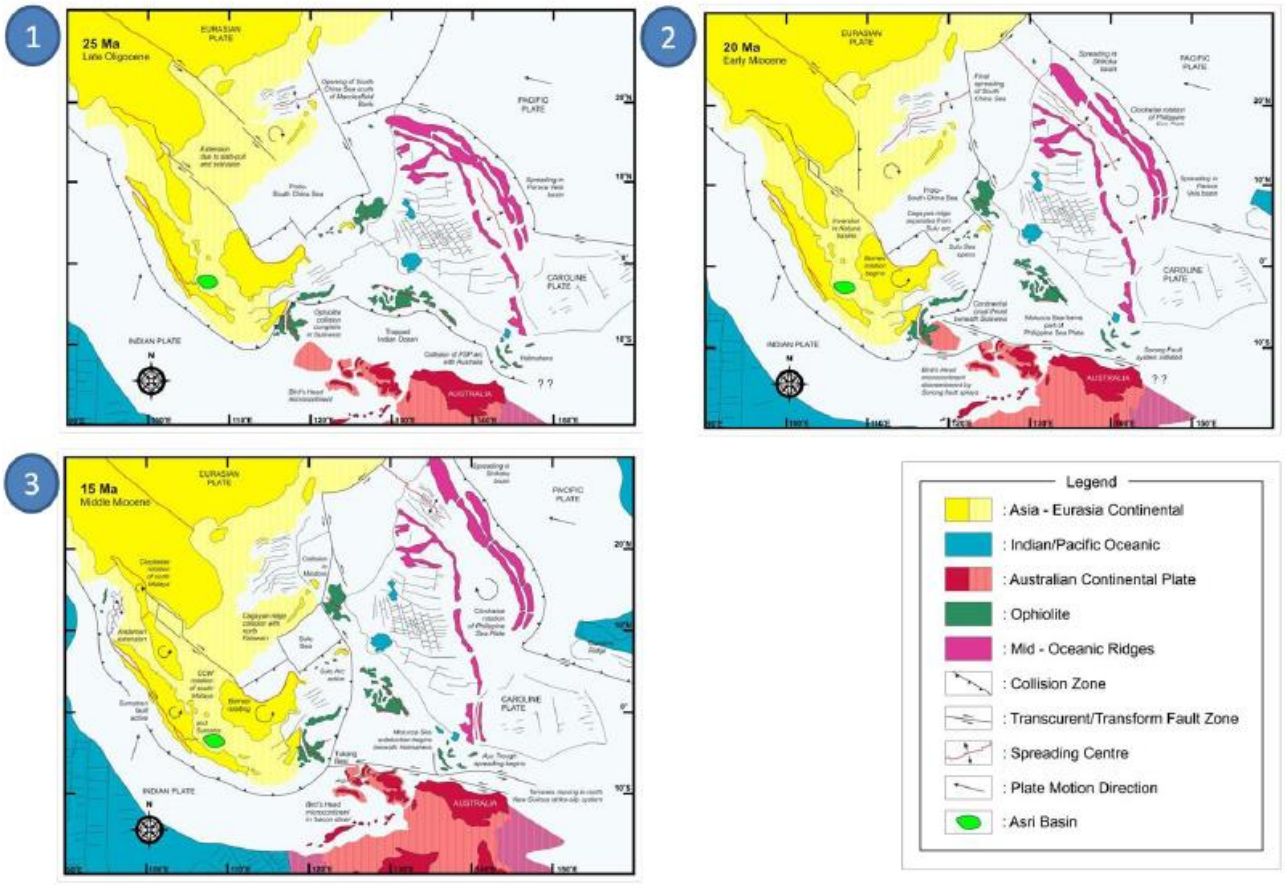


Figure 5: *Tectonic evolution of Asian Continental Margin during Late Oligocene (5.1), Early Miocene (5.2), and Middle Miocene (5.3).*

1998). The history of the Asri and Sunda Basin (as a part of Sundaland) can be divided into the three tectonic mega-sequences described below as defined by Longley (1997):

Stage I (50 – 43.5 Ma) – Corresponds to a period of early continental collision which led to the formation of many of the older syn-rift grabens. Stage I (50 – 43.5 Ma) – Corresponds to a period of early continental collision which led to the formation of many of the older syn-rift grabens. The India – Eurasia collision caused a slow-down in the oceanic spreading rates in the Indian Ocean reducing the convergence velocity along the Sunda Arc subduction system and resulting in a phase of extension in the adjacent fore-arc and back-arc areas. Daly et al. (1987) pointed out that the velocity decrease would cause the subduction slab to sink, with consequent decoupling of the slab and creation of an extensional environment in the arc region.

Stage II (43.5 – 32 Ma) – During which major plate reorganizations took place, resulted in the formation and active subsidence of a younger population of rifts. This extension resulted in the opening up of numerous half-grabens whose geometry and orientation was influenced by basement heterogeneity. Hall (1995) mentioned that South Sumatra has been rotated by approximately 15 degrees clockwise since the Miocene resulting in a present-day graben orientation.

Stage III (32 – 21 Ma) – Contemporaneous with sea floor spreading of the South China Sea, was a period during which rift ceased, local inversion took place, and a major marine transgression marked the beginning of post rift development.

Stage IV (21 – 0 Ma) – Characterized by a maximum transgression followed by several collision phases that led to inversions, uplift and the development of regressive deltaic sequences. This is equivalent to the early and late post rift stages.

PALEOGENE SEQUENCES FRAMEWORK

Basin Configuration

The Asri and Sunda Basins have been described as back-arc, half graben rift basins (Young and Atkinson, 1993) and a basin with a composite extensional style that is begun as an intracratonic, “sag style” basin (Aldrich et al., 1995). The basin is bounded by to the east by a N-S trending normal fault, downthrown to the west, whilst the southern margin is marked by a regional NW-SE trending wrench system.

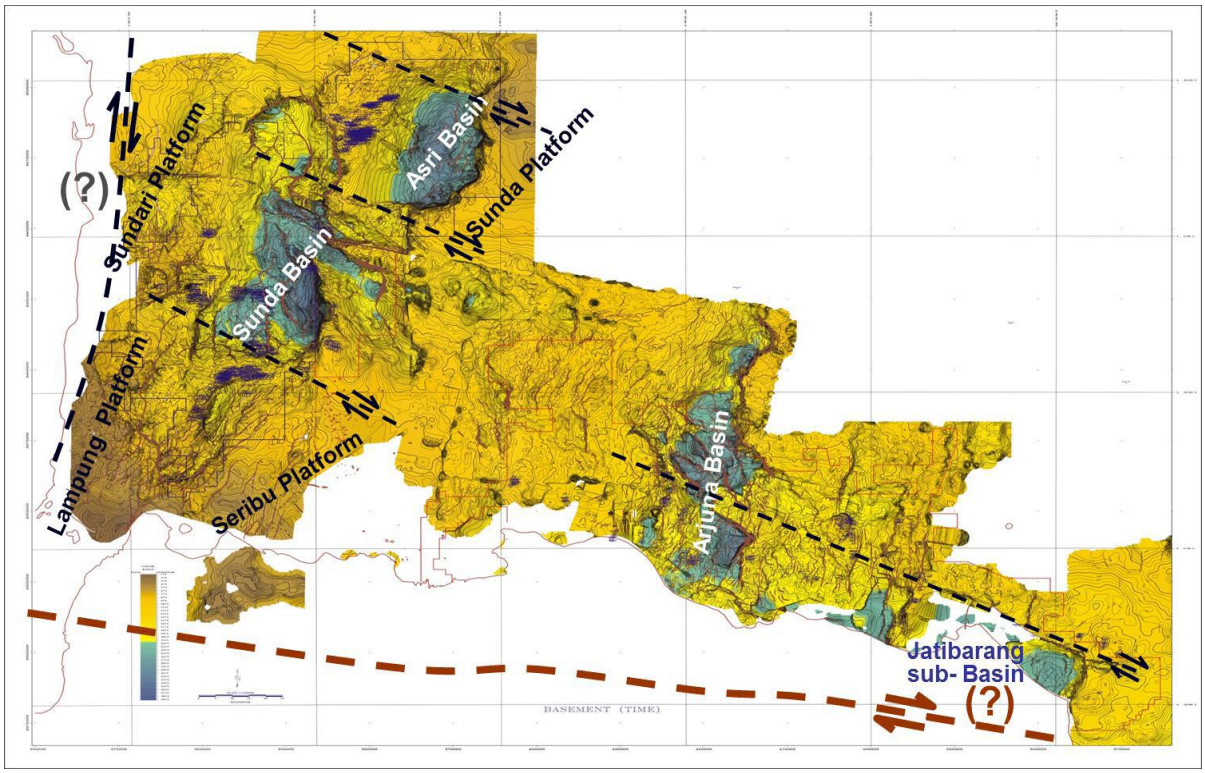


Figure 6: *Basement Time Structural Map of the NW Java Sea Basinal Area (modified after Koesoemadinata, 2004).*

Typical depocenters of Asri and Sunda Basins (i.e. filled by the Talangakar Fm., Zelda Member), are succeeded by broader Neogene ones, representing sag phase development. The N-S faulting may be a younger manifestation of the major basement shear system attributed to early Tertiary (54-30

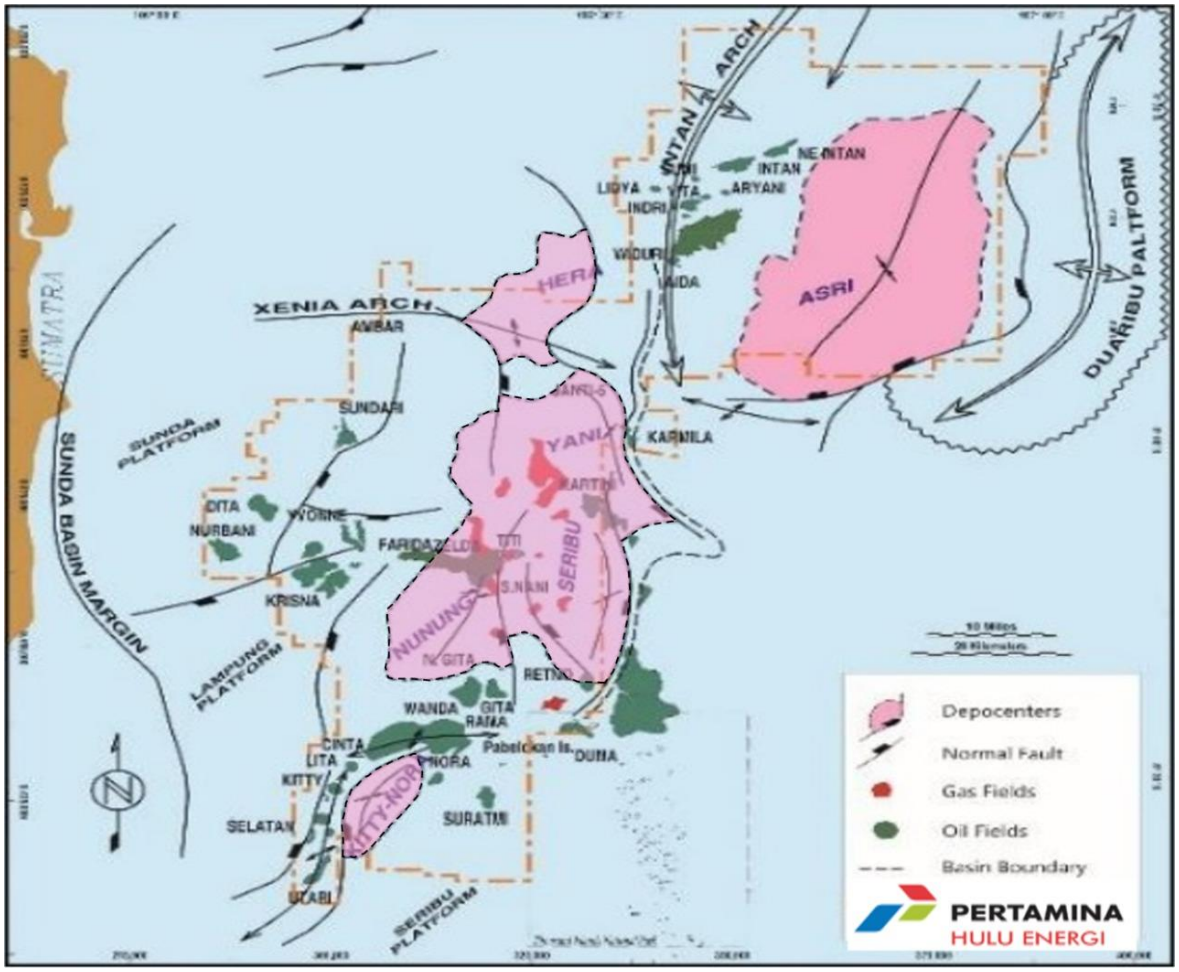


Figure 7: *Main structural features of the Asri and Sunda Basins.*

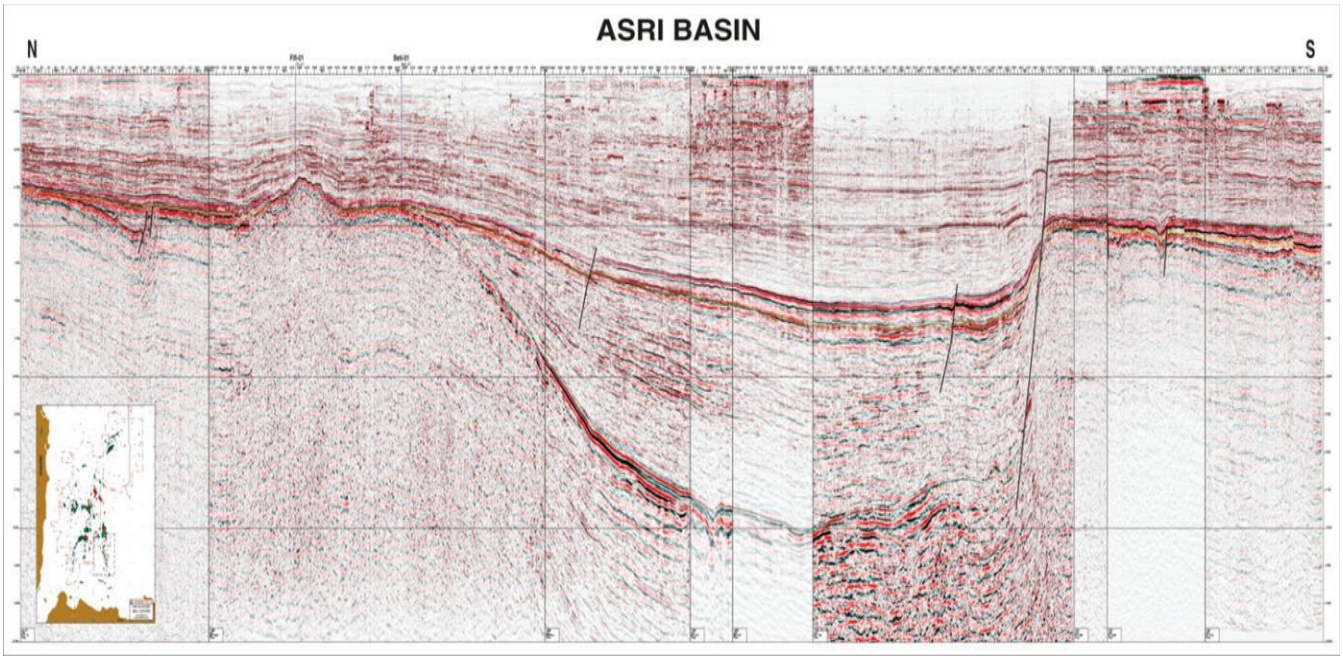


Figure 8: *Typical N-S seismic cross section, Asri Basin.*

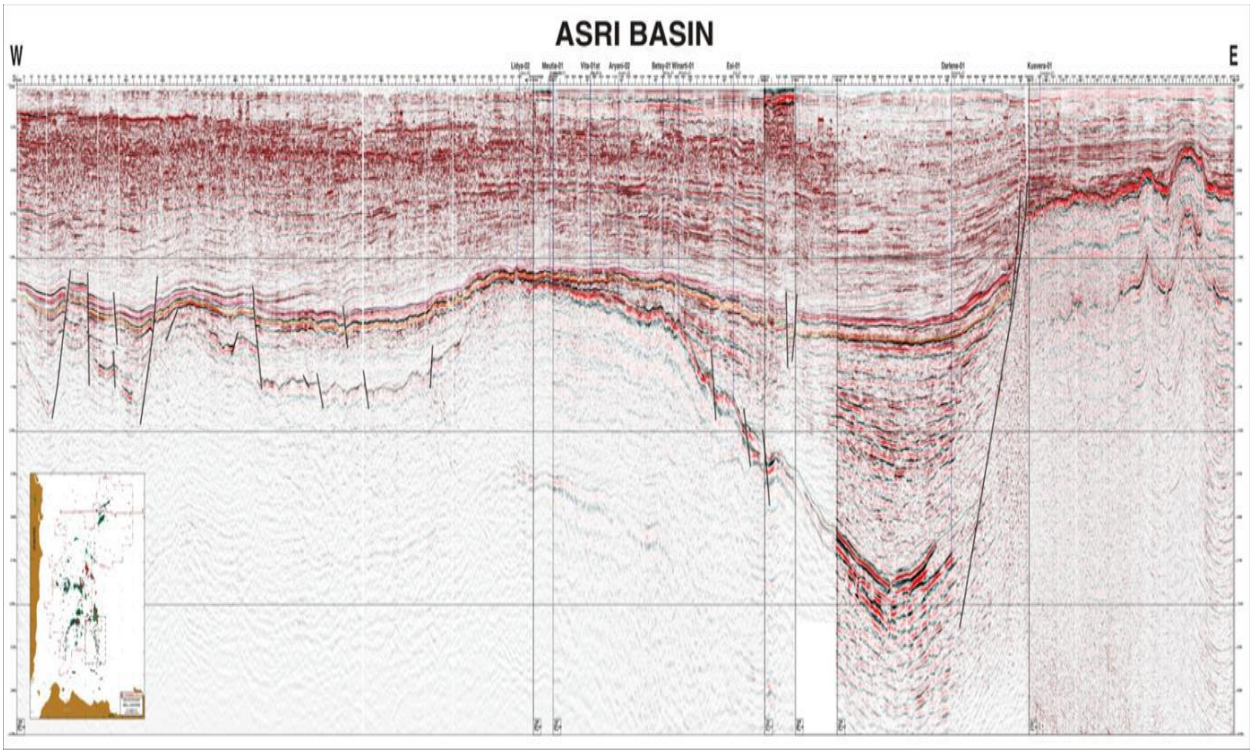


Figure 9: *Typical W-E seismic cross section, Asri Basin.*

Ma) as the collision of India with Eurasia took place (Tapponier et al., 1982), which simultaneously give rise to major NW-oriented shear zones e.g. the Sumatran, Thai – Burmese and Red River Faults. This NW trend also parallels the major right lateral (dextral) Sumatra fault zone and is clearly a fundamental regional crustal feature. In Java, this orientation swings round to become roughly E-W and is also well developed within Sunda Basin in particular (Wight et al., 1997).

Figure 8 shows the main structural features in the Asri Basin, with major fault, which are generally, oriented N-S. An E-W seismic cross-section shows major fault with N-S orientation and various minor structures near the flexural margins developed in the Asri Basin as shown in Figures 8 and 9. According to Wight et al. (1986) the depocenter contains about 5 km thick of Cenozoic sediments as a result of subsidence.

The Sunda Basin is dominated by various structural features, including structural highs, grabens, and numerous normal faults as shown in

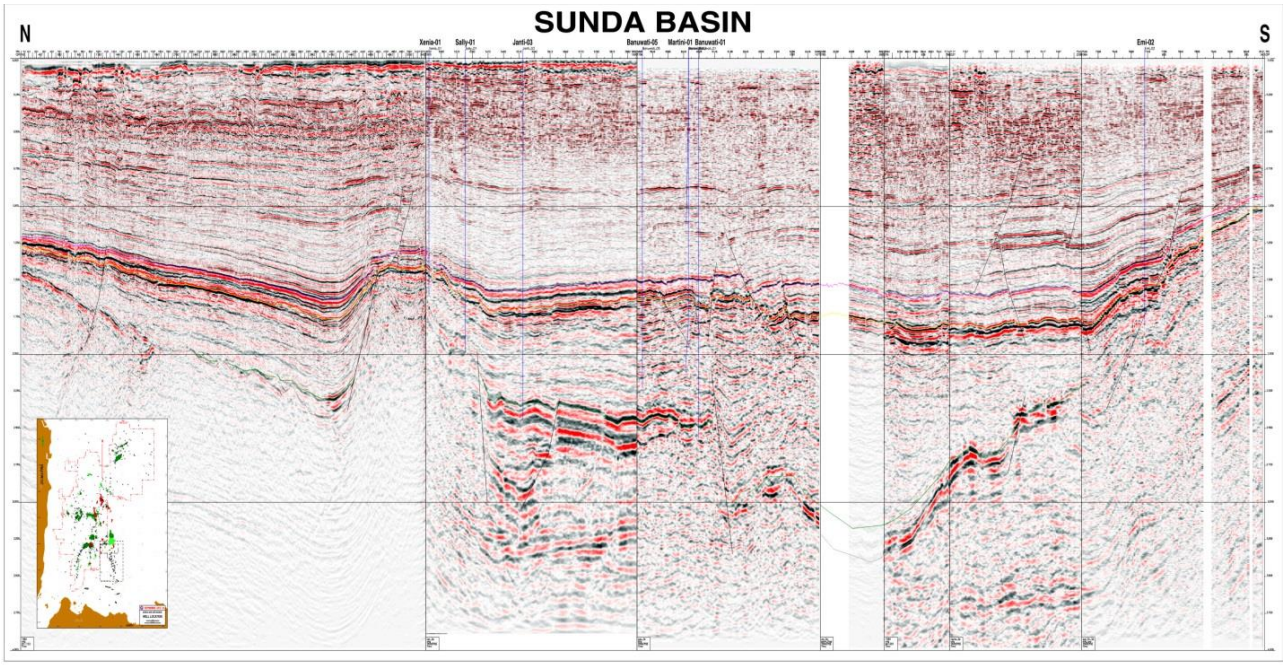


Figure 10: *Typical N-S seismic cross section, Sunda Basin.*

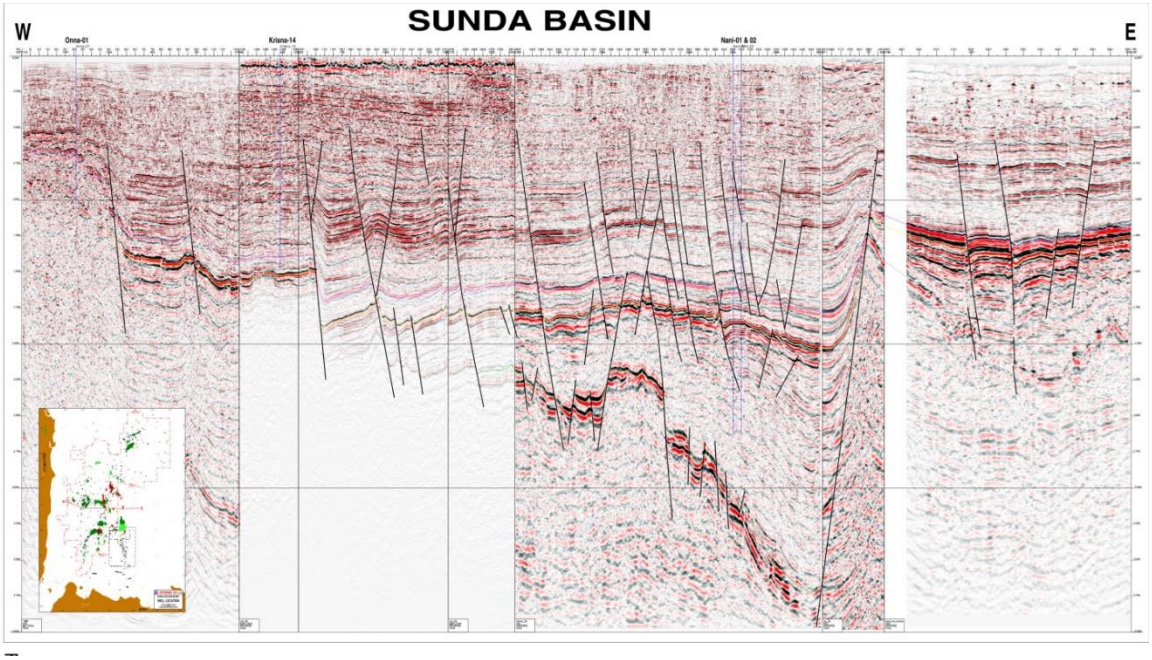


Figure 11: *Typical W-E seismic cross section, Sunda Basin.*

Figures 10 and 11. The structural highs consist of mainly early Tertiary domes and arches that underwent extensive erosion during the Paleogene and horsts that formed during Oligocene rifting (Wight et al., 1986; Sudarmono et al., 1997). High density of faults identified with N-S and NE-SW trend orientations are also shown in Figures 10 and 11.

Based on birds' eye point of view, the major faults in Talangakar Formation interval mostly have N-S trend orientations but some strike NW – SE as shown in Figure 12. The faults generally act as the depocenter boundaries and record vertical displacement. The basin is also surrounded, and underlain, by platforms of Lower to Upper Cretaceous igneous and metamorphic rocks which were rifted during Eocene to Early Oligocene times.

Producing field and undeveloped discoveries from Asri and Sunda Basins which have been identified were mapped and can be shown in Figure 13. Asri Basin located in the Northeastern part of Offshore Southeast Sumatera block, has some producing fields and potential undeveloped discoveries in Northwest part of the Asri Basin depocenter. Sunda Basin located in the Southern part of the block, has developed several oilfields and potential undeveloped discoveries. Oil fields and Gas fields which have been developed in SES Working Area marked as green polygon and red polygon.

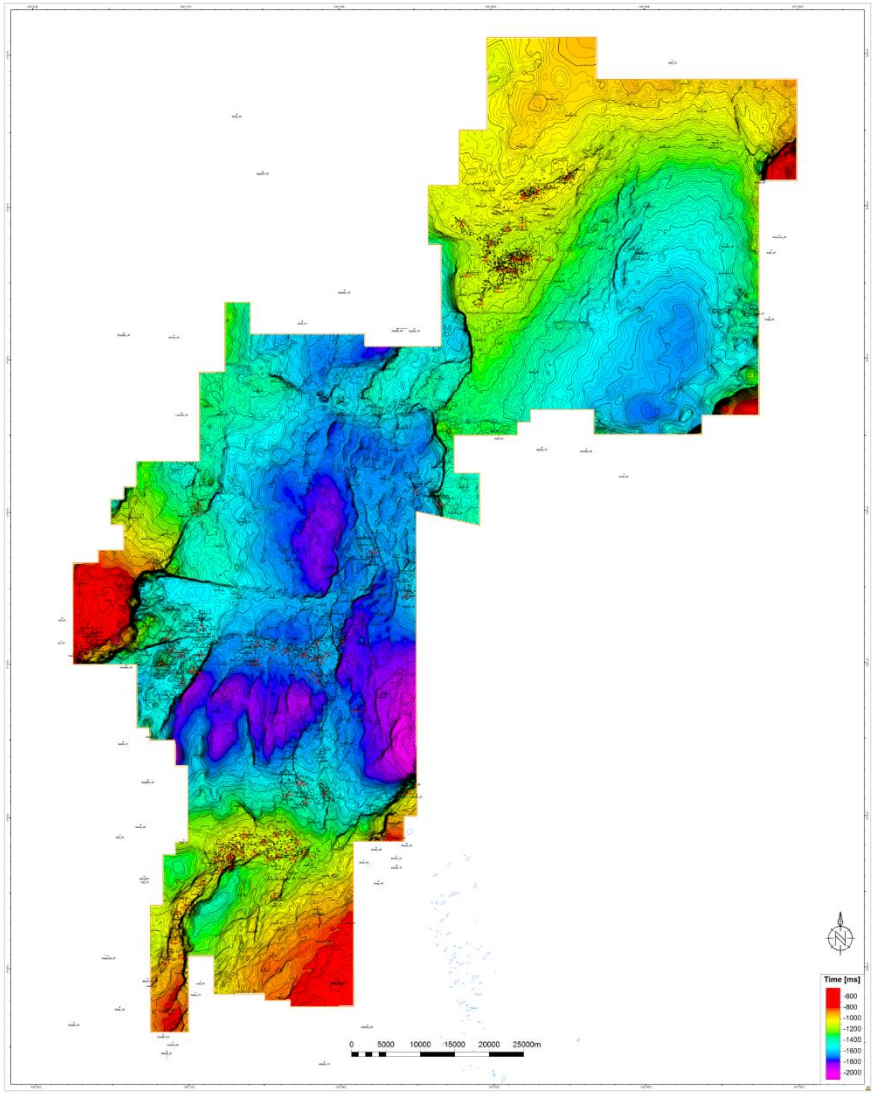


Figure 12: *TWT structural map of Talangakar Formation in Asri & Sunda Basins.*

Basin Stratigraphy

As the exploration activities developed, several informal stratigraphic units were widely used for practical purposes related to the local stratigraphic character of the reservoir rocks and oilfield's name. In the Asri Basin and Sunda Basin the term of the Zelda and Gita Members, which are the upper and lower units, respectively, of the Talangakar Formation that form the main reservoirs in the Asri oilfields are widely used. The Zelda Member consists of interbedded fluviatile sandstone, claystone, shale and siltstone units with the predominant unit comprising braided streams containing thick, stacked reservoir sandstones. The low energy fluviatile deposits above form discrete channel sandstones which form the shoestring sand type of deposits.

The Gita Member represents the lowering energy of deposition dominated by cut and fill channel sandstone, overbank, and swamp claystone deposits.

SEISMIC EXPRESSIONS

In the Asri and Sunda basinal area several series of significant structures which play an important role for hydrocarbon exploration have been identified. The positive structures are dominated by platform area flanking ~~to~~ depocenters: horst blocks (arches) and paleo-highs. These structures, separating the depocenters, were the focus for hydrocarbon migration and they are an important factor for reservoir distributions. Most of them were in situ and were not affected by the Plio-Pleistocene uplift as normally seen in South and Central Sumatra basins.

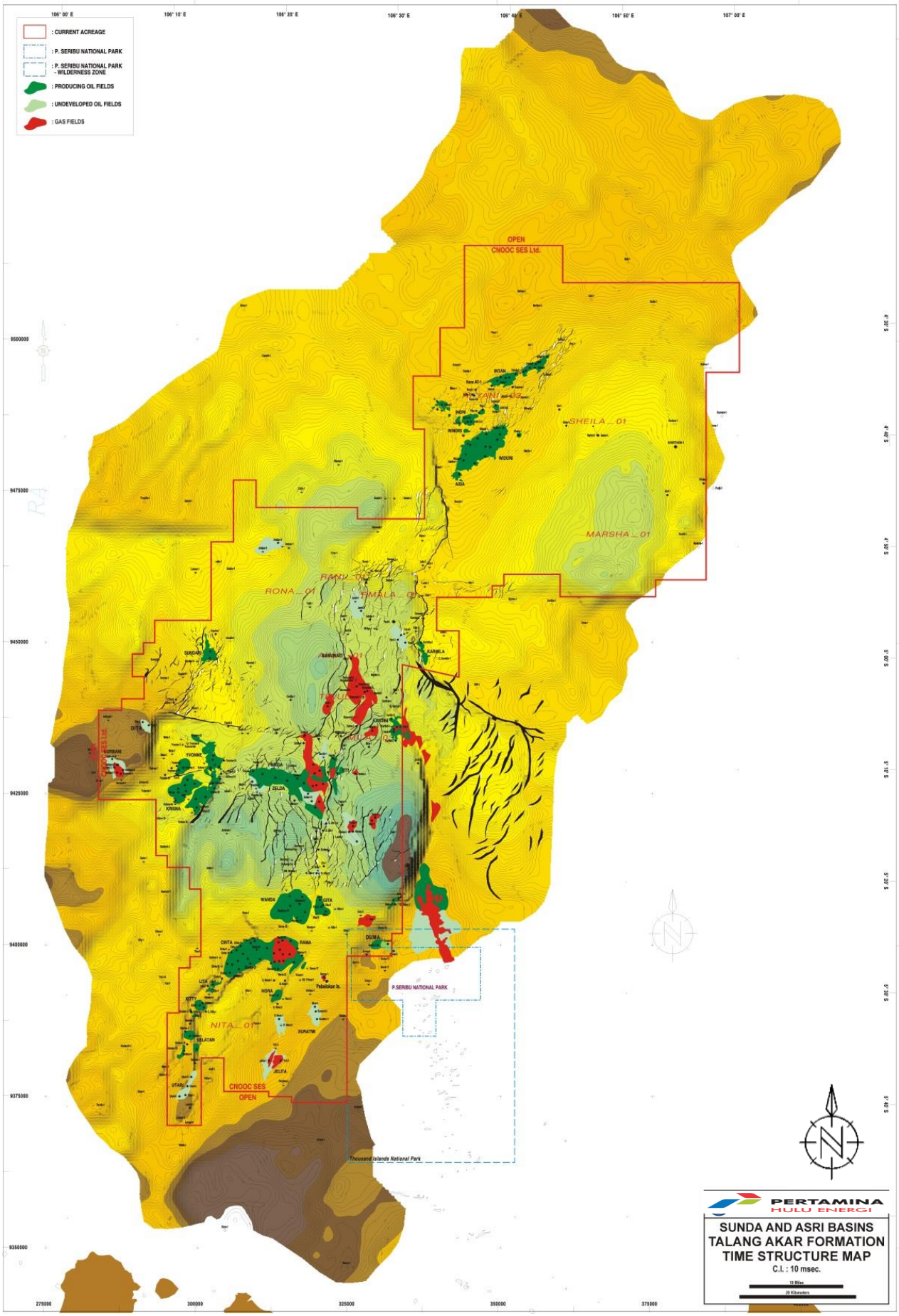


Figure 13: *Time structural map of Talangakar Formation (Asri & Sunda Basins) with hydrocarbon fields overlay.*

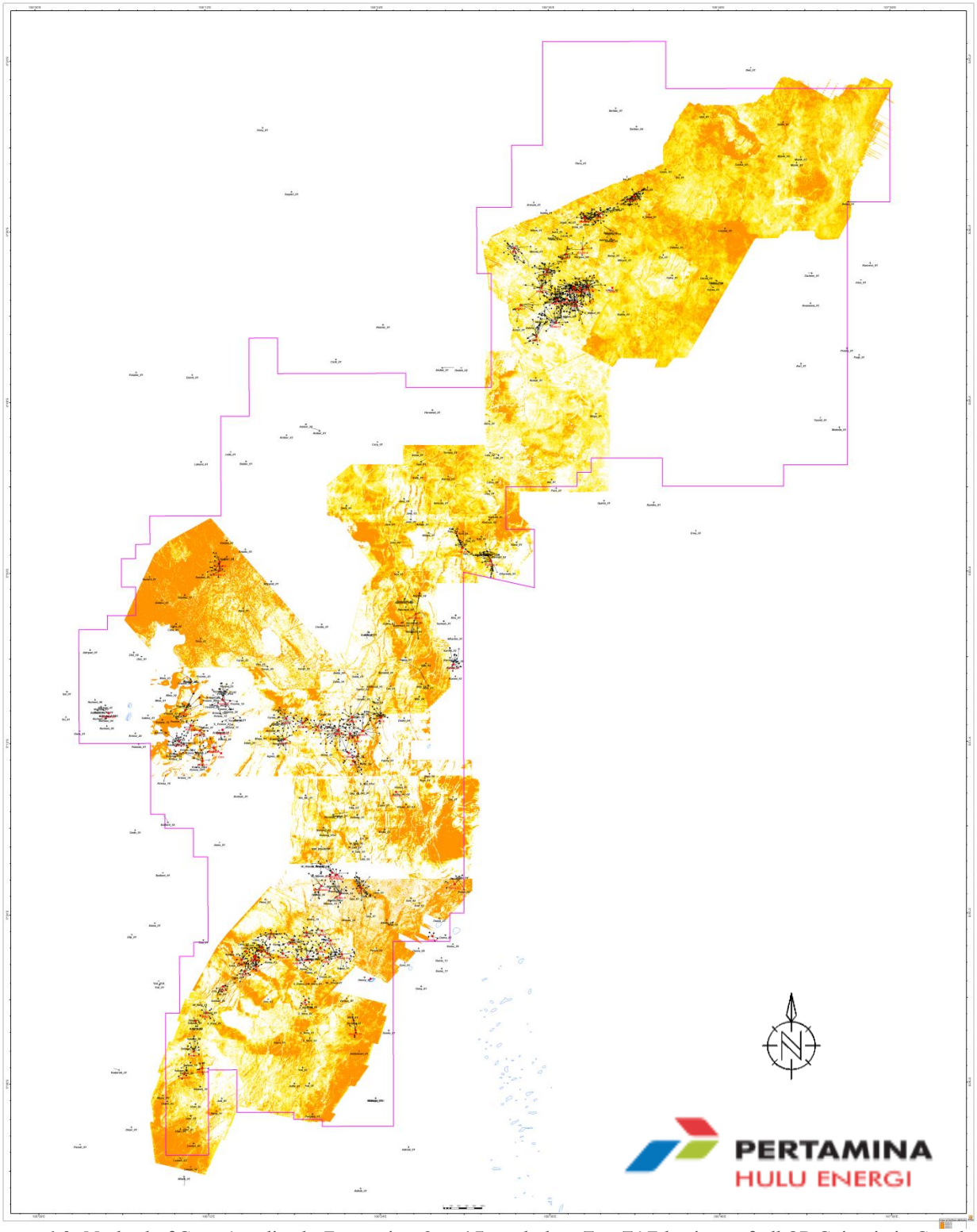


Figure 14: *Method of Sum Amplitude Extraction 0 to 15 ms below Top TAF horizon of all 3D Seismic in Sunda and Asri Basins (bright orange mean high amplitude which describe channel sandstone body inside interbedded coal-shale layer).*

Intan - Widuri Platform

Intan - Widuri platform area forms the western flank of the Asri Basin which is cut by several series of NE-SW trending faults. This area became the focus of exploration after the Intan and Widuri discoveries in 1987 and 1988. The structure on this platform is generally a three-way dip closure bounded by down-to basin-margin series of en-echelon faults i.e. Intan closure, and a four-way dip closure as seen in the Widuri (Widuri is 3 way – fault bounded to NW) and Indri closure.

The only productive area found to date in the Asri Basin is the Intan and Widuri platform on the NW flank of the basin. All oilfields are currently producing from the syn-rift sandstones (Zelda Member) and early sag sandstones (Gita Member) reservoirs.

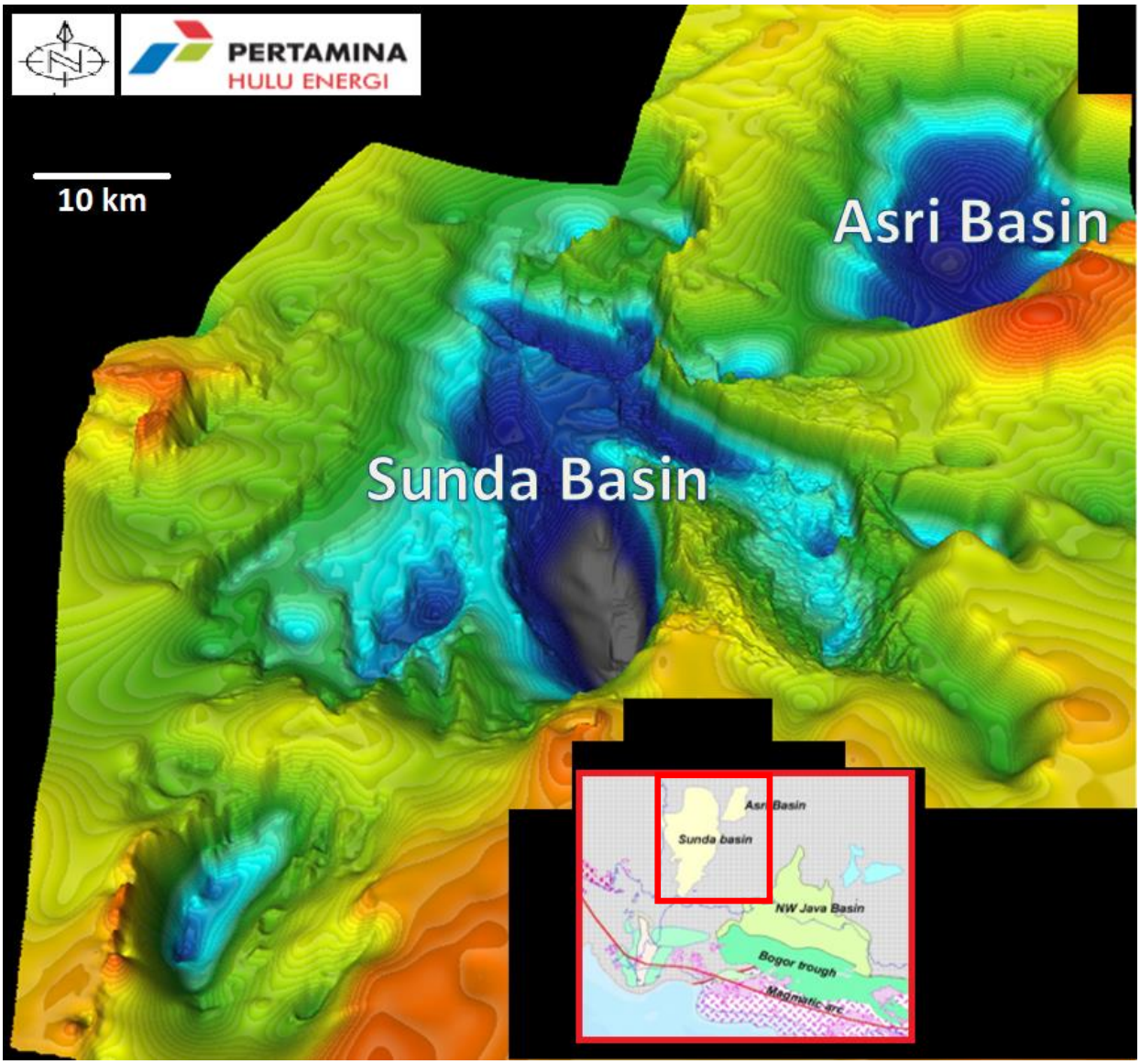


Figure 15: *Basement configuration of the Asri & Sunda Basins.*

The trapping mechanism in these fields is a large three-way dip-faulted closure (Intan and NE Intan) and four-way dip closures (Indri) except for the Widuri oil accumulation, which is a combination structural-stratigraphic trap. In Widuri, the majority of oil accumulation is found outside the closing contour; therefore, it involves the interplay between channel sand geometry (35, 34, and 33 series reservoirs) and stratigraphic pinch out. An accumulation within the 36-1 series sandstone is the only independent four-way dip closure found in the Widuri area. Additional traps are found as small four-way dip closures in the Intan-Widuri platform, which have also been proved to be productive (Chessy, Lidya, Aida). The Aida Field has commercially developed and went onstream on December 1995 with an IP of 10,200 BOPD.

Selatan – Cinta - Rama Horst

This is an elongated fault block trending E-W in the Cinta-Rama Field. The fault swings to the SW-NE trending Selatan horst, bordering the Kitty-Nora depocenter. This arch extends for approximately 24 miles and plunges gently northward into the Sunda depocenter. This high trend was a positive area during early rift time, comprising a basement paleo-high at Rama Field and horst block at the Cinta and Selatan Fields. Although most of the high trend was a paleohigh, enhancement of the structuring is thought to have occurred in Middle Miocene to Middle Pliocene uplift as seen in the Cinta Field. The Selatan-Cinta-Rama horst plays an important role for hydrocarbon migration and trapping. The Rama basement high was the site of the carbonate reef build-up of the early sag unit (Baturaja Formation) and the whole horst block was a long migration path for hydrocarbon accumulation in the Sunda area. Six oil fields (Rama, Cinta, Lita, Kitty, Selatan, and Utari) have been discovered along the Selatan-Cinta-Rama horst.

A large four-way dip closure that was cut by several series of faults is associated with major and old structural features of the basin. The Cinta anticline on the Cinta and Rama horst block is the largest trap (4,300 acres) found to date in the basin, it is associated with early basement high features; perhaps a positive block during early rift

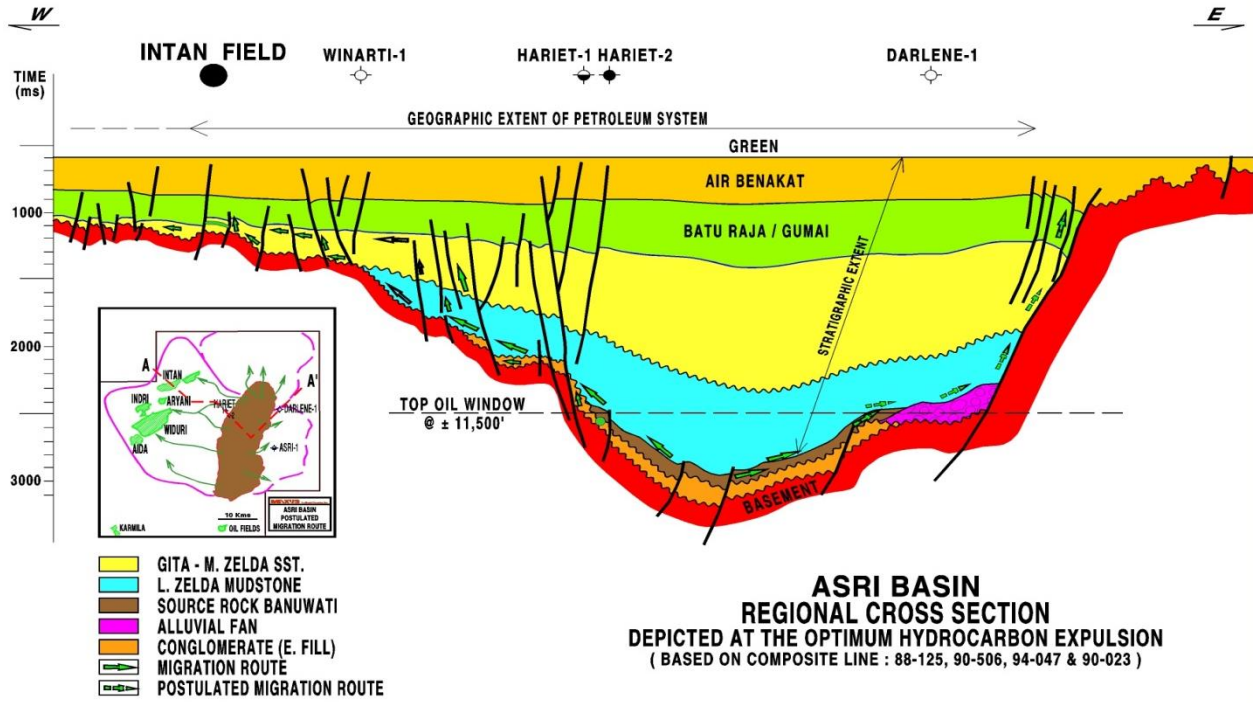


Figure 16: *Petroleum system of Asri Basin (structure at time of peak h/c expulsion).*

fills sedimentation where the syn-rift fills onlap on it. Differential compaction over a large paleo-high and subsequent fault rejuvenation has enhanced the folding of the Cinta anticline. Similarly, the structural trap over the Farida-Zelda arc was interpreted to have been formed in a similar way, but at a younger age.

Zelda - Farida Arch

The Zelda-Farida arch is an E-W trending, faulted anticline cut by several N-S trending, en-echelon normal faults. The anticline is 16 kilometers and plunges to the west near the Krisna high. To the east, the Zelda-Farida arch is bounded by the northern end of the Zelda horst fault which provides the avenue for oil migration from the Seribu depocenter to the Zelda-Farida arch. This long high trend arch was a very significant avenue for oil migration to the east, and which reached far to the west, in the Krisna and Nurbani fields. The origin of the Zelda-Farida arch is not a simple process. The relationship of the basement and early rift faulting that cut in the syn-rift unit (Top Talangakar Formation) is complex as it was affected by various degrees of reactivation of early

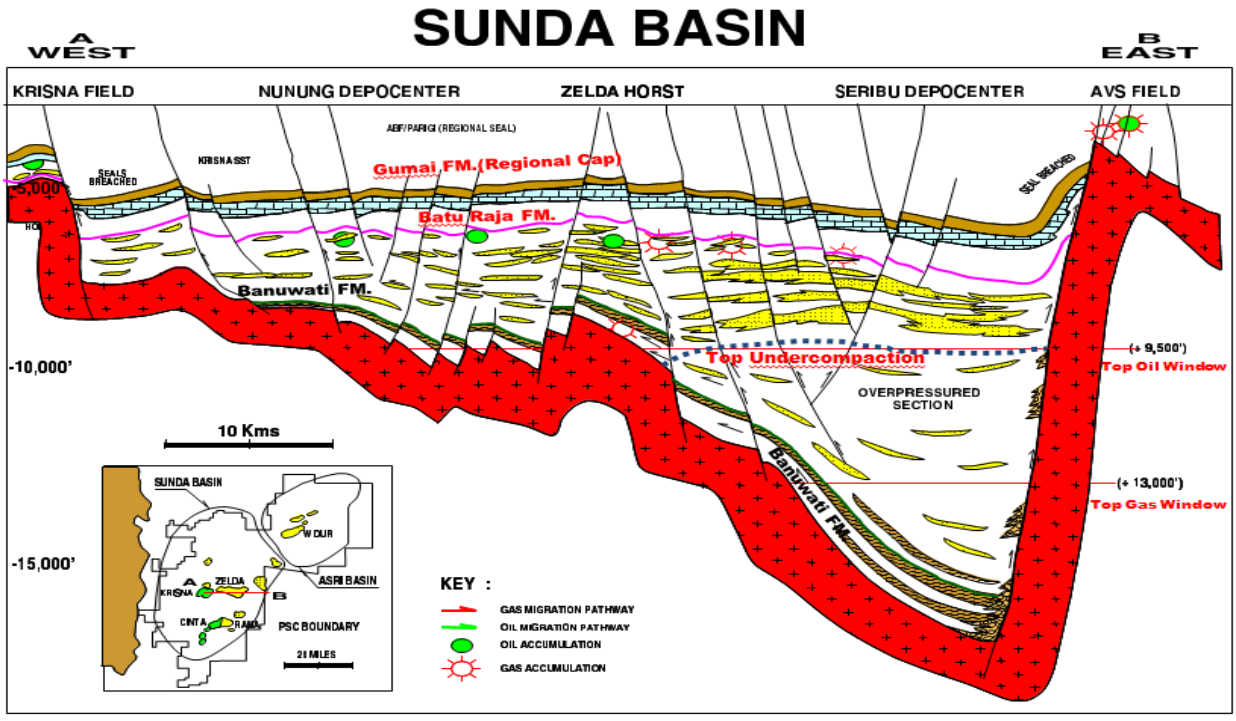


Figure 17: *Petroleum system of Sunda Basin (Present-day structure).*

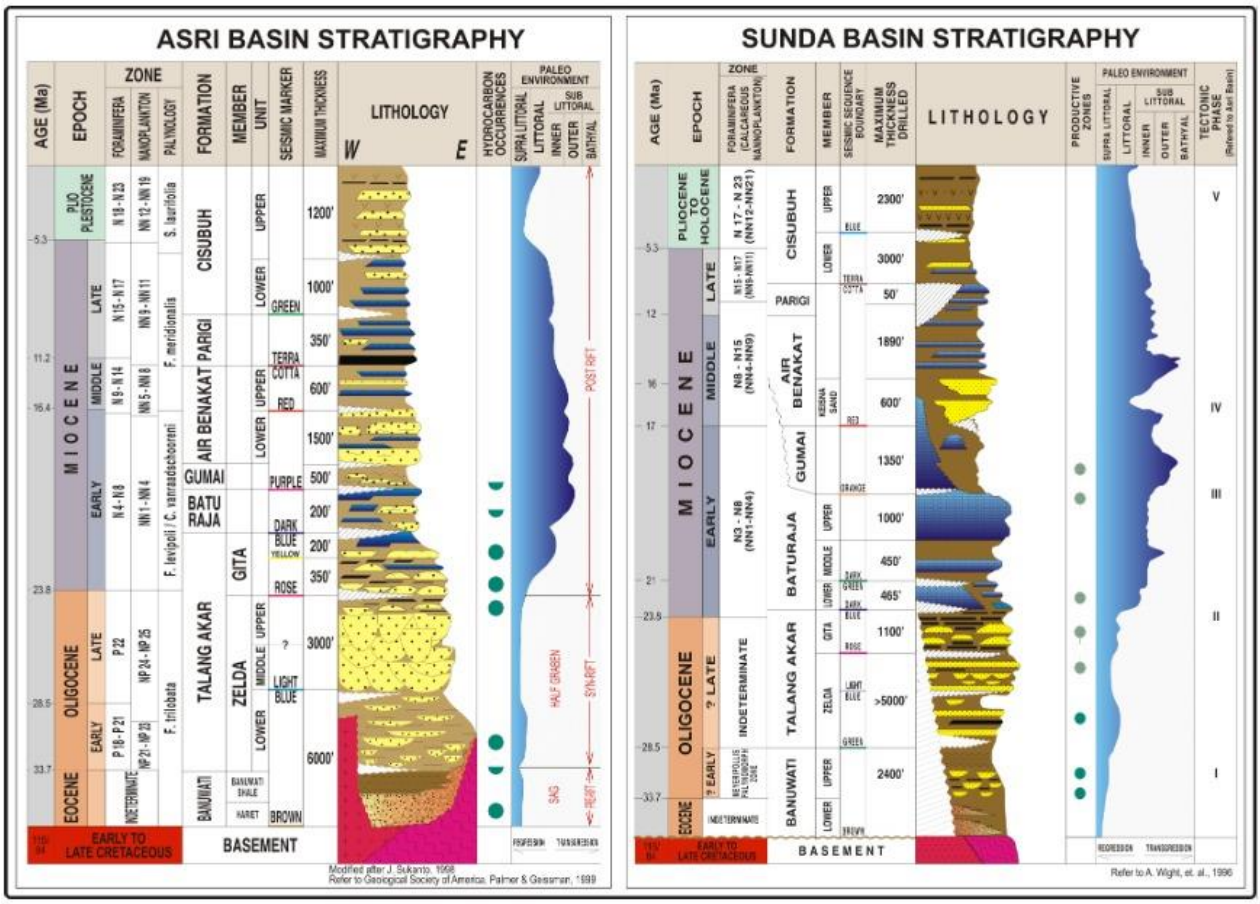


Figure 18: *Stratigraphic columns of Asri & Sunda Basins.*

faulting and the formation of antithetic and synthetic faulting. The Zelda-Farida arch (high trend) is formed by a series of en-echelon fault closures that form a long E-W trending high which occurred during the middle Miocene mild tectonic events. The Zelda and Farida Fields are located along this high trend.

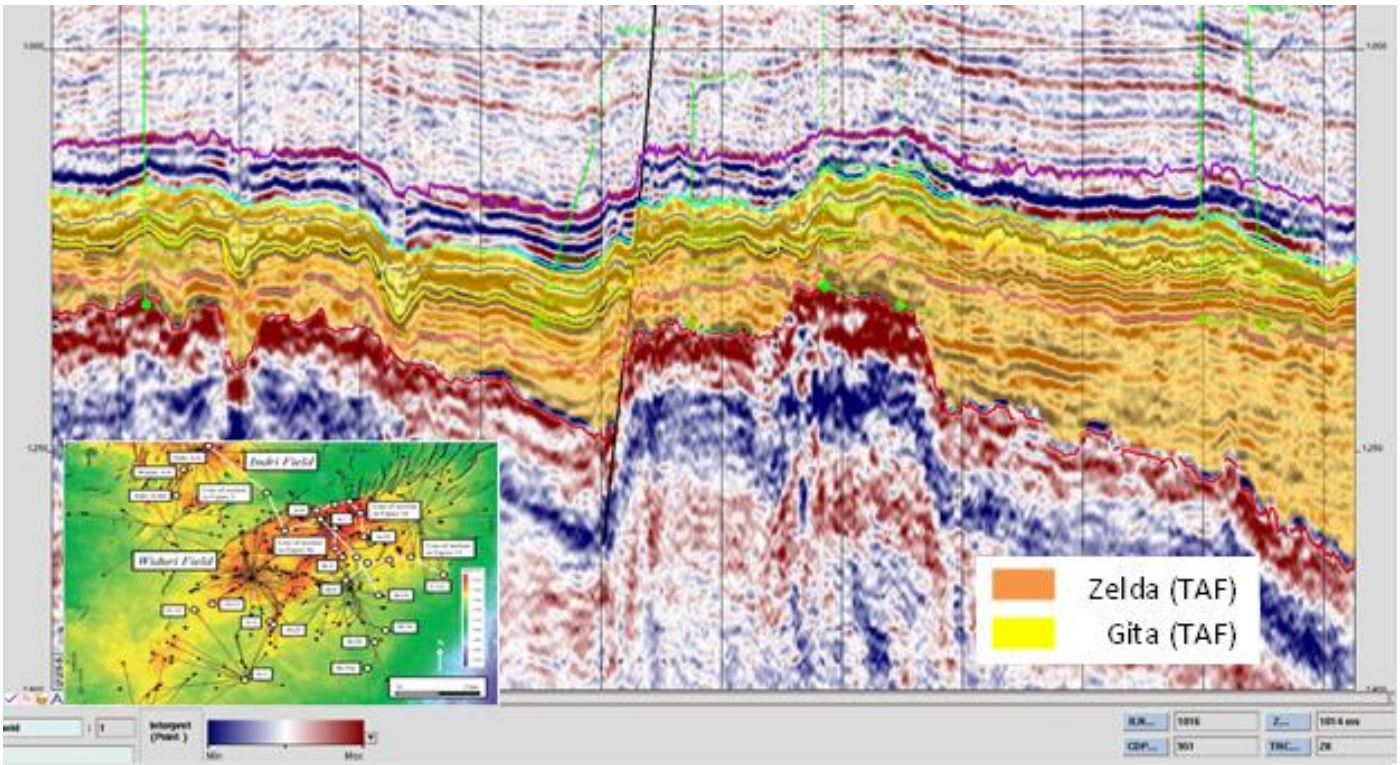


Figure 19: *Three-way dip fault closed structure, Intan-Widuri Field.*

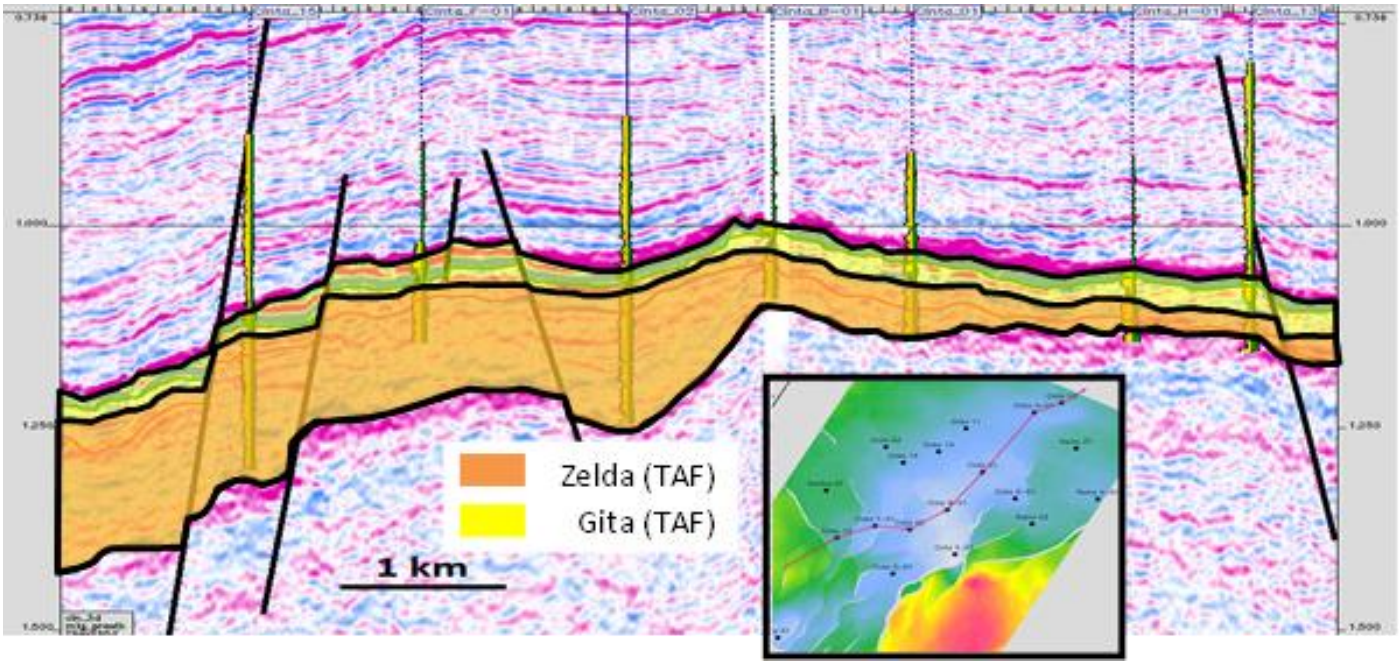


Figure 20: *Faulted anticline, Cinta Field.*

The E-W trending Farida and Zelda High is located in the center of the Sunda Basin, spanning approximately 15 kilometers. The structure is a west-plunging anticline cut by a series of NE-SW trending synthetic and antithetical intra- basinal faults. The overall structure is bounded by structural low areas to the north and southern flanks that may be related to the major central basin N-S trending compression similar to the Cinta-Rama high but much younger in age. Oil accumulation is limited in the sandstones of the syn-rift unit (Zelda). The Farida and Zelda High trend is located in between two generative basins, the Janti-Yani to the northeast and Seribu to the southeast. Oil migration out of the kitchen areas was focused onto the Farida-Zelda high via fluvial sandstone reservoirs and syn-rift faults. The fluviatile sandstones were effectively connected. They formed a long migration route along the high. The oil perhaps did not move Stratigraphically upwards from the syn-rift sandstone until this unit pinches out east of the Krisna high. The oil then spilled beyond the west plunging nose and was trapped in the Krisna high area (Krisna-Yvonne fields), filling traps in the west basin basement highs, (e.g. Nurbani field).

Zelda - Gita Horst

The Zelda-Gita horst extends approximately 32 kilometers from the Zelda Field to the Gita Field separating the main Seribu depocenter from the

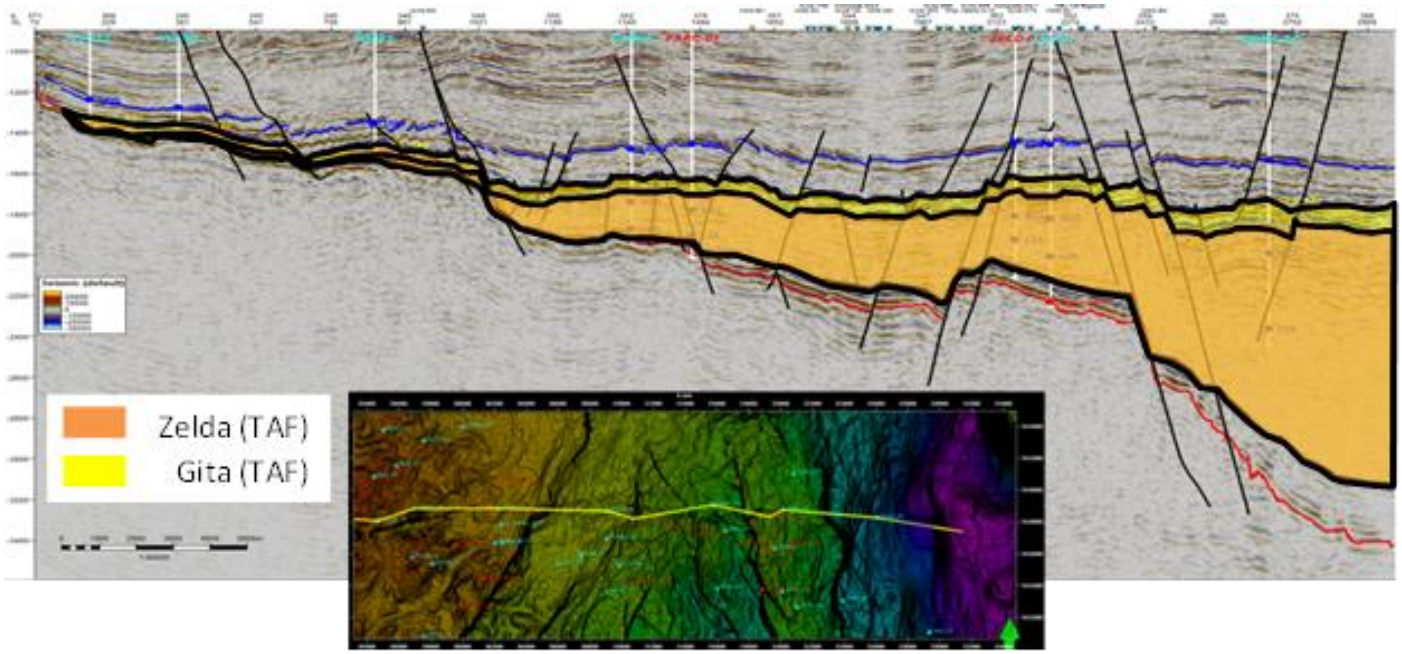


Figure 21: *Fault trap, Farida Field.*

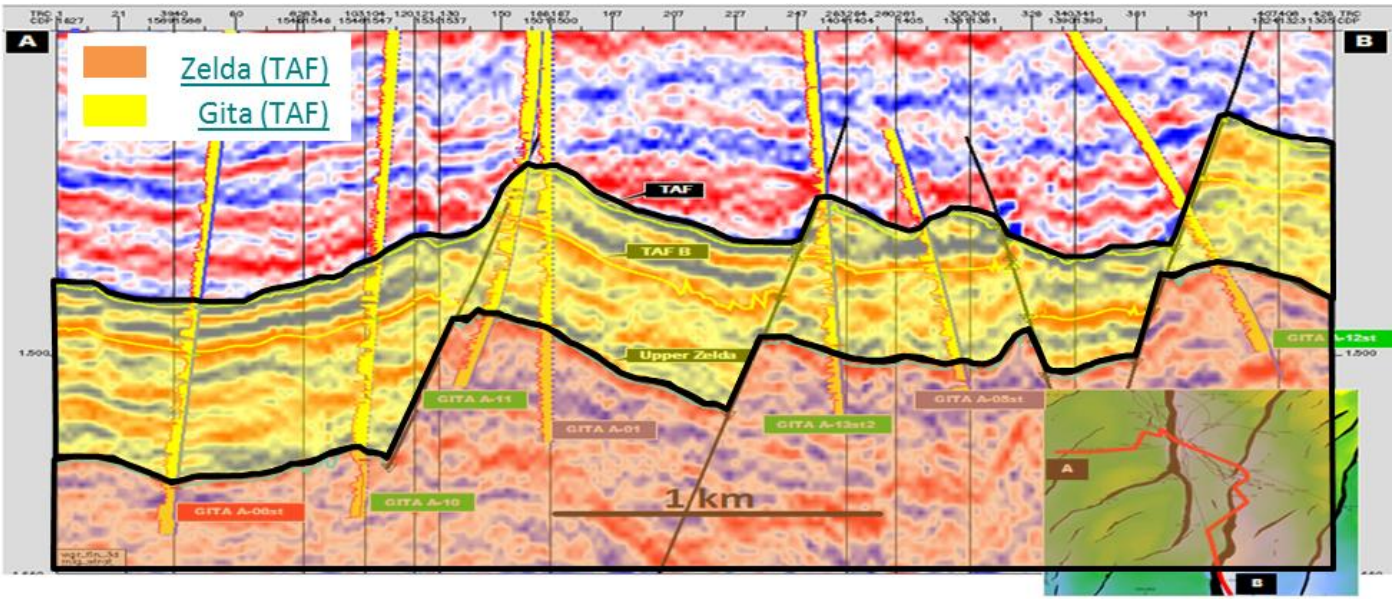


Figure 22: *Fault trap, Gita Field.*

Nunung depocenter in the west and is oriented roughly N-S. The horst generally dips to the east where the early rift fills unit onlap it. In the middle of the horst, the feature forms a poorly defined saddle. The horst is one of the most important structures in the Sunda area as its eastern fault system forms the avenue for hydrocarbon migration on to the Zelda-Farida arch system. In addition, the horst which was active during syn-rift time (Talangakar Formation) also served as a barrier to the transportation of westerly-derived sands. This resulted in a relatively low sand-shale ratio for the syn-rift unit deposited in the Seribu depocenter to the east of the Zelda-Gita horst.

The non-marine early and syn-rift fill units and the marine units of early sag fill formed a variety of structural and stratigraphic traps or combination of both in the Asri Basin. The traps are associated with clastic reservoirs of the early and syn-rift units of the Talangakar Formation. Trap classification is based on the location of major hydrocarbon accumulations relative to the Asri Basin and Sunda Basin structural settings and histories.

Oil and gas were found in the early rift fluvial sandstones (Banuwati clastics) and syn-rift sandstone (Zelda member) and in the early sag-fill sandstone (Gita member) reservoirs. However, only one field, the Gita Field, at the southern end of the horst, was commercially developed from a faulted anticline. The Zelda field is a series of fault-traps) Additional traps may be present along the Zelda horst. The oil spilled to the west was trapped in the E-W trending channel sandstone of the early sag fill unit (Gita member) in the Wanda field. The trapping mechanism of this field is purely

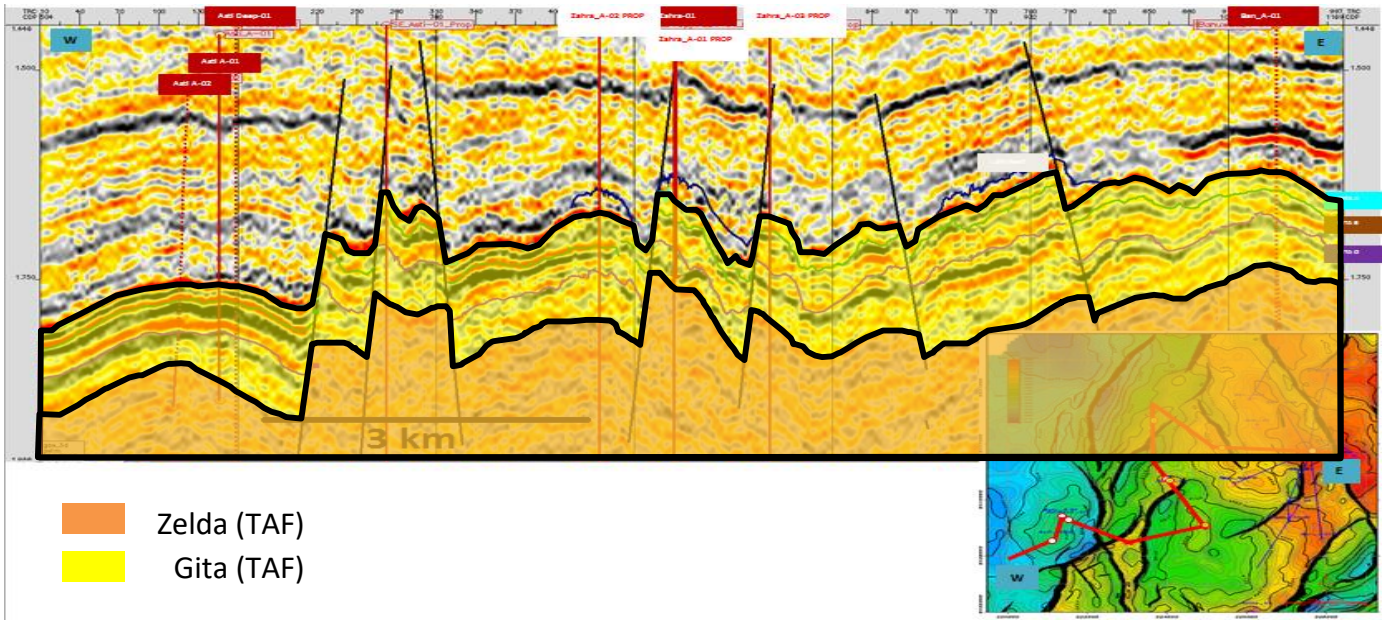


Figure 23: *Keystone folding, Asti-Banuwati Field.*

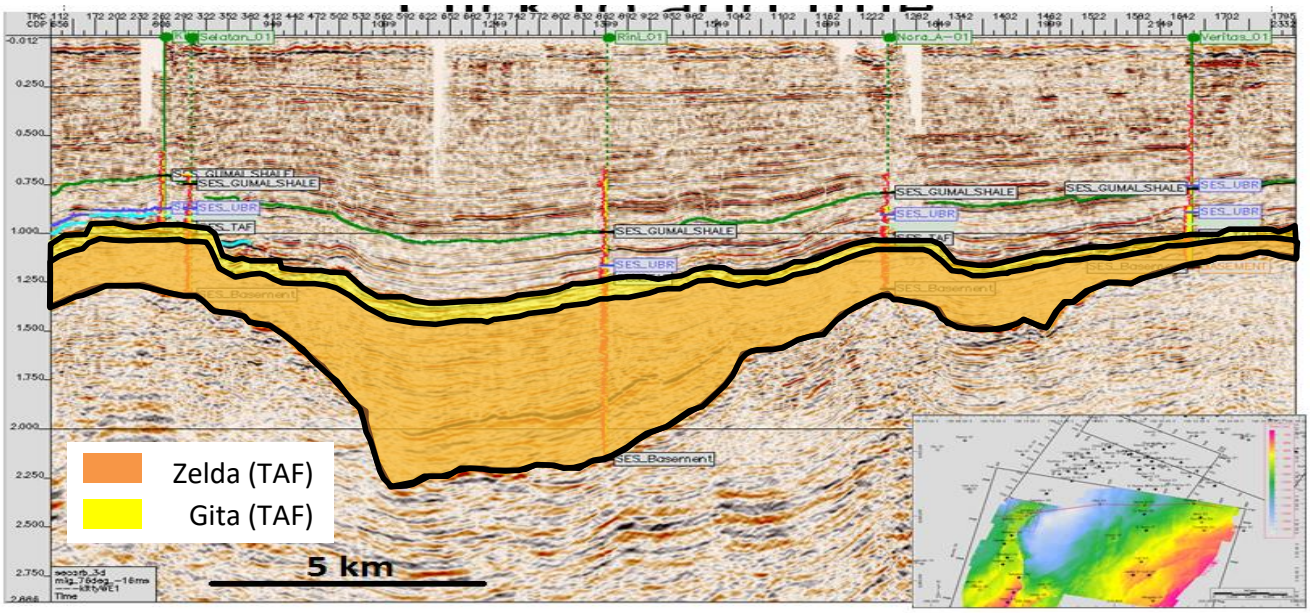


Figure 24: *Depocenter, Kitty-Nora Area.*

stratigraphic trap associated with E-W trending channel sandstone intersected by a N-S trending normal fault.

The Banuwati Gas Field structure is located in the central basin area, on the northern flank of the Seribu depocenter. The structure was formed by a keystone fault set (antithetic and synthetic faults) which produced a downthrown rollover along the N-S trending normal fault. Gas migrated vertically from the basin deep along the faults was trapped in the early sag basin fluvial-deltaic sandstones (Gita member).

Other highs, including the Xenia arch located north of the Yani depocenter, Quinta high in the southern part of the Asri Basin and in the smaller scale the Anita nose in the Nunung depocenter have-been drilled without success. Migration route disruption and/or trap integrity may be responsible for their failures.

Central Basin Horst and Arch

The NW-SE-trending Selatan-Kitty-Cinta-Rama horst located in the southern part of the Sunda Basin is a long hydrocarbon bearing series of traps. Oil and gas were trapped in clastic sandstone reservoirs (Talangakar Formation) and reefal carbonate reservoirs (Baturaja) in the Rama, Cinta, Kitty and Selatan fields and also in smaller fields including the Lita and Utari fields. The Cinta Field

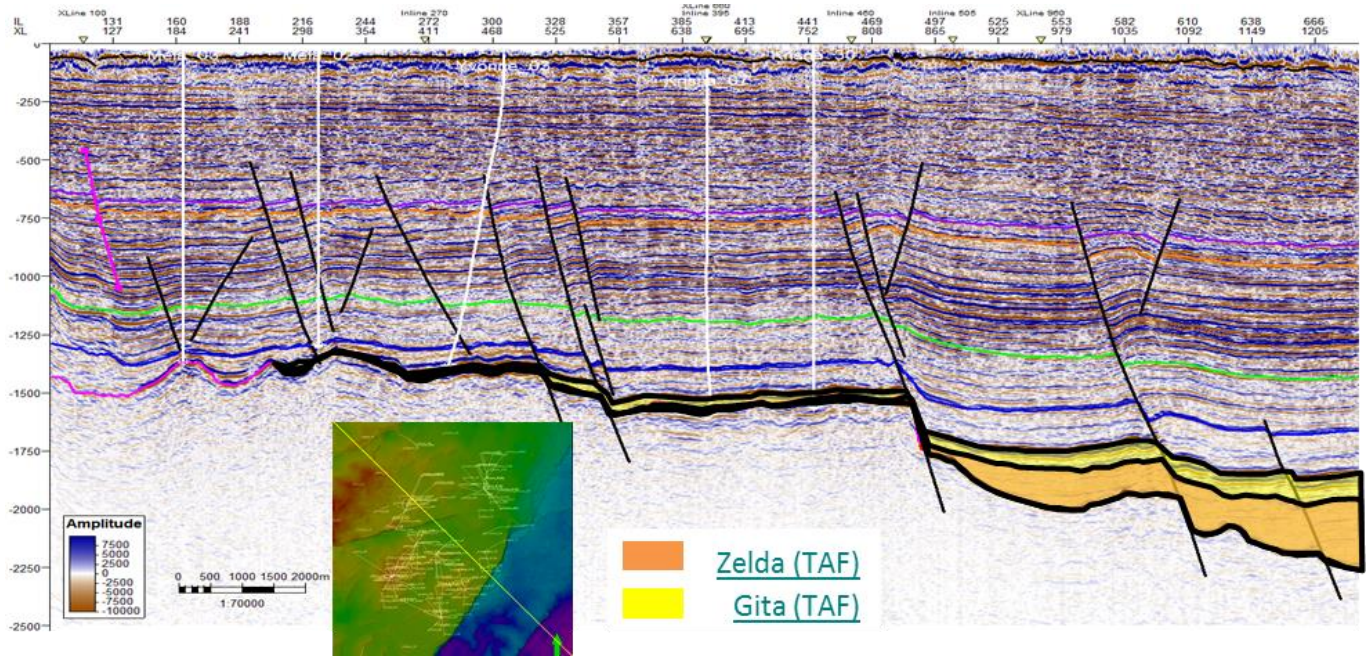


Figure 25: *Structural stratigraphic trap formed by fluvial sandstone pinch-out over a low relief closure, Yvonne Field.*

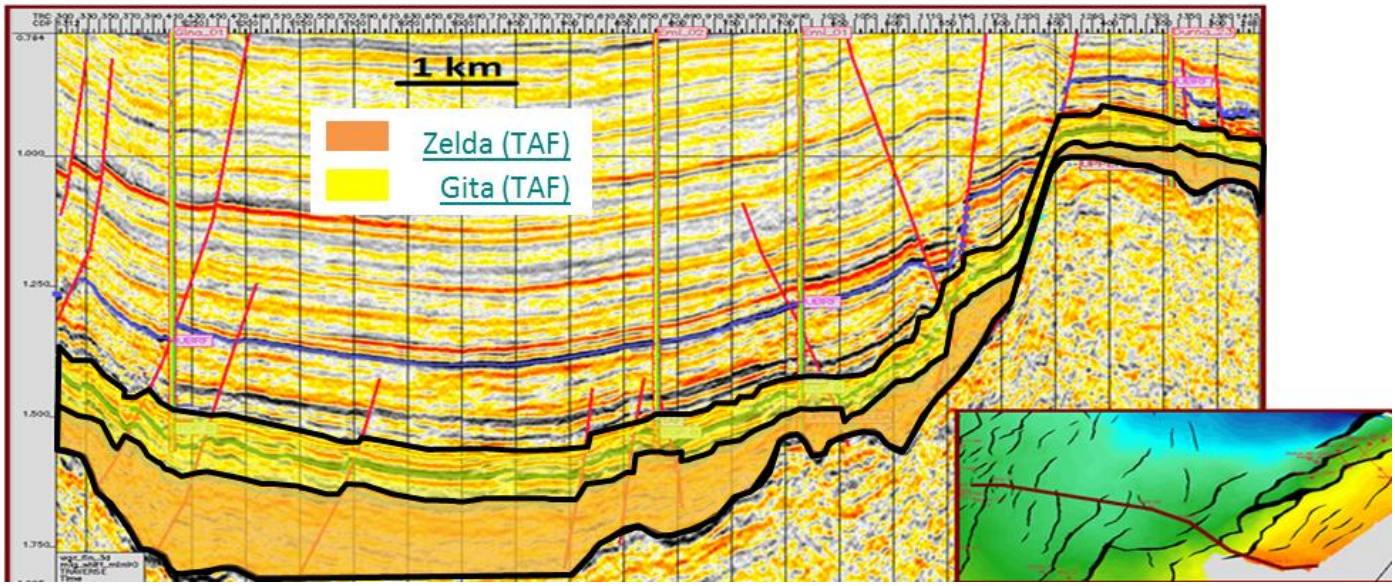


Figure 26: *Three-way dip fault closed anticline, Sundari Field.*

is a faulted four-way dip closure covering an area of 4,300 acres. It is the largest oil accumulation in the Sunda Basin, whereas the Rama, Selatan and Kitty fields are associated with a structural-stratigraphic trap within Baturaja carbonate buildups that grew on a basement high. This horst trend is a paleohigh and it has been high throughout the generative history of the basin. Although the horst block is surrounded by several depocenters i.e. the Kitty-Nora depocenter to the east and Nunung to the north, however oil trapped in the horst block area is thought to come from the Seribu depocenter to the NW, via an eastern plunging structure of the Cinta-Rama arch and the southern tail of the N-S trending Zelda horst, a long migration path as long as 20 km on the horst block and approximately 30 km from the kitchen area. It is questionable that the surrounding Kitty-Nora and Nunung depocenters have generated hydrocarbons; at least the current available well data collected from the depocenters gave no positive answer. Also, basin modelling indicated very little volume of source rocks in the oil maturity window to supply significant migration.

Western Basement Highs

The Krisna High, located on the western flank of the Sunda Basin, is a paleo-high where the early and syn-rift sediment is absent or relatively thin, and upon which the reefal build-up (Baturaja) grew on the high and formed an effective hydrocarbon trap for the Krisna and Yvonne Fields. The trap is in a Lower Baturaja fringing reef complex surrounding the high and an Upper Baturaja carbonate, four-way dip closure on the crest of the high (Krisna-D). The reefs grew following a transgressive carbonate deposition episode during early Miocene time. Oil spilled from the Farida nose

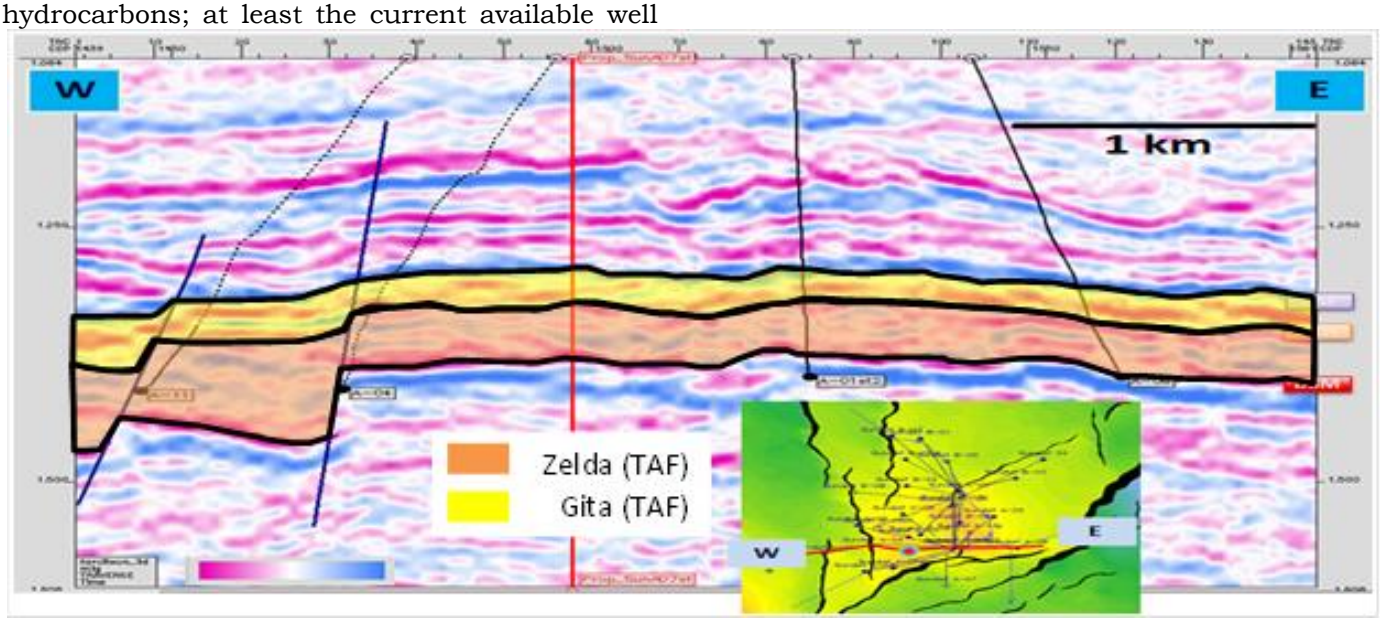


Figure 27: *Fault trap, Emi-Retno Field.*

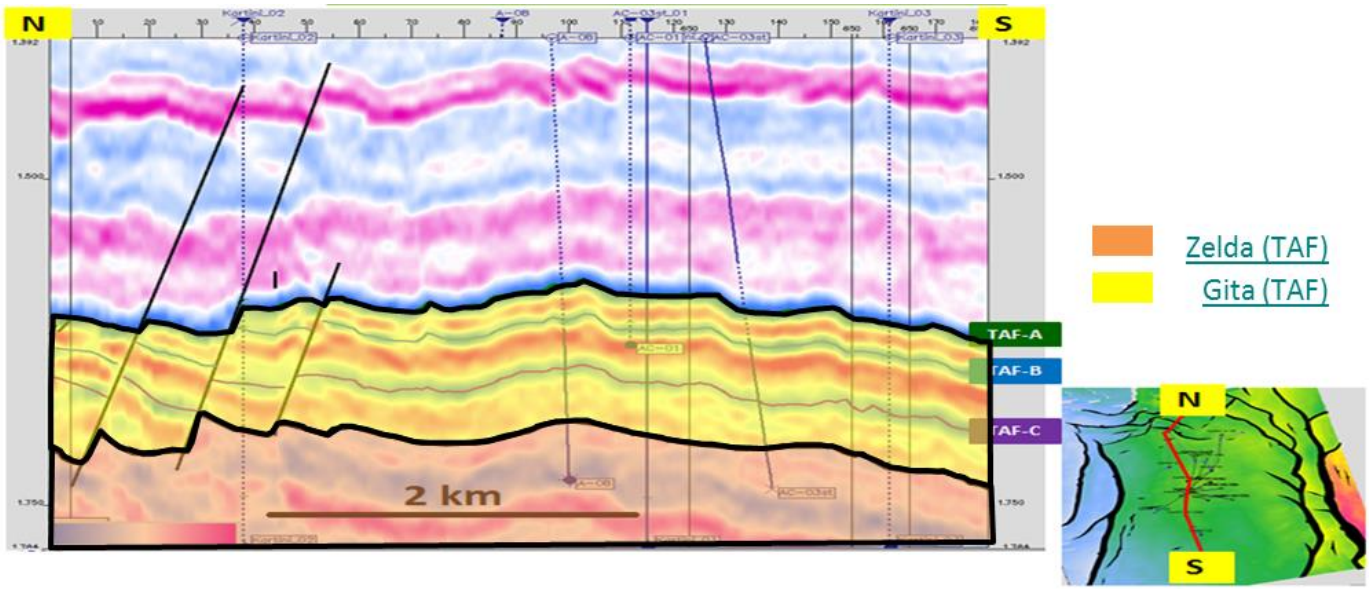


Figure 28: *Downthrown trap associated with major basin bounding fault, Kartini Field.*

continued to migrate along the basement surface zone via fluviatile sandstones (Gita) into larger carbonate build-up traps (Krisna and Yvonne-A). Some of the oil was trapped in the Gita sandstones associated with a low relief closure as seen in the Yvonne-B. Source rock has not been identified in the surrounding marine shale on the Krisna High.

The Nunung depocenter hydrocarbon generative capacity is questionable. Migrating hydrocarbons, if any, should occur up the fault via the Krisna fault and then into the Krisna Field. Further to the West, on the upthrown side of the Sundari-Segama fault, the Nurbani and Dita reefs and along the Citra high, effective oil and gas traps associated with reefal buildups and sand pinch outs were found, although most of the finds are non-commercial, despite the large volume in place of Nurbani (approx. 100MMBO) due to low API gravity oil. No surrounding kitchen areas (deep basin) were found in this west basin margin, therefore migration in this area was a result of a continuation of oil spilled updip from the Krisna Field. Oil accumulation in the Sundari Field, a faulted anticline, is thought to come from the Yani depocenter located downdip from the trap via long-range migration at the basement/sediment interface and thence through syn-rift sandstones of the Nina-Mawarti homocline.

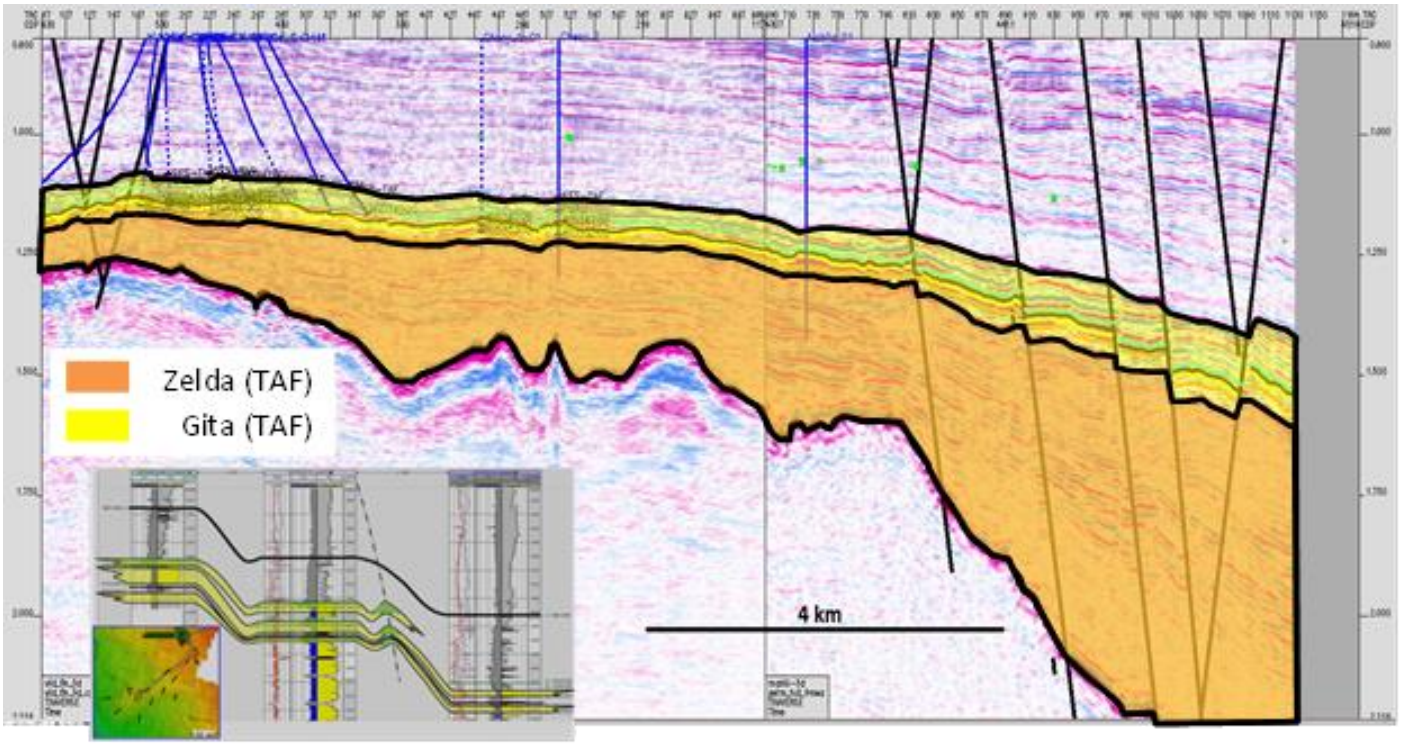


Figure 29*: Combination of four-way dip closure and stratigraphic trapping, Chessy Field.*

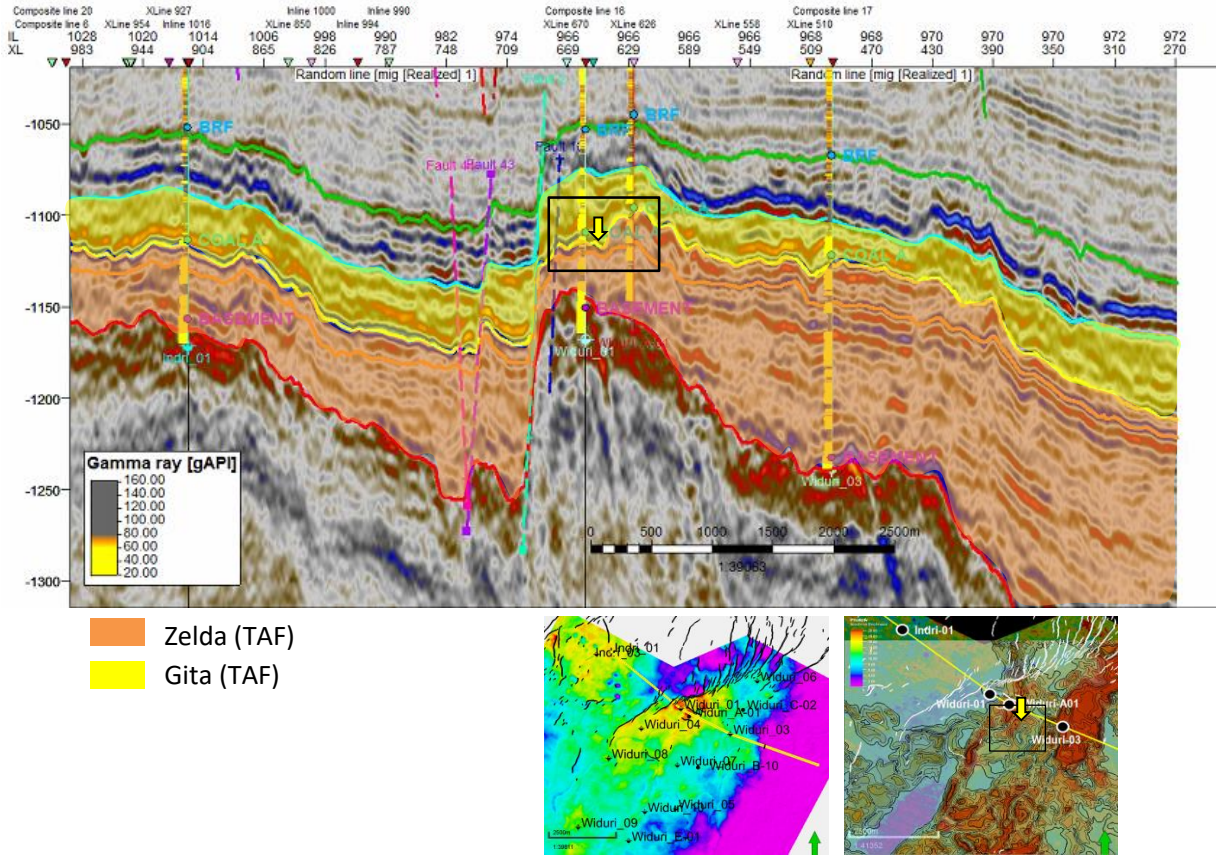


Figure 30: *Four-Way Dip Closure showing the channel edge at Upper Zelda Sandstone (35-1), Indri Field.*

Eastern Basin Boundary

A series of oil and gas fields have been discovered along the major Seribu Fault of the Sunda Basin. The hydrocarbon accumulations are in fault traps (Emi-Retno Field) and a downthrown rollover (Kartini Field). They share common vertical migration pathways along the Seribu fault system and production from the fields are from several stratigraphic levels with a majority from the Baturaja Carbonates and Talangakar Sandstones. Some oils have also been tested from basement (Duma-3). Dip towards the fault becomes a critical aspect for trapping of a downthrown side closure. Oil may not be trapped downthrown where reservoirs dip away from the faults which serve as primary migration conduits in the Seribu fault system. The Seribu fault was active since the inception of rifting in the Oligocene (syn-rift) time and continues to present day. Although no well has penetrated the deepest part of the Sunda Basin, seismic character indicates that alluvial fans of the Eastern part of the Sunda Basin may be lacking. At least in the northern part of the fault trend the Yani accumulation is on a large fan.

Seribu Fault

Thus, the upthrown, basin-margin side of the Seribu fault was not a major topographic high (A fault cannot be a high) during early rift time (Banuwati), although at present day its growth now forms a major half graben. It also serves as a major vertical migration avenue connecting the mature early rift's lacustrine source in the downthrown side to structural and stratigraphic traps located at shallower depths. In the Asri Basin, on the other hand, oil migration along the eastern basin bounding fault were mostly dry holes with no oil shows. Well-developed alluvial fans are reported from the drilling of Darlene-1 and Asri-1 wells, suggesting that a platform east of the Asri fault was an active topographic high during early rift deposition producing fault-related fan sediments. The implication of negative results of the east Asri Basin exploration is that oil migration could not reach the fault that would serve as a major vertical avenue due to the presence of low permeability alluvial fan (i.e. Darlene fan) along the downthrown side of the Asri fault.

Conversely, to the west, in the Widuri area, four-way dip closure combined with stratigraphic components enhance the trapping capability of a structural trap. Most of the oil in Widuri was trapped outside the closing contour of the fault-bounded structure. It was also modified by sand geometry distribution of the thicker 34 and 35 series channel sandstones. Additional productive four-way dip closures were found in the Aida and Indri fields and in series of smaller accumulations such as Chessy and Lidya. The role of stratigraphic aspects for trapping hydrocarbon in the later accumulations is unknown at present time as most

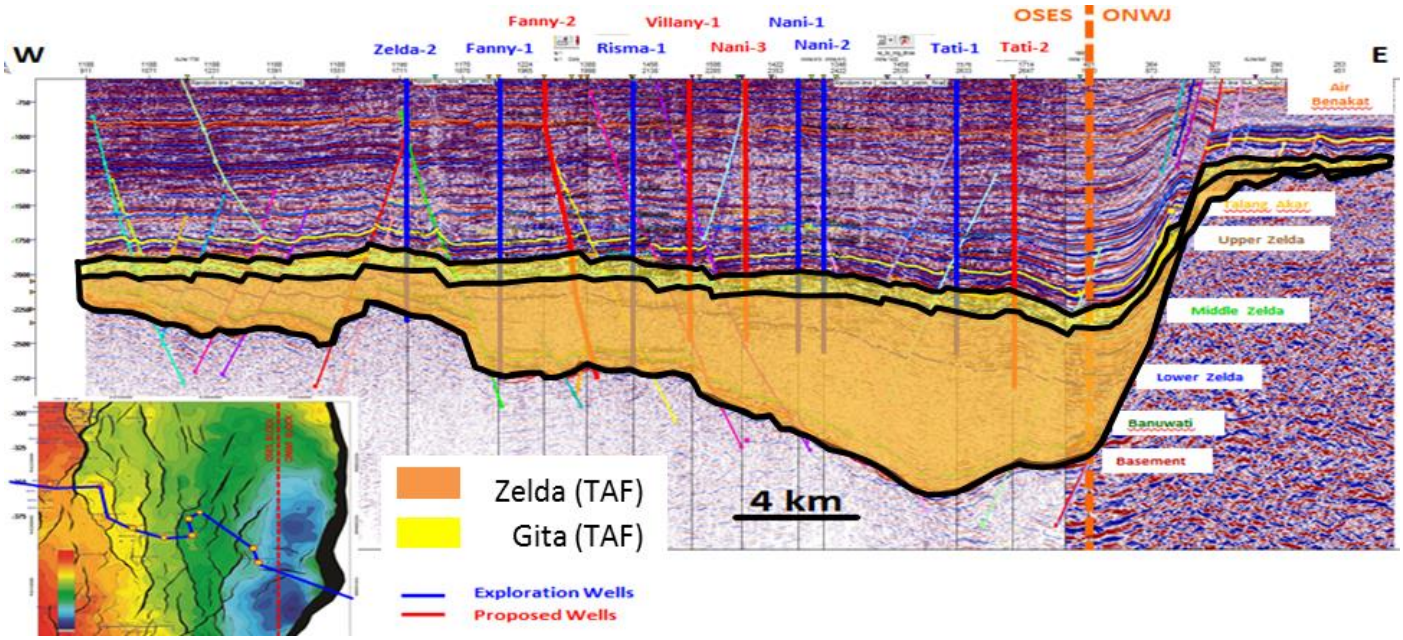


***Figure 31**: Seismic section of Risma-Nani-Tati Area.*

of the closures mostly were only tested by a single successful exploratory well. The stratigraphic trap element comes from thinner, discrete channel sands draped over the high, which are likely to have small faults sealing them due to their thinner nature (many of these faults are of sub-seismic definition).

Deep Basin

Oil accumulation in the deep basin occurs in the early rift-fill, conglomeratic and medium to coarse grained sandstones. These were deposited in braided stream environments in low sinuosity channels. Janti-3 tested 2450 BOPD and Yani-1 tested 1100 BOPD, in conglomeratic sandstone reservoirs. Their commerciality has yet to be proven as the volumes contained by the trapping mechanism are still poorly understood. The trapping mechanism for oil in Janti-Yani area may either be associated with a large stratigraphic trap, or associated with a less significant, three-way dip fault closed structure, which juxtaposed fluviatile sandstone reservoir against the lacustrine shale source rocks across the fault. Currently 3D seismic mapping is being conducted to solve problem for further prospecting in the area.

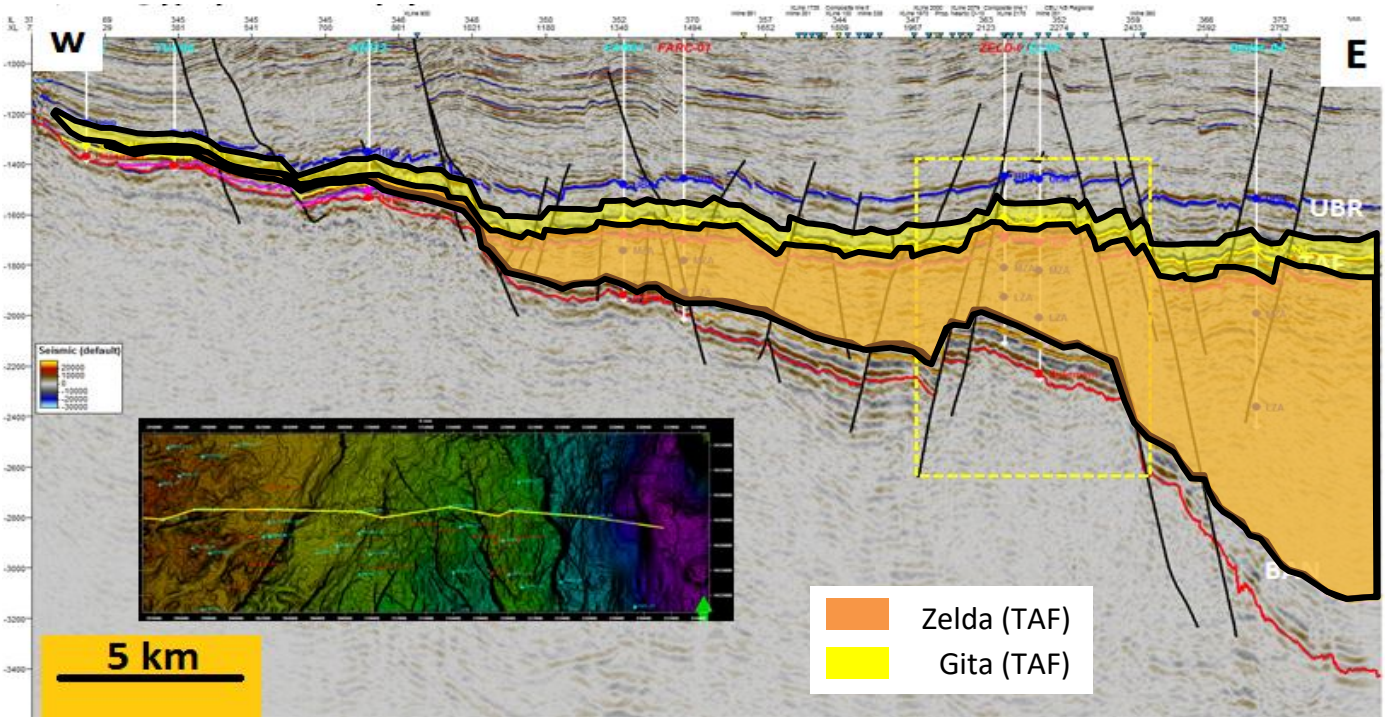


***Figure 32**: Seismic section of Yvonne-Farida-Zelda Area.*

SUMMARY AND CONCLUSIONS

Oil to source rock correlation in the Asri & Sunda Basins revealed that the oil is low sulphur, type-I crude generated from lacustrine, algal-dominated shale source rock of the early syn-rift fill. This is the Banuwati shale, found mostly in the depocenter, and has an average thickness of 300 ft. TOC is in the range of 1.87% - 8% with an average TOC of 5% and hydrogen index (HI) in the range of 573 to 637 mg HC/g C. The Banuwati shales reached the main phase of oil generation at depths of 10,000 – 12,000 ft. when transformation ratio (TR) reached around 80%-90%, as early as the Middle Miocene time (15 Ma) such as the model created in the Asri Basin. Oil migrated upward through basin bounding faults and lateral migration reached several tens of kilometers away from the kitchen area along the basement surface and its weathered zone, porous and permeable sandstones of early and syn-rift unit (Talangakar Formation).

The remaining exploration potential still exists, and commercial fields are still to be found despite the mature exploration stage of both the Asri & Sunda Basins, after more than 45 years of drilling activity. Future exploration plays are associated with the deep basin, in the early rift fill units (Lower Zelda Member and Banuwati Clastics) and within meandering fluvial channel sandstones, which requires high quality seismic data, new technical approaches and advanced technologies to define. Also, infill drilling with the help of excellent 3-D seismic data is still being conducted within major fields to sustain current level of production.

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